The Impact of Safety Management Systems on Safety Performance: Commercial Aviation Operations

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The Impact of Safety Management Systems on Safety Performance: Commercial Aviation Operations

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Abstract

Aviation is a complex and safety-critical industry. Although the aviation system is one that cannot be completely free of hazards and associated risks, the final goal is always the elimination of aircraft accidents and/or serious incidents. Because there are no guarantees that human activities or human-built systems will be completely free from operational errors and their consequences, safety has to be a dynamic characteristic of the aviation system where risks to safety need to be constantly mitigated.

The acceptability of safety performance is frequently predisposed by domestic as well as international norms and culture. Provided safety risks are kept under an appropriate level, the aviation system can be expected to maintain the appropriate balance between production and protection. Previous research has shown that organisations with a certified safety management system (SMS) had significantly lower accident rates (Thomas, 2012). However, there was no agreement about which SMS components individually contributed most to safety performance, as well as a general lack of consistency in terms of which SMS elements most affected safety performance.

Therefore, this study seeks to determine the impact of SMSs on safety performance for commercial aviation operations using two case studies. The first case study looks at SMSs within the general aviation/charter operation sector while the second case study reviews SMSs for the airline sector of the industry. This study starts with a review of the evolution of aviation safety, and of the approaches taken to implement, improve and enhance safety in safety-critical industries such as aviation, nuclear, marine, rail and petrochemical. Variations were identified between the International Civil Aviation Organization (ICAO) SMS model and the models adopted by some ICAO member states. The experience of implementing an SMS in Australia for regular public transport or airline-type operations was reviewed by this study together with a review of the independent Australian National Audit Office (ANAO) post-SMS implementation audit to seek out lessons learnt and recommendations for continuous improvements.

This study sought to determine the impact of SMSs on safety performance for commercial aviation operations. The hypothesis tested by conducting the two case studies was that SMSs improve the safety performance of commercial aviation operations. The first case

study involved an analysis of de-identified Flight Safety Foundation (FSF) audit findings from their Basic Aviation Risk Standard (BARS) program for their customers operating in the general aviation/charter sector of the industry. The second case study was conducted as a review of aviation SMSs and the measurement of safety performance for the sampled population of operators involved with airline-type operations in Australia. This case study revealed, through a pre- and post-SMS test measure over the period from 2006ï2013, that safety performance has improved with safety management systems (SMSs).

In addition, various correlation analyses were conducted in both case studies to determine the relationships, significance and effects that SMS, airworthiness, flight operations and ground handling audit findings, and the number of accidents and safety reports to the Air Transport Safety Bureau (ATSB) have on each other.

The results show a moderate to strong positive relationship between the number of SMSs and flight operations audit findings. As for SMSs and airworthiness, the results suggest that it is a weak to moderate positive relationship. The relationship between SMSs and ground handling is a moderate positive one. A strong positive relationship exists between the number of audits conducted and the number of audit findings. There is a moderate positive relationship between airworthiness and flight operations audit findings. The concluding chapter of the thesis introduces the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method to test the Civil Aviation Safety Authority (CASA) SMS framework and to define its critical dimensions and components. The DEMATEL method has the real advantage of providing a visualisation of the structural relationships and identifying key components in an SMS framework. In addition, this method has shown that it can identify the net initiating factors and the net multiplier factors of an SMS to assist management in the prioritisation of its components. A key output from the DEMATEL tool is that the impact direction map (IDM) shows that the SMS dimension, safety assurance, plays the most critical role in an effective SMS: its associated sub-components of continuous improvement of the safety system, safety performance monitoring and measurement, and management of change have the highest net influence of all the SMS factors.

Statement of Originality

This work has not previously been submitted for a degree or diploma in any university. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

Richard Yeun

18 April 2015

Disclaimer/Publications

Richard Yeun is a Safety System Inspector with the Civil Aviation Safety Authority (Australia). This article reflects his own views, opinions and analyses, and does not represent nor necessarily reflect the views or position of the Civil Aviation Safety Authority or the Government of Australia on any of the issues considered or discussed.

The following paper was published during the work conducted on this thesis, the text of which is included in part in the thesis:

1) Yeun, R., Bates, P. & Murray, P., Aviation Safety Management Systems. *World Review of Intermodal Transportation Research, Vol. 5*, No. 2 (2014), pp. 168ï 196.

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This thesis is the culmination of three years of research work in the field of safety management systems.

First and foremost, I would like to thank my primary supervisor, Associate Prof. Paul Bates, and alternate supervisor, Associate Prof. Patrick Murray, for their advice, support and help throughout this journey.

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Professional editor, Valerie Williams, provided copyediting and proofreading services, according to the guidelines laid out in the university-endorsed national ñGuidelines for editing research thesesò.

Last but not least, my heartfelt thanks to my wife, Eileen, and my children, Mark, Sarah and Dawn. Your patience, love and never-ending support have helped me tremendously in this pursuit.

Table of Contents

List of Figures

List of Tables

Abbreviations

AHP	analytic hierarchy process
AHSQ	Air Operator Certificate (AOC) Holder Survey Questionnaire
ALARP	as low as reasonably practicable
ALoSP	acceptable level of safety performance
AMO	Approved Maintenance Organisation
AMSS	Australian Maritime Safety Authority
ANAO	Australian National Audit Office
ANP	analytic network process
AOC	Air Operator Certificate
APE	accident prevention effort
ARS	acute radiation syndrome
ASAP	Aviation Safety Action Program
ASRP	Aviation Safety Reporting Program
ASRS	Aviation Safety Reporting System
ATSB	Air Transport Safety Bureau
BARS	Basic Aviation Risk Standard
BoM	Bureau of Meteorology
CAA (UK)	Civil Aviation Authority (UK)
CAAP	Civil Aviation Advisory Publication
CAAS	Civil Aviation Authority of Singapore
CAO	Civil Aviation Order
CASA	Civil Aviation Safety Authority (Australia)
CEO	Chief Executive Officer
DEMATEL	Decision-Making Trial and Evaluation Laboratory
EMS	Environment Management System
DoD	Department of Defense (US)
FAA	Federal Aviation Administration
FDAP	Flight Data Analysis Program
FSF	Flight Safety Foundation

Abbreviations

GA	general aviation
GDP	gross domestic product
HCRPT	high capacity regular public transport
HF	human factors
HFEM	Human Factor and Error Management System
HRO	high reliability organisation
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IDM	impact direction map
IMO	International Maritime Organization
INDICATE	Identifying Needed Defences in the Civil Aviation Transport Environment (safety program)
INPO	Institute for Nuclear Power Operations
IOSA	IATAôs Operational Safety Audit (program)
IRM	impact relationship map
KPI	key performance indicator
L-H-S	liveware-hardware-software (system)
LCRPT	low capacity regular public transport
MCDM	multiple criteria decision-making (model)
MTOW	maximum take-off weight
NAIIC	Nuclear Accident Independent Investigation Commission
NASA	National Aeronautics and Space Administration
NISA	Nuclear & Industrial Safety Agency (Japan)
NTS	non-technical skills
NTSB	National Transportation Safety Board (US)
OHSMS	Occupational Health and Safety Management System

Abbreviations

PPP	purchasing power parity
QE	quantifiable effect
QMS	quality management system
QSM	Quantum Safety Metrics
RPK	revenue passenger-kilometre
RPT	regular public transport
SAR	Singapore Airworthiness Requirements
SARPs	Standards and Recommended Practices
SDR	Serious Defect Report
SIS	safety intelligence system (strategy)
SMM	Safety Management Manual (ICAO)
SMS	safety management system
SOP	standard operating procedure
SSP	State Safety Program
TC	Transport Canada
UK	United Kingdom
UN	United Nations
USA/US	United States of America/United States
WANO	World Association of Nuclear Operators

Declaration

The undersigned informed and sought an approval from the Civil Aviation Safety Authority (CASA) on 9 July 2012 for the conduct of this PhD research whilst under the employ of CASA.

An approval dated 26 July 2012 (see Appendix 9) was subsequently granted by Mr Peter Cromarty, Acting Executive Manager of the Operations Division, to the undersigned.

This is to declare that the conduct of this research has met the terms of reference and conditions as per CASAôs approval stated above.

Richard Yeun
18 April 2015

Definition of Terms

Accident[1]: An occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which:

a person is fatally or seriously injured as a result of:

- being in the aircraft, or
- direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or
- direct exposure to jet blast,

except when the injuries are from natural causes, self-inflicted, or caused by other persons, or when injuries are to stowaways hiding outside the areas normally available to the passengers and crew, or the aircraft sustains damage or structural failure which,

- adversely affects the structural strength, performance or flight characteristics of the aircraft, and
- would normally require major repair or replacement of the affected component, except for engine failure or damage, when the damage is limited to the engine, its cowlings or accessories; or for damage limited to propellers, wing tips, antennas, tyres, brakes, fairings, small dents or puncture holes in the aircraft skin; or the aircraft is missing or is completely inaccessible.

ALARP[1]: óAs low as reasonably practicableô means a risk is low enough that attempting to make it lower, or the cost of assessing the improvement gained in an attempted risk reduction, would actually be more costly than any cost likely to come from the risk itself.

Change management[1]: A systematic approach to controlling changes to any aspect of processes, procedures, products or services, both from the perspective of an organisation and individuals. Its objective is to ensure that safety risks resulting from change are reduced to as low as reasonably practicable.

[1] Civil Aviation Safety Authority (CASA). (2009). Safety Management Systems for Regular Public Transport Operations. CAAP SMS-1(0). Civil Aviation Safety Authority, Canberra, ACT.

Definition of Terms

Consequence[2]: Outcome or impact of an event.

Error[2]**:** An action or inaction by an operational person that leads to deviations from organisational or the operational personõs intentions or expectations.

Hazard[2]**:** A source of potential harm.

High capacity regular public transport (HCRPT)[3]**:** Regular public transport operations conducted in high capacity aircraft. A high capacity aircraft refers to an aircraft that is certified as having a maximum capacity exceeding 38 seats, or having a maximum payload capability that exceeds 4,200 kg.

Human factors (HF)[2]**:** The minimisation of human error and its consequences by optimising the relationships within systems between people, activities and equipment.

Incident[2]**:** An occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation.

Just culture[2]**:** An organisational perspective that discourages blaming the individual for an honest mistake that contributes to an accident or incident. Sanctions are only applied when there is evidence of a conscious violation or intentional reckless or negligent behaviour.

Likelihood[2]**:** Used as a general description of probability or frequency.

Low capacity regular public transport (LCRPT)[3]**:** Regular public transport operations conducted in aircraft other than high capacity aircraft, that is, aircraft with a maximum capacity of 38 seats or less, or having a maximum payload capability of 4,200 kg or below.

Management[2]**:** Management comprises planning, organising, resourcing, leading or directing, and controlling an organisation (a group of one or more people or entities) or effort for the purpose of accomplishing a goal.

[2] Ibid.
[3] Australia Transport Safety Bureau (ATSB). (2012). Aviation Research Report. AR-2012-025.

Definition of Terms

Non-technical skills (NTS)[4]: Specific HF competencies such as critical decision-making, team communication, situational awareness and workload management.

Quality management system (QMS)[4]: A set of policies, processes and procedures required for planning and execution (of production/development/service) in the core business area of an organisation.

Risk[4]: The chance of something happening that will have an impact on objectives.

Risk assessment[4]: The overall process of risk identification, risk analysis and risk evaluation.

Risk identification[4]: The process of determining what, where, when, why and how something could happen.

Risk management[4]: The culture, processes and structures that are directed toward realising potential opportunities whilst managing adverse effects.

Safety[4]: The state in which the probability of harm to persons or of property damage is reduced to, and maintained at, a level which is ALARP through a continuing process of hazard identification and risk management.

Safety culture[4]: An enduring set of beliefs, norms, attitudes and practices within an organisation, concerned with minimising the exposure of the workforce and the general public to dangerous or hazardous conditions. In a positive safety culture, a shared concern for, commitment to and accountability for safety is promoted.

Safety management[4]: May be described as managing the identification and reduction of hazards until they reach the ALARP criteria.

Safety management system (SMS)[4]: A systematic approach to managing safety, including the necessary organisational structures, accountabilities, policies and procedures.

[4] Civil Aviation Safety Authority, op. cit.

Definition of Terms

System safety[5]: The application of engineering and management principles, criteria and techniques to optimise safety by the identification of safety-related risks and eliminating or controlling them by design and/or procedures, based on acceptable system safety precedence.

Violation[5]: Intended or deliberate deviations from rules, regulations or operating procedures. A person committing a violation fully intends their actions. Violations can be one of four different types:

- Routine ï common violations promoted by an indifferent environment: ñwe do it this way all the timeò
- Optimising ï corner-cutting based on the path of least resistance: ñI know a better way of doing thisò
- Exceptional or situational ï one-off breaches of standards/regulations dictated by unusual circumstances that are not covered in procedures: ñwe canõt do this any other wayò; or
- Acts of sabotage ï acts of harmful intent to life, property or equipment.

[5] Ibid.

Chapter 1 Introduction

1.1 Introduction

The International Civil Aviation Organization (ICAO) is a United Nations (UN) specialised agency, created sometime after 1944 upon the signing of the Convention on International Civil Aviation, commonly referred to as the Chicago Convention. In collaboration with its member states and global aviation organisations, ICAO develops international Standards and Recommended Practices (SARPs) which the member states reference when developing their legally-enforceable national civil aviation regulations (International Civil Aviation Organization [ICAO], 2014a). Currently, there are over 10,000 SARPs reflected in the 19 Annexes to the Chicago Convention which ICAO oversees, and it is through these provisionsð as well as ICAOôs complementary policy, auditing and capacity-building effortsð that todayôs global air transport network is able to operate close to 100,000 daily flights, safely, efficiently and securely in every region of the world (ICAO, 2014a).

In Article 44 of the Chicago Convention, one of the aims and objectives of ICAO is to ñinsure the safe and orderly growth of international civil aviation throughout the worldò (ICAO, 2006a, p. 20). Air travel is arguably central to the globalisation taking place in many other industries as it facilitates economic growth, trade, international investment and tourism. On average, travel for both business and leisure purposes grew strongly worldwide over the last decade with about three billion people using air transport in 2012 and the annual passenger figure increasing by 4.7% since 2011 (ICAO, n.d.). In addition, the total scheduled passenger traffic grew at a rate of 4.9% in terms of revenue passenger-kilometres (RPKs) in 2012 (ICAO, n.d.).

Figure 1.1 shows the annual growth rate in world passenger traffic between 2002 and 2015. With an expected 4.2% annual growth rate for gross domestic product (GDP) at purchasing power parity (PPP) for the world economy, the growth in world air traffic is predicted to be 5.9% in 2014 and 6.3% in 2015 (ICAO, n.d.).

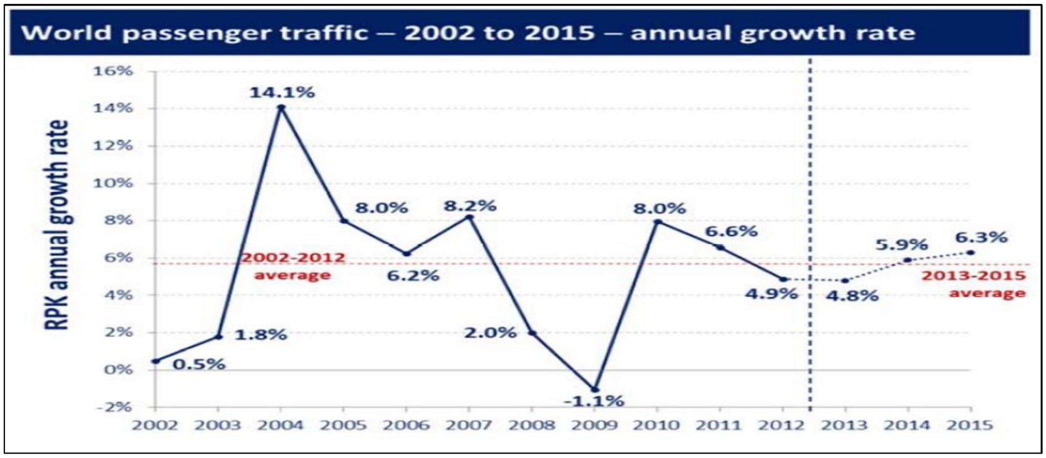

Figure 1.1: World Passenger Traffic Annual Growth Rate
Source: (ICAO, n.d.)

As ICAOôs primary indicator of aggregate safety in the global air transport sector is the accident rate, this rate is studied by ICAO based on scheduled commercial air traffic with a maximum take-off weight (MTOW) above 2,250 kg (ICAO, 2011, p. 12). The exposure data comprise scheduled commercial operations that involve the transportation of passengers, cargo and mail for remuneration or hire (ICAO, 2011, p. 12). Figure 1.2 shows the accident rate between the years 2006ï 2012. The accident rate of 3.2 accidents per million departures in 2012 is the lowest recorded rate since ICAO began tracking the global accident rate (ICAO, 2013d, p. 9).

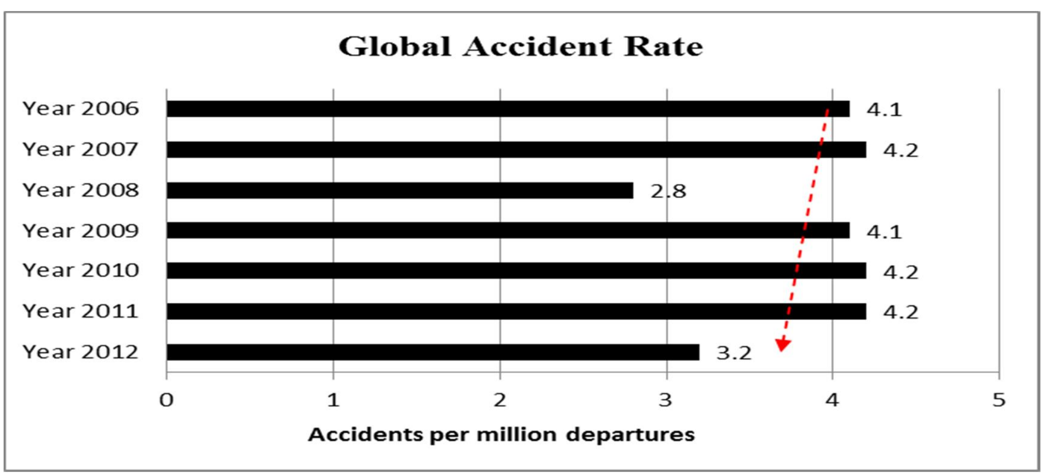

Figure 1.2: Global Accident Rate
(Reconstructed from ICAO, 2013d, p. 9)

Figure 1.3 shows that the annual number of accidents from 2006ï 2011 was generally stable, varying between 110 and 120 per year. This translates to an accident rate of approximately four accidents per million departures until 2011 (ICAO, 2013d, p. 21).

In 2012, there was a 21% year-over-year decrease in the total number of accidents in scheduled commercial air transport compared to 2011, while traffic increased marginally at approximately 1% during the same period. Consequently, the 2012 accident rate decreased to 3.2 accidents per million departures (ICAO, 2013d, p. 21).

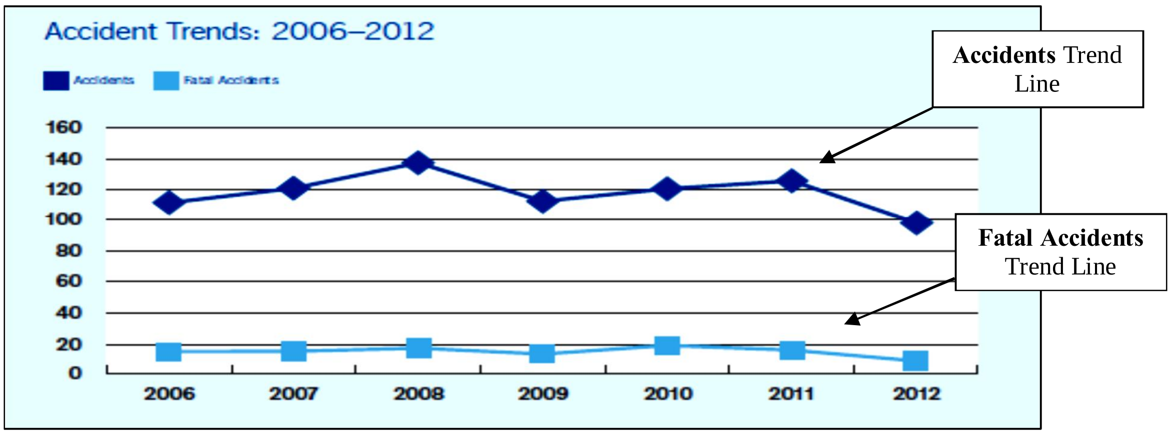

Figure 1.3: Accident Trends (2006–2012)
Source: (ICAO, 2013d, p. 21)

Figure 1.4 shows the number of fatalities that correspond to the fatal accidents shown in Figure 1.3. The harmonised accident rate for ICAO and the International Air Transport Association (IATA) reflects a 33% decrease for 2012 over 2011 (ICAO, 2013b, para. 1). The 2012 ICAO/IATA harmonised rate is 2.4 accidents per million flights for all commercial aircraft types above 5,700 kg. The figure is derived from safety-related events involving substantial aircraft damage or serious injury and is down from 3.6 accidents per million flights from when it was first developed and published in 2011 (ICAO, 2013a, para. 2).

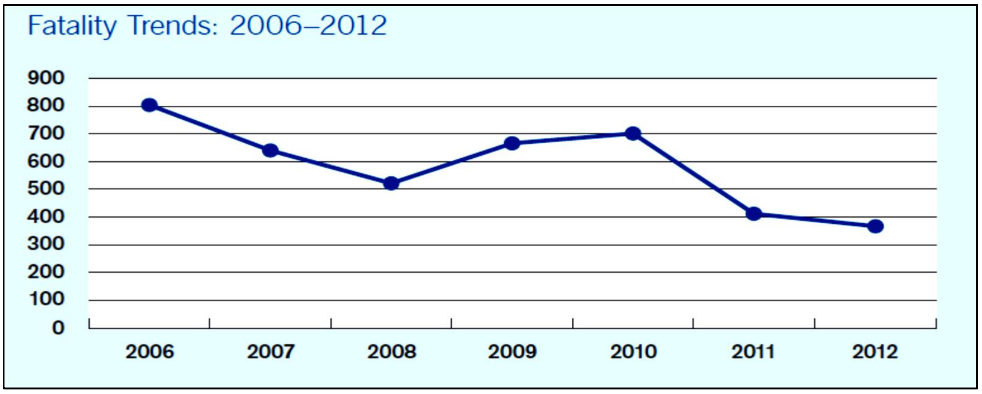

Figure 1.4: Fatality Trends (2006–2012)
Source: (ICAO, 2013d, p. 21)

Notwithstanding the current low global accident rates, a challenge facing the international civil aviation industry is the maintenance of safety in a rapidly expanding industry and within the limited resources of oversight authorities (Civil Aviation Safety Authority [CASA], 2009).

Stranks (1994) argued that most poorly managed organisations, if left alone, tend to become less safe. Accordingly, management neglect, workersô apathy and a lack of analysis will all contribute to a less-safe operation. Conversely, a successful safety management system (SMS) has been claimed to produce very positive safety outcomes (Stranks, 1994).

The importance of SMSs was recognised by ICAO which required all contracting states implement an SMS by 1 January 2009 (European Aviation Safety Agency, 2007). Safety and safety performance should focus on the aviation systemôs ability to manage safety risk at acceptable levels (Safety Management International Collaboration Group, 2010, p. 1). The limitations of a prescriptive regulation for safety management are increasingly acknowledged internationally with performance-based regulation considered to be an effective tool to manage safety in high consequence operations (Safety Management International Collaboration Group, 2010, p. 1). Performance-based regulation concentrates on measurable outcomes to assess system safety performance. The management of safety via a performance-based approach is best represented by an SMS (safety management system).

In the case of Australia, Section 11 of the *Civil Aviation Act 1988* requires the Civil Aviation Safety Authority (CASA) to perform its functions in a manner consistent with the obligations of Australia under the Chicago Convention and any other agreement between Australia and any other country or countries relating to the safety of air navigation (*Civil Aviation Act 1988*). In addition, the Air Transport Safety Bureau (ATSB) issued four recommendations to CASA between 2002 and 2007 to mandate SMS implementation for passenger-carrying operators (Australian National Audit Office [ANAO], 2010, p. 27). In 2009, CASA amended Civil Aviation Orders (CAOs) 82.3 and 82.5 to require the establishment and maintenance of SMSs by Australian low capacity regular public transport[6] (LCRPT) and high capacity regular public transport[7] (HCRPT) operators in Australia, respectively.

A total of 18 HCRPT and 17 LCRPT operators were affected by this requirement. A difference in the safety oversight strategy adopted by CASA with the introduction of SMSs is the shift away from the traditional prescriptive approach, aimed exclusively at regulatory compliance, to the SMS approach which is underpinned by a philosophy of mutual responsibility and accountability (Department of Infrastructure and Transport, 2011, p. 30).

This new approach increases the responsibility of service providers, who exercise day-to-day control over the maintenance of a safe operating environment, to focus on safety throughout the organisationGs structures, policies and procedures (Department of Infrastructure and Transport, 2011, p. 30). The Australian Government and its aviation agencies retain a critical role in maintaining quality assurance of the broader safety system which includes safety oversight and data collection, analysis and exchange procedures (Department of Infrastructure and Transport, 2011, p. 30). These aviation agencies collect, then analyse and report on a range of aviation safety data. These data are used within AustraliaGs safety system to monitor trends in aviation safety, and to identify areas where safety issues may need to be addressed in the most appropriate ways (Department of Infrastructure and Transport, 2011, p. 30). An important element of a mature system of safety management oversight is agreement between the safety regulator and service providers on the key performance indicators (KPIs) and expected level of performance to be achieved (Department of Infrastructure and Transport, 2012, p. 24).

[6] Operators using aircraft other than high capacity aircraft, being aircraft with a seating capacity of 38 seats or less or a maximum payload of 4,200 kg or less.
[7] Operators using high capacity aircraft, defined as aircraft that are certified as having a maximum seating capacity exceeding 38 seats or a maximum payload exceeding 4,200 kg.

1.2 Statement of Problem

In the course of this research, it was found that, due to the very specific and restrictive nature of the thesis topic, much of the currently available academic material lacks the regulatory background information to adequately provide a meaningful and comprehensive literature review.

Therefore, a corresponding and complementary review of the suite of regulatory SMS literature published by the different civil aviation regulatory agencies is relevant and important. This research seeks to investigate the impact of SMSs on safety performance for commercial aviation operations. Given that many of the ICAO member states have not formally required SMSs for their commercial transport operators, the choices are therefore very limited, with only a small handful of ICAO member states having implemented an SMS, for example, Canada, United Kingdom (UK), Singapore and Australia. Furthermore, all the safety data of operators held by the aviation regulators are typically of a confidential nature and not easily obtained for such a study.

Therefore, an alternative is to use the Flight Safety Foundation (FSF)ôs Basic Aviation Risk Standard (BARS) audit data for its predominantly corporate and general aviation (GA) customer base that operate mainly small to medium-sized fixed and rotary wing aircraft.

With the introduction of SMSs, the management of aviation safety changed from an industry best practice to a regulatory requirement (Roelen & Klompstra, 2012). Consequently, aviation authorities must find new ways to define the safety management activities of the industry, and industry must find the means to demonstrate compliance with the regulations (Roelen & Klompstra, 2012). Many countries departed from traditional forms of safety oversight which were carried out by large numbers of product inspections to safety oversight that is focused on the monitoring of SMSs using safety performance indicators (Roelen & Klompstra, 2012). In the late 1970s, the shift in safety management from an approach that focused on adherence to prescriptive legislation to an approach that focused on an organisation taking responsibility for managing its own unique risk profile heralded the era of outcome-based legislation and self-regulation (Feyer & Williamson, 1998). Self-regulation is defined as the requirement that an organisation ensures that it has taken all reasonably practicable steps to ensure the health and safety of its workforce (Feyer & Williamson, 1998). The impetus for this swing in regulatory orientation was a spate of catastrophic events, such as the Seveso disaster (see appendix 10) in 1976, in a diverse set of industry domains.

The consequences of this disaster included mandatory systematic management systems across facilities in Europe that handled dangerous substances (Anvari, Zulkifli, & Yusuff, 2011).

In this environment, SMSs emerged as a conglomerate of safety-related activities that empowered an organisation to discharge its responsibilities under the spectre of self-regulation (Thomas, 2012, p. 2). ñInstead of completely walking away from regulation, the role of the regulator has in turn evolved to one that attempts to support and evaluate the strengths and weaknesses of a safety management systemò (Thomas, 2012, p. 2). This change has not only presented challenges to an organisation that now must effectively self-regulate, but also to the regulator who must now evaluate the effectiveness of a system, rather than monitor compliance with a prescriptive regulation (Thomas, 2012, p. 2).

This study seeks to test the hypothesis that SMSs improve the safety performance of commercial aviation operations. In conjunction with this aim, the study will require a method by which to measure the effectiveness of an SMS and to establish safety performance indicators.

1.3 Research Objectives

What is unclear with the progressive implementation of SMSs and the associated literature as well as the regulatory requirements is how to measure the impact of an SMS on the operatorõs achievement of safety performance. In addition, there is no tool available as a standard aid for operators and regulatory agencies designed specifically for SMS measurement. Accordingly, this study is designed to contribute to the pool of knowledge by meeting the following objectives:

1. Examine the history and progress of safety for commercial aviation operations
2. Explore how safety performance is measured and determined for commercial aviation operators
3. Investigate the hypothesis that SMSs improve the safety performance of commercial aviation operations

4. Develop a tool for measuring the effectiveness of a safety management system (SMS).

1.4 Research Questions and Hypothesis

The study addresses the following two research questions:

1. What is aviation safety?
2. How is aviation safety performance measured?

In addition, the study proposes the following hypothesis:

Hypothesis 1: Safety management systems (SMSs) improve the safety performance of commercial aviation operations.

1.5 Thesis Structure

In keeping with the aims of this research project, this thesis is divided into 10 chapters, followed by references and appendices:

- Chapter 1 provides an introduction and background to the study.
- Chapter 2 outlines the evolution of aviation safety, aviationô s regulatory framework, early approaches to safety performance measurement and approaches towards the development of a safety measurement tool.
- Chapter 3 provides a detailed analysis of the building blocks of an SMS, variations of SMS models adopted worldwide and SMSs in other safety-critical industries.
- Chapter 4 is a review of Australiaô s experience and lessons learnt from the implementation of the ICAOô s mandated State Safety Program (SSP) and safety measurement systems (SMSs).
- Chapter 5 establishes the methodology for the measurement of aviation safety performance and the impact of SMSs on commercial aviation operations using the case study approach. The first case study is about SMSs in the corporate and general aviation sector and the second case study involves SMS implementation for the airline sector.
- Chapter 6 reports the results from the case studies.
- Chapter 7 discusses the results in light of the findings from the literature.

- Chapter 8 describes the Decision-Making Trial and Evaluation Laboratory (DEMATEL) tool for mapping the relationships and identifying key components of an SMS framework.
- Chapter 9 provides the conclusions arising from this research.
- Chapter 10 provides the recommendations for further consideration.
- List of references.
- Appendices.

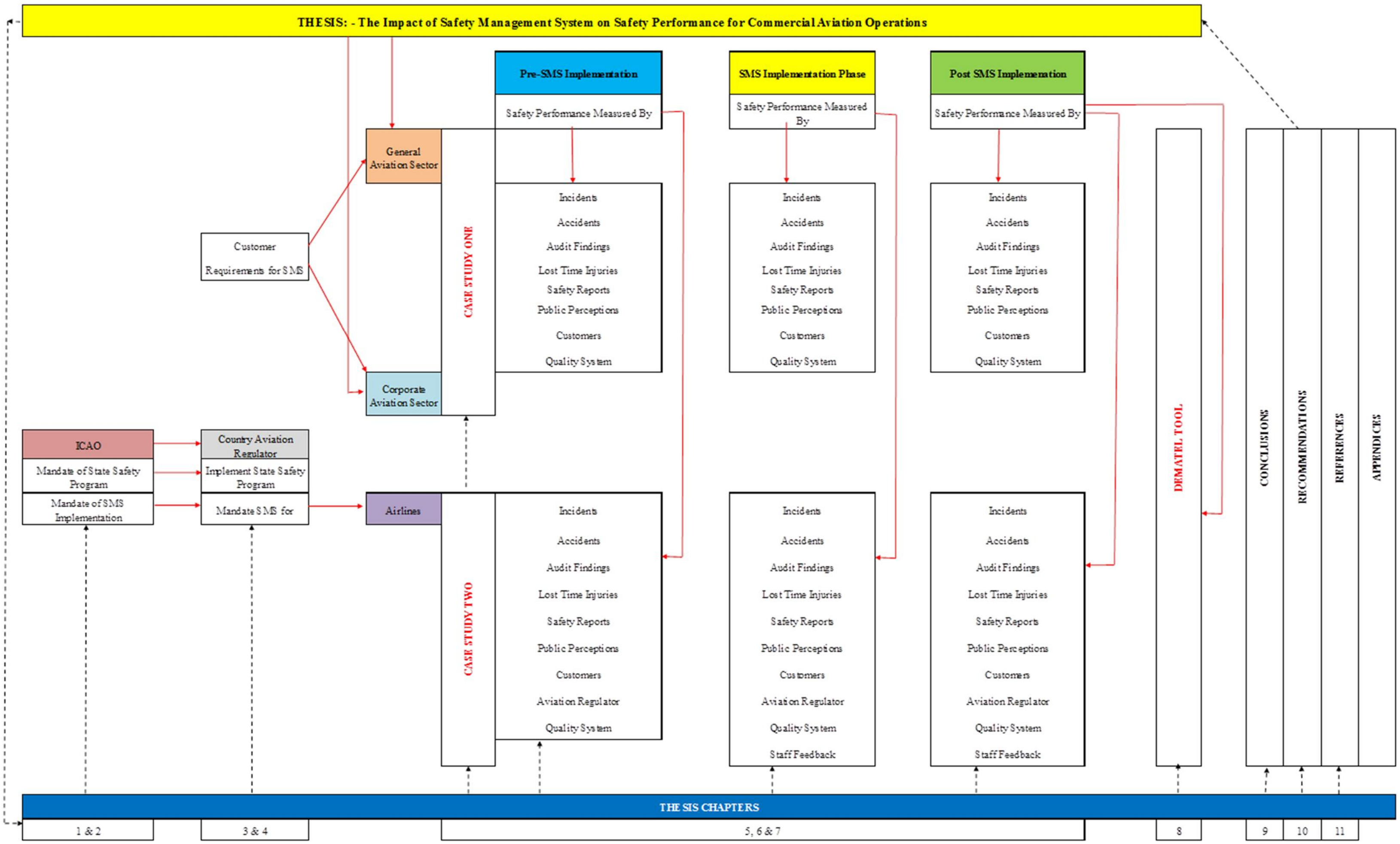

Figure 1.5: Research Structure and Methods Used

Chapter 2 Literature Review

2.1 Introduction

This chapter seeks to provide an answer to the first research question about what is meant by the term ćaviation safetyĝ. Within the context of aviation, safety is the state in which the possibility of harm to persons or of property damage is reduced to, and maintained at or above, an acceptable level through a continuing process of hazard identification and safety risk management (ICAO, 2013c). It is a term encompassing the theory, investigation and categorisation of flight failures, and the prevention of such failures through regulation, education and training.

2.2 Safety Eras

Muir and Thomas (2003) noted that the aviation industry has achieved a remarkable safety record, making it the safest form of mass transportation in the world today. Similarly, ICAO also states that aviation is arguably the safest mode of mass transportation and one of the safest socio-technical production systems in the history of humankind (ICAO, 2009, p. 3-5). Achievements in the transformation of the aviation system from what was a fragile system to what is now the first ultra-safe system in the history of transportation can be attributed to the unrelenting pursuit of safety and the efforts invested by the aviation safety community (ICAO, 2009, p. 3-5).

As illustrated in Figure 2.1, three distinct eras are apparent in the progress of aviation safety.

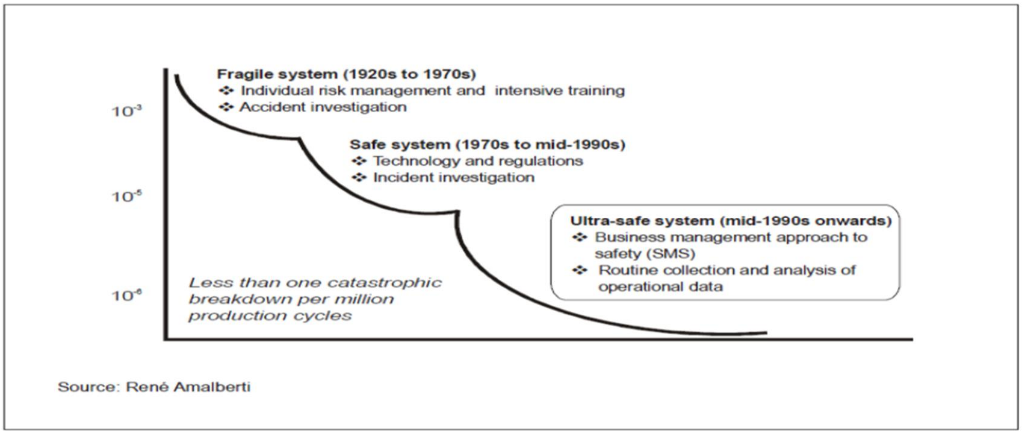

Figure 2.1: First Ultra-Safe Industrial System
Source: (ICAO, 2009, p. 3-7)

The first era spans from the early 1900s to the late 1960s. This period had a fragile system, characterised by safety breakdowns that, although not a daily occurrence, certainly did not happen infrequently (ICAO, 2009, p. 3-5). Consequently, the safety understanding and prevention strategies during this era were mainly derived from accident investigations as there was really no apparent system (ICAO, 2009, p. 3-5).

Hollnagel (1993) suggested that there should be a closer study of past accidents in order to discover if something could be learnt to prevent future accidents. The investigation of accidents was the most extensively used tool for documenting operational performance and defining remedial strategies.

Fatal or serious accidents/incidents often catalyse the improvement of a safety system as a thorough accident investigation can reveal how specific behaviours, including errors and error management, can generate an unstable or catastrophic situation. Such events can cause an airline, either temporarily or permanently, to change the management of its safety system (Maurino, 2001). The aviation industry functioned because individuals literally took it upon themselves to propel it forward with the safety focus squarely on individuals and on the individualôs management of safety risks. In turn, this built upon the foundations provided by intensive training programs (ICAO, 2009, p. 3-5).

The ôhuman eraô came into being from 1970 and continued through to the middle of 1990. During this stage of the evolution of aviation safety, aviation not only became a system, but a safe system accompanied by significant reductions in the frequency of safety breakdowns and a more encompassing understanding of safety (ICAO, 2009, p. 3-5).

The new safety focus was on the broader system and not just on individuals. Consequently, this led to a search for safety lessons beyond those generated by accident investigation to one with an emphasis on the investigation of incidents. This migration to a broader perspective of safety and incident investigation was accompanied by the mass introduction of technology and an ensuing multiple-fold increase in safety regulations (ICAO, 2009, p. 3-5).

Progressing from the human era to the present day, aviation entered into the third era of safety reliability, the ‘organisational era’. Attributes of this era include an ultra-safe system which is defined as a system that experiences less than one catastrophic safety breakdown every one million production cycles (ICAO, 2009, p. 3-5).

From a global perspective and notwithstanding regional spikes, accidents became so infrequent to the point that they were exceptional events or anomalies in the system. Serious incidents also became fewer and further apart. In concert with this reduction in occurrences, the shift towards a broad systemic safety perspective that had started to emerge during the previous era was consolidated (ICAO, 2009, p. 3-5).

Fundamental in this merging of eras was the adoption of a businesslike approach to the management of safety based on the routine collection and analysis of daily operational data to create a safety space. Theoretically, the organisation can operate freely within this safety space whilst it delivers its services with the assurance that it has maximum resistance to the safety risks that are consequential to the hazards which exist in its operational context (as shown in Figure 2.2 [ICAO, 2009, p. 3-6]). Therefore, a balanced allocation of resources to pursue the organisation’s protection and production goals is important and relevant to the definition of the boundaries of an organisation’s safety space. This businesslike approach to safety underlies the rationale of safety management systems (SMSs). Owing to the deeply-ingrained notion of safety being the absence of accidents or serious incidents, the safety boundary of the safety space rarely exists in aviation organisations (ICAO, 2009, p. 3-6).

Despite the existence of early safety warnings and flags, they are for the most part ignored or not acknowledged (ICAO, 2009, p. 3-6). When organisations experience an accident or serious incident, it is only then that they learn they may have misbalanced the allocation of resources (ICAO, 2009, p. 3-6). Under the perspective of safety being the absence of accidents or serious incidents, the organisation looks for worst-case outcomes or a lack thereof as an indication of successful safety management (ICAO, 2009, p. 3-6).

This approach is not so much safety management as it is damage control. Aviation organisations need to transition to a safety management approach to ensure that the safety boundary is defined, thus also defining the organisationôs safety space (ICAO, 2009, p. 3-6). A challenge with the evolution of safety reliability is the need to develop a different more proactive system to collect additional safety data that are beyond just accident and incident reports.

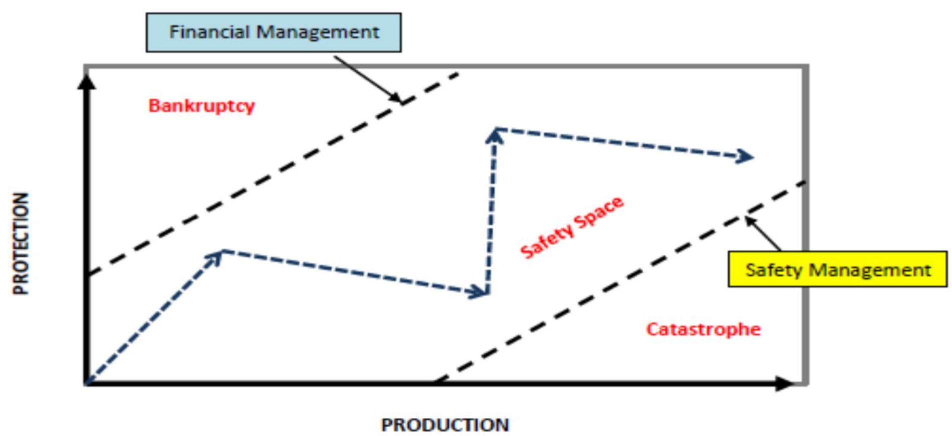

Figure 2.2: The Safety Space
(Constructed from ICAO, 2013c, pp. 2-14)

Until the late 1970s, safety data collection was mostly effected through accident and incident investigations and it invariably became increasingly scarce as improvements in safety led to a reduction in accident numbers (ICAO, 2009, p. 3-6).

Furthermore, in terms of safety data acquisition, a weakness associated with the accident and serious incident investigation process is that it is reactive and requires a trigger such as a safety breakdown for the safety data collection process to be launched (ICAO, 2009, p. 3-6). This challenge was met by an expanded collection system including safety data from accidents and serious incidents, and safety data from low-severity events available through mandatory and voluntary reporting programs (ICAO, 2009, p. 3-6).

This newer system for safety data acquisition has the advantage of being proactive as the triggering events required for launching the safety data collection process are of significantly lesser consequence than those that trigger the process for capturing accident and serious incident safety data. It was noted by ICAO that, in order to sustain safety in moving to this ultra-safe system and to support the businesslike approach to safety underlying SMSs, larger volumes of safety data, acquired without the need for triggers, were required (ICAO, 2009, p. 3-8). To complement the existing proactive and reactive safety data collection systems, a predictive safety data collection system was needed. This led to the development of electronic data acquisition systems and to the introduction of non-jeopardy self-reporting programs to collect safety data from normal operations without the need for triggering events to launch the safety data collection process.

The current stage of the evolution of predictive safety data collection systems comprises data acquisition systems based on direct observation of operational personnel during normal operations (ICAO, 2009, p. 3-8). A key reason for the need of an SMS despite the current trend indicating safety excellence in the aviation system is because, as alluded to by ICAO, like any human-made system, it is far from perfect (ICAO, 2009, p. 3-8).

Aviation is an open system that operates in an uncontrolled natural environment and is subject to environmental disturbances (ICAO, 2009, p. 3-8). The fact is that it is impossible to design a perfect open system because it is impossible to anticipate all possible operational interactions between people, technology and the context in which aviation operations take place (ICAO, 2009, p. 3-8). Monitoring normal operations on a real-time basis allows for the identification and correction of flaws and drawbacks that were not anticipated during system design (ICAO, 2009, p. 3-8).

Bayuk (n.d., para. 1) states that, in the light of todayôs very low accident rate, any further improvements to the level of safety using the traditional approach will be extremely difficult. A new way has to be found. To achieve the goal of increasing aviation safety whilst being capable of addressing human factor (HF) issues, this new way must be proactive because human error has been recognised and generally accepted as the prime cause of most aviation accidents (Bayuk, n.d., para. 2).

The development of this new approach must focus on the control of processes as opposed to the primary reliance on inspection and remedial actions on end-products. This approach in aviation system safety is called a safety management system (SMS). One may easily conclude that these human errors allude simply to carelessness or incompetence on the job. Such a conclusion may not be accurate as investigations are finding that the human is only the last link in a chain that leads to an accident (Bayuk, n.d., para. 2).

Prevention of these accidents will not be possible simply with a change of people. The desired increase in safety can only be realised when the underlying causal factors are identified and addressed. The adoption of a systems approach to safety management is a prerequisite to achieving the overall enhancement of safety in the most efficient manner.

The integration of a safety culture which promotes and practises risk mitigation as well as risk reduction across every segment and the entire fabric of an organisation is crucial (Bayuk, n.d., para. 3). Safety management is founded on the premise that there will always be safety hazards and human errors: ñ[an] SMS establishes processes to improve communication about these risks and take action to minimize them. This approach will subsequently improve an organisationôs overall level of safetyò (Bayuk, n.d., para. 4).

2.3 Regulation of Aviation

The economic regulation of commercial aviation in the United States of America (USA) was first enacted by Congress with the *Civil Aeronautics Act 1938* and in the *Federal Aviation Act 1958*. Regulation of aviation had the following aims: to encourage and develop a sound air transportation system to satisfy the needs of commerce, the postal service and defence, and to promote efficient service at reasonable charges, without unjust discrimination and undue preference or unfair or destructive competitive practices and competition, to the extent necessary to assure the sound development of air transportation that met these requirements (Fulda, 1961).

The Australian Government, through the Department of Infrastructure and Regional Development, contributes to the prosperity of the economy and the well-being of all Australians by fostering a viable, competitive and safe aviation industry. International and domestic aviation connects Australians with each other and with the rest of the world. It is also central to the Australian economy (Department of Infrastructure and Regional Development, 2015). Aviation safety regulation is a complex web. The regime created by the Chicago Convention was a key part of the post-World War II new world order and consequently mirrors the regulatory approach of the industrialised nations at that time (Jennison, 2013). The International Civil Aviation Organization (ICAO) was given the power to make rules, called Standards, that are presumptively binding on member states: provision is also provided for a state to file a difference with ICAO if it cannot meet the Standards. This quasi-legislative power has been used by ICAO to keep pace with the economic, technical and political developments that have fundamentally altered aviation in the intervening years. This also includes significant movement by ICAO into security, environmental matters and aspects of economic regulation, notwithstanding the Conventionôs nearly exclusive emphasis on safety. States develop their own safety regimes in compliance with ICAO SARPs, which are arranged by subject matter in Annexes, to the Convention (Jennison, 2013).

2.4 Approaches to Safety

The design and implementation of an SMS has the potential to be a major change to the organisation and consequently can generate new safety hazards. The use of a safety assessment tool coupled with a group of experienced managers systematically questioning and challenging all aspects of the organisationôs current and planned approach to safety management should reduce the risk of surprises in implementing the SMS; enhance the groupôs knowledge of the current situation and requirements; and prepare the way for effectively implementing change (ICAO, 2006b).

The growing belief within the aviation community is that effective implementation of a State Safety Program (SSP) and an SMS requires the existing prescriptive approach to safety to be complemented with a performance-based approach. A performance-based approach, supported by the collection and analysis of relevant data, makes good business sense while simultaneously providing an equivalent level of safety (ICAO, 2013c).

An SMS aims to introduce supplementary performance-based elements for more effective control of safety risks (ICAO, 2013c). In a conventional compliance-based regulatory environment, the approach to safety management is relatively rigid and prescriptive whereby safety regulations are used as administrative controls. This type of regulatory framework is supported by inspections and audits to assure regulatory compliance (ICAO, 2013c). In contrast, in a performance-based, enhanced safety environment, certain performance-based elements are introduced within a prescriptive framework. This allows the compliance aspect of a regulation to have room for more flexible, risk-based performance. As a result, some elements within the SMS and SSP frameworks may be managed on an increasingly performance-based approach rather than being a purely prescriptive approach. These performance-based elements are under the safety assurance and safety risk management components of the respective frameworks (ICAO, 2013c). The performance-based elements within an SMS/SSP framework include the process for safety performance monitoring and measurement at the individual product or service provider level as well as at the state level. This element allows the organisation to select its own safety monitoring indicators and to set relevant alerts and targets pertinent to its own context, performance history and expectations (ICAO, 2013c).

2.5 Problems with Measurement of Safety Performance

The aviation industry is highly complex, technical, dynamic and unforgiving. The primary objective for any operator in the aviation industry is to operate safely with aviation operators having a primary role in ensuring safety (Department of Infrastructure and Transport, 2011). Understanding safety performance in aviation at the level of forming a theoretical framework suitable for its measurement has opened various discussions about the goals of a safety management system (SMS). Perhaps some of the major attempts to provide a deeper insight for this purpose are in the body of work by different researchers such as G.D. Edkins (1997, 1998); Huan-Jyh Shyur; Paul O'Connor, Angela O'Dea, Quinn Kennedy and Samuel E. Buttrey (2011); Yueh-Ling Hsu; Wen-Chin Li; Kuang-Wei Chen; James J.H. Liou, Leon Yen and Gwo-Hshiung Tzeng (2008); Han-Chun Chang (with Liou and Tzeng) (2007); and Matthew J.W. Thomas (2012).

The measurement of safety performance is notoriously problematic as measures such as accident rates and compensation costs tend to be reactive and relatively infrequent (Cooper & Phillips, 2004). The emphasis on safety results (Cohen, 2002) usually translates to meaning that the success of safety is measured by lower levels of system failure. Many modern approaches advocate the use of proactive measures such as safety climate, hazard identification and the observed percentage of safe behaviour with the focus being on current safety activities to ascertain system success rather than on system failure (Strickoff, 2000). Used in combination, both approaches can assist organisations to ascertain the effects of their safety programs.

A derivative from behavioural safety, the observed percentage of safe score is thought to be one of the most useful indicators of current safety performance (Reber, Wallin, & Duhon, 1989). Based on random behavioural sampling, employee observers record the number of safe and unsafe behaviours performed by their peers, against predetermined checklists of safety-related behaviours derived from accident/incident reports. The observation results are used to compute a percentage safe score which is used in many ways, for example, in setting improvement targets, but is primarily intended to provide ongoing feedback so people can adjust their performance accordingly (Cooper, Phillips, Sutherland, & Makin, 1994). Reviews of behavioural safety studies have demonstrated dramatic improvements in safety performance (Grindle, Dickinson, & Boettcher, 2000; McAfee & Winn, 1989) in terms of reductions in accidents, workersô compensation costs and insurance premiums.

To date, there does not appear to be any published study has established a clear direct link between measures of safety climate and actual safety behaviour (Cooper & Phillips, 2004). The reported relationships between safety climate and safety behaviour have largely been inferred from structural equation models based on a variety of self-report instruments (Cooper & Phillips, 2004). The notable exception to this trend is Glendon and Litherlandôs (2001) attempt to measure both safety climate perceptions and actual safety behaviours in road construction (Cooper & Phillips, 2004). Contrary to expectations, but in accordance with structural equation models, this study failed to establish a direct relationship between the two (Cooper & Phillips, 2004). The authors speculated that the information obtained from the two forms of measurement is so independent that safety climate and safety behaviour exist independently under a super-ordinate safety construct or culture (Cooper & Phillips, 2004). However, the authors also postulated that the number of observations conducted over the course of one day in five-minute periods violated recommendations (Tarrants, 1980) for this type of measurement This suggests two competing explanations (Cooper & Phillips, 2004):

(1) There is no direct link between safety climate and safety behaviour or

(2) That a relationship between safety climate scale scores will be found if behavioural measurements are taken over longer periods of time.

2.6 INDICATE Safety Program

A proactive method to improve airline safety performance, namely, the óIdentifying Needed Defences in the Civil Aviation Transport Environmentô (INDICATE) safety program, was evaluated subsequent to a small number of highly publicised fatal aircraft accidents within the Australian regional airline industry in the 1990s (Edkins, 1998, p. 275) with this evaluation preceding the SMS requirements for regular public transport (RPT) operators in Australia. In the investigations that ensued for the accidents that involved Monarch Airlines aircraft VH-NDU and Seaview Air aircraft VH-SVQ, a common theme that emerged from both inquiries was that ñairline management take full responsibility for safety, and that both the aviation industry and aviation safety authorities, must be more proactive in identifying safety deficiencies so that the potential for accidents is reducedò (Edkins, 1998, p. 277).

In addition to public inquiries, the high social and economic costs of aviation accidents are forcing the industry to consider proactive safety management programs as a means to improve how aviation safety hazards are identified and addressed (Edkins, 1998, p. 277). Furthermore, an effective proactive safety program represents very real monetary benefits; however, despite these benefits, there are few formal safety management programs designed to proactively prevent airline accidents within the Australian community (Edkins, 1998, p. 277). This is partly due to a number of misperceptions that proactive safety programs are only applicable to high capacity aircraft operators; that they are costly to implement and maintain; and that they require system safety expertise for effective management (Edkins, 1997; Edkins & Brown, 1996). Edkins noted that while Reasonôs model of accident causation has been used successfully in retrospectively examining accident-contributing factors (ICAO, 1993), a system is needed where latent failures such as inadequate training, poor management communication and inadequate maintenance can be monitored proactively. Consequently, this has led to number of proactive indicators with the methodology being developed based on Reasonôs model.

These indicators periodically monitor the organisational latent failures that have appeared in catastrophic accidents (Edkins, 1998, p. 278). Examples include the Tripod-DELTA system (Hudson, Reason, Wagenaar, Bentley, Primrose, & Visser, 1994) used by Shell International in their drilling and exploration operations and the REVIEW system (Reason, 1993) that focuses on predicting latent failures or making them more visible so remedies can be implemented to improve safety at British Rail (Edkins, 1998, p. 278).

The results of Edkinôs study provided strong evidence that the INDICATE program has had a positive influence on safety management within the participating airline (Edkins, 1998, p. 291). The findings at the conclusion of the study suggested the following:

1) Measuring safety culture provides a useful method to monitor changes in company safety performance and may assist in identifying elements of a safety management program that require improvement (Edkins, 1998, p. 293).

2) Measuring the individualôs subjective estimation of risk may also provide management with feedback regarding the employeeôs appraisal of the safety of their operation (Edkins, 1998, p. 293).
3) There may be a point where a lower perception of risk could be potentially unhealthy for an organisation (Edkins, 1998, p. 293).
4) The greatest source of variance in airline safety is not necessarily aircraft equipment or the category of operation, but the real cost comes from the safety culture of organisations within the aviation system (Edkins, 1998, p. 293).
5) A small aviation company, operating on a limited budget, does not have to spend large amounts of money to improve its own safety culture. However, the benefits from implementing initiatives like safety management programs will ultimately help to improve the operational safety and professional service provided by the company (Edkins, 1998, p. 293).
6) Regardless of the type of safety program used by organisations, it is important to periodically evaluate whether the program is improving safety performance (Edkins, 1998, p. 293).

As Edkins (1998) explained, the results of the evaluation of the INDICATE trial suggest that measuring safety culture provides a useful method for monitoring changes in company safety performance and may assist in identifying elements of a safety management program, such as a hazard reporting system, that require improvement. Most importantly of all, the evaluation of the INDICATE program illustrates that the greatest source of variance is not necessarily aircraft equipment or the category of operation, but the real cost is from the safety culture of organisations within the aviation system. The benefits from implementing such initiatives will ultimately help to improve operational safety and, in some cases, reduce operating costs.

In comparing the CASA SMS model (CASA, 2009) with the INDICATE safety model in Table 2.1, it can be argued that the CASA SMS model is more comprehensive in its coverage of the safety factors than the INDICATE model, which has a primary focus on the hazard identification element. Therefore, it can be expected that the CASA SMS model will potentially yield an even more positive impact and influence on safety management within the participating airlines or organisations than the INDICATE model.

Table 2.1: Comparison of CASA SMS Model and INDICATE Safety Model

CASA SMS MODEL		INDICATE SAFETY MODEL
Similarities		
Component 1: Safety Policy, Objectives and Planning		
Element 1	Management Commitment and Responsibilities	
Element 2	Safety Accountabilities of Managers	Appointing an operational safety manager or officer who is available to staff as a confidante for safety-related issues
Element 3	Appointment of Key Personnel	
Element 4	SMS Implementation Plan	
Element 5	Coordination of the Emergency Response Plan	
Element 6	Documentation	
Component 2: Safety Risk Management		
Element 7	Hazard Identification Process	Conducting a series of regular staff focus groups to identify safety hazards within the organisation
		Establishing a confidential safety hazard reporting system
Element 8	Risk Assessment and Mitigation Process	
Component 3: Safety Assurance		
Element 9	Safety Performance Monitoring and Measurement	Conducting regular safety meetings with management
		Maintaining a safety information database
Element 10	Internal Safety Investigations	
Element 11	Management of Change	
Element 12	Continuous Improvement of the Safety System	
Component 4: Safety Training and Promotion		
Element 13	Training and Education	
Element 14	Safety Communication	Ensuring that safety information is regularly distributed to all staff

2.7 Measuring Safety Climate in Aviation

In a study examining safety climate within the commercial and military aviation sectors, the safety climate factors identified in the aviation safety climate questionnaires were found to be consistent with the literature that had examined safety climate in non-aviation high reliability organisations (OôConnor, OôDea, Kennedy, & Buttrey, 2011, p. 128). It was concluded therefore that the aviation safety climate tools had some construct validity (OôConnor et al., 2011, p. 128).

Rather than constructing more aviation safety climate questionnaires, it was recommended by OôConnor et al. (2011) that researchers should focus on establishing the construct and discriminant validity of existing measures by correlating safety climate with other metrics of safety performance as it is recognised that the accident rate in commercial aviation is too low to provide a sufficiently sensitive measure of safety performance (OôConnor et al., 2011, p. 128). The use of other measures of safety performance, collected as part of a companyôs aviation safety action program or flight operational quality assurance, could be used to assess the discriminant validity of an aviation safety climate tool (OôConnor et al., 2011, p. 128). Organisations have traditionally assessed their safety performance based on ôlagging indicatorsô of safety such as fatalities or mishap rates (OôConnor et al., 2011, p. 129). These lagging indicators show when a desired safety outcome has failed or has not been achieved. Conversely, as safety has improved and the frequency of mishaps has declined, mishap rates have ceased to be a useful metric of safety performance (OôConnor et al., 2011, p. 129).

Industries in which performance may be catastrophically impacted by failures in complex human technology systems are known as high risk industries (Shrivastava, 1986, cited in OôConnor et al., 2011, p. 129). High reliability organisations (HROs) are those organisations that succeed in avoiding catastrophes in high risk environments (Roberts & Rousseau, 1989, cited in OôConnor et al., 2011). Given the low numbers of accidents that occur in HROs, these organisations have started to examine ôleading indicatorsô of safety in an attempt to improve safety performance even further. Leading indicators of safety, as defined by the UKôs Health and Safety Executive (Health & Safety Executive, 2006, cited in OôConnor et al., 2011, p. 129), are measures of processes or inputs essential to deliver the desired safety outcomes (e.g., safety climate surveys and hazard reports). Therefore, leading indicators of safety provide a more proactive method by which to gain insight into the organisationôs safety performance and to identify areas in which efforts should be made to improve safety.

One of the most commonly used leading indicators of safety in non-aviation HROs is safety climate. Zohar (1980, cited in OôConnor et al., 2011) defined safety climate as a summary of perceptions that employees share about their work environment. Safety climate describes employeesô perceptions, attitudes and beliefs about risk and safety (Mearns & Flin, 1999, cited in OôConnor, 2011). It is a ósnapshotô of the current manifestation of the safety culture in the organisation.

The meaning of the terms ócultureô and óclimateô and whether they represent the same or different concepts has been debated in the literature (OôConnor et al., 2011, p. 129). The general consensus is that culture represents the more stable and enduring traits of the organisation and has therefore been likened to ópersonalityô. Safety culture reflects fundamental values, norms, assumptions and expectations which, to some extent, reside in societal culture (Mearns & Flin, 1999, cited in OôConnor et al., 2011, p. 129). Climate, on the other hand, is thought to represent a more visible manifestation of the culture which can be seen as its ómood stateô at a particular moment in time (Cox & Flin, 1998, cited in OôConnor et al., 2011, p. 129).

Wiegmann, Zhang, von Thaden, Sharma and Gibbons (2004, cited in OôConnor et al., 2011, p. 129) reported that ñfew formally documented efforts have been made to assess safety culture within the aviation industry, with the notable exception of military aviationò (Wiegmann et al., 2004, p. 117, cited in OôConnor et al., 2011, p. 129). This is a surprising finding, given that the civilian aviation industry has been a leader in the development and utilisation of a number of human-focused safety programs such as crew resource management (OôConnor et al., 2011, p. 129). In the past decade, due to the increase in aviation-specific safety climate research, there is now sufficient research to merit a literature review of this work. A key element missing from the literature is the extent to which aviation safety climate surveys actually measure what they are intended to measure and discriminate between groups varying in safety performance (OôConnor et al., 2011, p. 129).

To assess the discriminant validity of a safety climate questionnaire in commercial aviation, it is necessary to obtain safety performance information and questionnaire responses from a number of companies. Gaining this level of access and cooperation will undoubtedly be challenging (OôConnor et al., 2011, p. 136). Nevertheless, collaboration between rival companies with the goal of improving safety climate has been achieved in other domains, such as the offshore oil and gas industry (Mearns, Whitaker, Flin, Gordon, & OôConnor, 2003, cited in OôConnor et al., 2011, p. 136). Pooling safety climate data across companies provides a larger sample size for analysis, and allows discriminant validity to be evaluated (OôConnor et al., 2011, p. 136).

2.8 Airline Safety Measurement Using a Hybrid Model

Airline safety, as perceived by the flying public, focuses heavily on accidents without consideration of contributing elements affecting safety such as management, operations, maintenance, environment, aircraft design and air traffic control. Any measurement of aviation safety cannot simply assume that any one contributing factor is independent of other factors (Liou, Tzeng, & Chang, 2007, p. 243). ñSome previous efforts to measure aviation safety have assumed the criteria to be independent, but this is not the case in the real worldò (Liou et al., 2007, p. 243). To overcome this, Liou et al. (2007) developed a quantitative means of measuring the airline safety index. This was achieved via a hybrid multiple criteria decision-making (MCDM) model to address dependent relationships among criteria and by using the Decision-making Trial and Evaluation Laboratory (DEMATEL) with an analytic network process (ANP) to decide the relative weights of criteria, showing interdependence and feedback (Liou et al., 2007).

Accident rate is the most commonly used measurement in safety performance (Bureau of Transport and Communications Economics, 1992, cited in Liou et al., 2007). A deficiency of the use of this measurement indicator is that over 90% of ôlatentô events are not reflected (Liou et al., 2007, p. 243). Another way proposed for examining safety is the use of an MCDM model characterised by multiple conflicting criteria (Hwang & Yoon, 1981, cited in Liou et al., 2007, p. 243). Five principles need to be considered when criteria are being formulated, namely, completeness, operations, decomposition, redundancy and minimum size (Keeney & Raiffa, 1993, cited in Liou et al., 2007, p. 243). In the field of aviation safety, Chang and Yeh (2004, cited in Liou et al., 2007) developed an MCDM safety index, using 13 criteria, divided into four dimensions. In the construction of the index, through using an analytic hierarchy process (AHP), these criteria were assumed to be independent. Consistent with the argument put forth by Liou et al. (2007), such criteria are seldom independent in reality.

Liou et al. (2007) proposed a new safety measurement model based on the DEMATEL method to detect complex relationships and to build the relationship structure among the criteria for airline safety measurement. An analytic network process (ANP) was coupled with this to overcome the problem of dependence and feedback among criteria or alternatives, this being a general form of the AHP that releases hierarchical structural restrictions. In its simplest form, an airline safety index could be based on the aggregate accident rate for a period of time or for the number of landing cycles but this may be incomplete. While many studies provide useful insights into aircraft accident and incident data, the infrequency of accidents make it difficult to quickly detect and isolate problems (Liou et al., 2007, p. 244). Rose (1990) and Gellman Research Associates (1997), cited in Liou et al. (2007), suggested that airline accident rates may not be useful in predicting future accidents, thus indicating the need for an alternative index to identify airlinesô relative safety levels and to monitor trends.

While there are difficulties in quantifying precise values within complex evaluation systems, a complex evaluation environment can nevertheless be divided into subsystems to enable differences to be judged more easily as well as to measure scores. Furthermore, in a complex system, all criteria are related, either directly or indirectly, making it difficult to define a specific objective or aspect in isolation. While the vision of an interdependent system can lead to passive positioning, a clearer hierarchical structure can lead to linear activity, with no dependence or feedback, which may create new problems (Tzeng, Chiang, & Li, 2007, cited in Liou et al., 2007, p. 244).

In an example cited for Taiwan, the poor flight-safety record forced the Taiwanese government to impose many safety regulations upon airlines in an effort to reduce the accident rate (Liou et al., 2007). Proper measurement of safety records proved to be a challenge as insufficient data made objective assessment difficult. Human error also needs to be factored into consideration in any safety system (McFadden & Hosmane, 2001; Gill & Shergill, 2004, cited in Liou et al., 2007, p. 246). As previously mentioned, Chang and Yeh (2004) used an MCDM model and considered other factors, such as operations, maintenance and management, in addition to the accident rate, to evaluate the safety of airlines. However, their approach neglected the fact that in any real-life situation some degree of dependence exists between factors.

With the new safety measurement model used as the method for measuring levels of airline safety, 13 of Taiwanôs Civil Aviation Authority (CAA) safety inspectors conducted safety assessments and participated in the annual safety evaluation program for the six major airlines in Taiwan. For each of these airlines, the inspectors were asked to evaluate each criterion, excluding accident rates and ratios of certified technicians which were obtained directly from Taiwanȇs CAAȇs annual statistics report. The airlinesȏ normalised performance scores were obtained. Using the performance data of each airline and the weight of each criterion, the safety index of each airline was calculated. The results showed that when using the accident rate, as has been the case traditionally, as a safety index, the safety levels of four airlines were found to be identical, the reason being that overall there were very few air accidents. Such a result may potentially cause some airlines to cut back on safety expenditures in an effort to reduce their costs (Liou et al., 2007, p. 248).

If an airline uses the accident rate as a safety measurement when applying for new routes, flight quotas or safety rankings, it may not be easily differentiated from other companies. However, in contrast, by using the new safety measurement model that combines accident rate with three other dimensions, individual airline safety indexes may be more easily distinguished as has been shown from empirical testing of the approach which used the Taiwanese case study to illustrate its usefulness (Liou et al., 2007, p. 249).

2.9 Building an Effective Safety Management System for Airlines

This thesis argues the importance of the organisation in which people work as well as the management for whom they work as being critical elements in the understanding of the role that human factors (HF) play in major aviation accidents. The author suggests that human error and systemic defects have become the major cause of most aviation accidents as a direct result of the reliability of human beings and safety systems not improving at the same pace as the reliability of machines and computers over the years. A failed organisation is stated as a factor behind every accident (Brown, Willis, & Prussia, 2000, cited in Liou, Yen, & Tzeng, 2008, p. 20). The management of these organisation and management factors or latent factors has become increasingly important but little emphasis has been given to defining what constitutes an effective SMS and the relationship among the factors in a safety management system (SMS) (Santos-Reyes & Beard, 2002, cited in Liou et al., 2008, p. 20). The analysis of air safety has tended to be based on aggregate statistics of accident and incident rates over a period of time or number of landing cycles. Whilst Santos-Reyes and Beard (2002, cited in Liou et al., 2008, p. 20) acknowledged that these rates can provide useful insights, they also identified a number of problems with their use. Firstly, modern aircraft have become very reliable and accidents are infrequent making it hard to quickly detect a problem using accident rates. Secondly, past research has suggested that airline accident rates may not be useful in predicting the occurrence of future accidents. Thirdly, a safety system based on accident rates is one that has to wait for an accident to happen before it can react and, by todayôs safety standards, this is no longer an acceptable option. As a result, organisations have been shifting from a reactive to proactive approach to safety (Santos-Reyes & Beard, 2002, cited in Liou et al., 2008, p. 21). However, in different studies conducted by various researchers, none has clearly identified the structural relationship among the safety factors (Liou et al., 2008, p. 21). The first of these studies, by McDonald, Corrigan, Daly and Cromie (2000), examined the safety culture within maintenance organisations. This study included analysis of documentation, qualitative interviews, surveys of safety climate and attitudes and expected response to incidents as well as compliance with task procedures. The second study by Gill and Shergill (2004) used an industry-wide survey to assess employeesô perceptions of safety management and safety culture in the aviation industry. The third study by Liou et al. (2007) examined the relationship between safety records and organisational components.

As a consequence of the switch in focus and regulatory pressure, SMSs have been institutionalised by most airlines without any comprehensive SMS model for the aviation industry and the structural relationships among the safety factors of an SMS remaining unknown (Liou et al., 2008, p. 21). The proposed solution to address these issues is via a hybrid model combining fuzzy logic and the DEMATEL method to provide a visual representation of the structural relationships and identification of the key factors in a complex system, such as an SMS for airlines. In addition, it has been shown that the fuzzy DEMATEL model can be used to identify the net initiating factors and the net multiplier factors of an SMS to prioritise the management of such a system (Liou et al., 2008, p. 25). The impact relationship map (IRM) of this model shows the SMS for airlines as a safety triangle. Strategy and policy are at the top of safety triangle, implementation and human factors (HF) form the other two corners of this triangle, with monitoring and feedback playing a central role in the triangle (Liou et al., 2008, p. 25). On the other hand, the impact direction map (IDM) shows the most important role that is played by strategy and policy in an effective SMS, having the highest net influence on all the other factors (Liou et al., 2008, p. 25).

2.10 Sierra Scale/Accident Prevention Effort Tool

Stolzer, Halford and Goglia (2011, p. 285) noted that measuring safety is not quite as simple as measuring most other types of production in an organisation. The reason cited is that in the attempt to quantify safety, it is generally a case of trying to measure something that is not present: accidents. In analysing safety, the absence of accidents does not immediately translate to mean that a solid safety program is in place, nor does having an accident indicate a malfunctioning or non-existent safety program. Accident numbers are only part of the equation. The accident prevention effort (APE) is another element that exists in the formula for analysing safety. Each organisation has a distinct and quantifiable APE that can be measured, evaluated and adjusted to obtain the maximum benefits from its safety program. In addition, it can be used as a tool to provide management with the necessary information to make informed decisions on safety program outputs, resource needs and areas needing additional emphasis (Stolzer et al., 2011, pp. 285-286).

Three basic assumptions need to be made with respect to effective and ineffective safety programs. The first assumption is that organisations which appoint an auxiliary or collateral duty safety program manager and are actively engaged in loss control and accident prevention efforts are more likely to affect the level of accidental loss than organisations which have not done so. The second assumption is that, for all organisations, the safety program is more effective and has a greater probability of effectiveness when the program manager receives formal training in safety concepts and principles. The third assumption is that properly resourced safety programs are more capable and effective than under-funded or non-resourced programs (Stolzer et al., 2011, p. 286). In any organisation, these assumptions will provide the basis for establishing measurable safety criteria: through this model, a formula is used to determine a numerical rating to measure the safety program and process in place; the amount of activity within each program; the level of qualified and trained managers; and the level of management support in terms of resources. The following formula, also called the Sierra Scale, provides a relative measure by which an organisation can evaluate the effectiveness of is safety program (Stolzer et al., 2011, p. 286):

> Programs (P) x quantifiable effect (QE) = the degree of accident prevention effort (APE) or (P x QE) = APE.

By definition, programs (P) are formal programs, processes, policies or initiatives that are established and implemented by the organisation to enhance or positively impact accident prevention: therefore, the more programs that are in place within the organisation, the greater the opportunity to have a positive impact on accident prevention. Correspondingly, an increase in programs (P) will result in a higher accident prevention effort (APE). Quantifiable effect (QE) is defined as the number of tangible effects resulting from any given program as illustrated below.

Illustration 1

If an organisation has three accident prevention-related programs and is able to quantify eight significant effects, the breakdown for the operator is as follows:

Examples of Program (P)	**Effects (QE)**
Active risk management program	3
Monthly newsletter	2
Safety council	3
Total: 3 programs	8 quantifiable effects

The APE is (P x QE) = APE, that is, (3 x 8) = 24.

Let us assume that the organisation in Illustration 1 has programs in place but their safety manager is a part-time or collateral duty safety representative with no formal training. In this case, the APE remains at 24 because the organisation does have programs in place and is yielding some degree of accident prevention effort (APE):

> By using this APE formula, cause and effect can be established. An increase in either accident prevention programs or QE will positively impact the APE. This provides a safety metric by which an increase in APE can be numerically demonstrated to management. Accident prevention progress can be measured and documented, weaknesses can be identified, recommended improvements made and outcomes validated by measurable criteria. (Stolzer et al., 2011, pp. 288-289)

Based on the three basic assumptions, the APE is also significantly impacted by two other factors, the first of which is the degree of skill, training and experience of the safety manager. The second factor is program support in the form of demonstrated management commitment and resources (Stolzer et al., 2011, p. 289). When these two factors are added to the equation, an enhanced formula is obtained as illustrated below.

Illustration 2

The example of the same organisation as per Illustration 1 is used again, but with one change. The safety manager is now properly trained, qualified and/or credentialled to manage the program. In this case, the value of the program (P) will be increased to the second power because it is expected that a more capable safety manager will deliver a more effective program. Therefore, it is reasonable to allow for an increase in APE and the new equation would be as follows:

$(P^2 \text{ x } QE) = APE$ or $(3^2 \text{ x } 8) = 72$

In this scenario, the organisation has the same three prevention programs in place and the safety manager is full-time and properly trained or credentialled. The APE is 72 because it is reasonable to conclude that the program itself will function more efficiently and have a greater effect if the safety program manager is trained and qualified.

Illustration 3

If the operator and the qualified program manager can also demonstrate management support and operational resources, the program (P) in the equation is then increased to the third power with the reason being the third basic assumption. That is, an adequately resourced program has much greater potential for positive impact than a non-resourced program. Therefore, once again it is reasonable to allow for an increase in APE.

The revised APE is $(P^3 \text{ x } QE) = APE$ or $(3^3 \text{ x } 8) = 216$

It is important to note that in each of these illustrations, the number of programs (P) and the number of QEs remained the same. The increase in APE is exclusively obtained by having properly trained program managers and adequately resourced programs.

A number of rules need to be applied (Stolzer et al., 2011, pp. 290-291) and these are listed as follows:

1) The only way an organisation can be awarded a program (P) to the third power is by having both a trained and qualified program manager and demonstrating

management support. Both must exist in order to obtain APE credit to the third power.

2) To be awarded an APE increase for being trained and qualified, the program manager must have received training for the initial qualification and be able to demonstrate a continuing education and professional development training plan. Continuation training must be received, at a minimum, every two years to gain and maintain the increased APE benefit. In-house training can qualify for initial and continuation training. Each organisation sets its own rules; however, credentialling of these training rules by an accredited organisation is considered optimal.
3) The term óresourcedô means having adequate personnel and funds to administer a program with demonstrated and documented management emphasis, involvement, participation and oversight of the program.
4) It must be understood that because every organisation is unique in size and scope, organisational APE is specific only to one organisation and cannot be used to compare one organisation to another.
5) Every organisation must initially determine and define what they will call a program (P) and a quantifiable effect (QE). Once established, those definitions must then remain constant in order to demonstrate legitimate fluctuation in accident prevention effort (APE).
6) The organisation must establish criteria for evaluating programs and quantifiable effects (QEs). The evaluation must determine if a program (P) is active and effective, and if it will be awarded no credit, the raw value of a program (P), or an increased value of P^2 or P^3.

The way in which an organisation can designate a program as a P, P^2 or P^3 is by looking at the program and determining for which category it qualifies. To qualify, the program must meet the criteria as determined by the organisation. This is the opportunity by which an organisation can apply quantum safety metrics to itself (Stolzer et al., 2011, p. 291). An organisation also determines what constitutes a QE, what training qualifies someone to administer or oversee the program in question and what qualifies as a program in the first instance. As the organisation is designing the program as well as being tasked with its implementation, it is only logical that the organisation should be the one to say if the program is meeting its design expectations. The important thing is to establish and comply with the criteria.

Suggestions and guiding principles that will help to maintain stability and standardisation during the organisationøs evaluation of a program include breaking the evaluation down into two separate steps, as described below, for each program to be evaluated.

Step 1

Conduct an evaluation of the administration of the program. The focus of this assessment, conducted with the program administrator, is to examine and discuss the policy, standard operating procedures (SOPs), training records and other established procedures for the program. It is crucial at this stage to determine how the program is supposed to work both at the execution level and in theory. The program administrator must be able to show how senior management demonstrates involvement in the program and how the program is monitored and resourced.

Step 2

Conduct a performance-based evaluation by actual validation of the process in practice on the shop floor. Examples of activities associated with this review include interviews with staff, managers, supervisors and line workers as well as asking them to demonstrate how they carry out tasks related to the program.

Quantum Safety Metrics (QSM) and the Sierra Scale provide an organisation with leading safety assurance indicators; a method to measure and set goals; and the means to easily predict and project an increase in the organisationøs accident prevention effort (APE). Quantum Safety Metrics (QSM) make safety assurance tangible by providing management with concise costó benefit analysis information that is quickly referenced and with measurable options to increase their overall accident prevention effort (APE). In addition, the scale can be used as an internal evaluation tool by comparing current to desired accident prevention effort (APE). This, in tum, assists in the development of strategies to accomplish the desired APE goal. By establishing milestones for increased APE and conducting follow-up evaluations, the organisation can demonstrate measurable growth and progression towards program enhancement (Stolzer et al., 2011, p. 292). It has been stated that QEs are essentially accidents prevented and, as such, safety program managers can use the formula to illustrate the number of accidents avoided. One can determine past QEs simply by evaluating the organisationʼs historical data and records. The number of past QEs can then be used to estimate the number of potential accidents avoided for a given period in the past. The outcome is the ability to illustrate and quantify the actual number of accidents prevented (Stolzer et al., 2011, p. 292).

Chapter 3 Safety Management Systems

3.1 Background

The International Civil Aviation Organization (ICAO) wrapped up its first Safety Week in 2013 by confirming that 2012 was one of the safest years on record for global aviation (ICAO, 2013a, para. 1). Both ICAO and IATA published their annual safety reports reflecting impressively positive outcomes and a harmonised accident rate reduced by 33% for 2012 from the rate in 2011 (ICAO, 2013b, para. 1). The 2012 ICAO/IATA harmonised rate came in at 2.4 accidents per million flights for all commercial aircraft types above 5,700 kg. The figure was derived from safety-related events involving substantial aircraft damage or serious injury and was down from 3.6 accidents per million flights from when it was first developed and published in 2011 (ICAO, 2013a, para. 2).

History tells us that the foundation of aviation safety is built upon the reactive analysis of past accidents and the corrective actions introduced to prevent the recurrence of those events. In the light of todayôs very low accident rate, it has become apparent that any further improvements to the level of safety using this traditional approach will be extremely difficult (Bayuk, n.d., para. 1). A new way has to be found. This new way must be proactive in order to achieve the goal of increasing aviation safety and be capable of addressing human factor (HF) issues because human error has been recognised and accepted generally as the prime cause of most aviation accidents (Bayuk, n.d., para. 2). The development of this new approach must focus on the control of processes as opposed to the primary reliance on inspection and remedial actions on end-products. This innovative approach in aviation system safety is called a safety management system (SMS).

One may easily conclude that these human errors allude solely to carelessness or incompetence on the job. Such a conclusion may not be accurate as investigations are finding that the human is only the last link in a chain that leads to an accident (Bayuk, n.d., para. 2). Prevention of these accidents will not be possible simply with a change of people. The desired increase in safety can only be realised when the underlying causal factors are identified and addressed. The adoption of a systems approach to safety management is a prerequisite to the overall enhancement of safety in the most efficient manner. The integration of a safety culture which promotes and practises risk mitigation as well as risk reduction across every segment and the entire fabric of an organisation is crucial. Safety management is founded on the premise that there will always be safety hazards and human errors. ñSMS[s] establish processes to improve communication about these risks and take action to minimize them. This approach will subsequently improve an organizationôs overall level of safetyò (Bayuk, n.d., para. 4).

3.2 Definition of a Safety Management System (SMS)

The Civil Aviation Safety Authority (CASA) in Australia defines an SMS as ñ[a] systematic approach to managing safety, including the necessary organisational structures, accountabilities, policies and proceduresò (CASA 2009, p. 8). The Civil Aviation Authority of Singapore (CAAS) defines an SMS as ña systematic, explicit and proactive process for managing safety that integrates operations and technical systems with financial and human resource management to achieve safe operations with as low as reasonably practicable riskò (Civil Aviation Authority of Singapore [CAAS], 2008, p. 2). The UK Civil Aviation Authority (CAA [UK]) defines an SMS as ñan explicit element of the corporate management responsibility which sets out a companyôs safety policy and defines how it intends to manage safety as an integral part of its overall businessò (Civil Aviation Authority [CAA [UK]], 2002, p. 2). In an update to this definition, the UK CAA states that ñ[an] SMS is a proactive and integrated approach to safety. It should be integrated into the management system of an organisation (CAA [UK), 2010, p. 3). Transport Canada (TC) defines an SMS as ña businesslike approach to safety. It is a systematic, explicit and comprehensive process for managing safety risks. As with all management systems, a safety management system provides for goal setting, planning, and measuring performanceò (Transport Canada [TC], 2001, p. 1). A feature commonly found amongst the different definitions of an SMS is that it is a systematic process of hazard identification and managing safety risks to a level as low as reasonably practicable (ALARP) in order to achieve the objective of maintaining a safe operation.

3.3 Reasons for Implementing SMSs in Aviation

The main reason for the implementation of SMSs by ICAO member states is due to their obligations to comply with ICAOôs international standards and procedures. Australiaôs Civil Aviation Safety Authority (CASA) has stated that there is a strong economic and safety case for developing and implementing a safety management system (SMS). Potentially, an effective SMS can result in a reduction in incidents and accidents, a reduction in direct and indirect costs, safety recognition by the travelling public, reduced insurance premiums, reduced loss of staff productivity and proof of diligence in the event of legal or regulatory safety investigations (CASA, 2009, pp. 50-51). In addition, CASA has stated that mandating SMSs would overcome the limitations of the exclusive use of technical and operational standards in a rapidly expanding industry with global interconnectedness (CASA, 2008, p. 16). This would complement the current prescriptive approach with a more performance-based approach by giving legislative effect to the SMS requirement contained in ICAO Annex 6 Part 1 that requires RPT operators to implement a safety management system (SMS) (CASA, 2008, p. 16).

In its recognition that safety cannot be achieved by simply introducing rules or directives concerning the procedures to be followed by operational employees, the Civil Aviation Authority of Singapore (CAAS) states that safety must encompass most of the activities of the organisation. The CAAS continues by stating that SMSs have much in common with modern quality assurance practices, but place even more emphasis on proactive hazard identification and risk analysis. An SMS includes areas of the organisation that may not be directly involved with day-to-day flight or maintenance operations, but nevertheless have the potential to affect aviation safety (CAAS, 2006, p. 29). In addition, the UK Civil Aviation Authority (CAA) has noted that there is no recognised standard in aviation for defining a typical safety management system (SMS). Therefore, it has been necessary to adapt best practice from other industries in order to provide guidelines for those parts of the aviation industry that wish to implement a formal safety management system (SMS) (Civil Aviation Authority [UK], n.d.). Transport Canada (TC) notes that the aircraft accident rate which had previously been improving continuously since the end of World War II has levelled off and is now essentially stable (Transport Canada [TC], 2012a). As the industry grows and departures increase, the total number of accidents will also increase. While the current rate of accidents is at an all-time low, it is assumed that any appreciable increase in the total number of accidents would be unacceptable to the general public. Therefore, to avoid this situation, Transport Canada (TC) indicates that it needs to reduce the accident rate even further (Transport Canada [TC], 2012a). The steady improvement in the accident rate has been considerably attributable to improvements in technology, such as the introduction of more reliable engines and navigation systems.

However, the majority of todayǿs accidents can be attributed to human or organisational factors. With a few notable exceptions, there is little opportunity for technological solutions for these types of accidents. Safety management systems (SMSs), on the other hand, offer the most promising means of preventing these types of accidents (Transport Canada [TC], 2012a).

> Safety management systems (SMS[s]) help companies identify safety risks before they become bigger problems. Transport Canada regulations require the aviation industry to put safety management systems in place as an extra layer of protection to help save lives. (Transport Canada [TC], 2012b, para. 1)

3.4 Aviation SMS Models

The ICAO SMS model (Figure 3.1) is recommended as a generic model for ICAOǿs member states. However, it is interesting to note that the models of some ICAO Council member states that introduced SMSs before 2009 such as Australia (Figure 3.3), Singapore (Figure 3.4), the UK (Figure 3.5) and Canada (Figure 3.6) differ in minor ways from the ICAO model and also from each other. Table 3.1 highlights the commonalities and differences of these frameworks.

3.4.1 International Civil Aviation Organization (ICAO) SMS Model

The International Civil Aviation Organization (ICAO) safety management Standards and Recommended Practices (SARPs) are contained in Annexes 1; 6, Parts I and III; 8; 11; 13; and 14. These Annexes address the activities of approved training organisations; international aircraft operators; approved maintenance organisations; organisations responsible for type design and/or manufacture of aircraft; air traffic service providers; and certified aerodromes.

The ICAO safety management SARPs address three distinct requirements:

a) Requirements regarding the State Safety Program (SSP), including its acceptable level of safety
b) Requirements regarding SMSs, including the safety performance of an SMS
c) Requirements regarding management accountability vis-à-vis the management of safety during the provision of services.

The ICAO safety management SARPs introduce the notion of acceptable level of safety as the way of expressing the minimum degree of safety established by the state which must be assured by an SSP, and the notion of safety performance as the way of measuring the safety performance of a service provider and its safety management system (SMS) (ICAO, 2009, pp. 6-1, 6-2). In terms of the implementation of an SMS, ICAO recommends that the SMS should be commensurate with the organisationӳ size and the complexity of the services provided. The ICAO SMS framework comprises four components and 12 elements (ICAO, 2009, pp. 7-App 2-1, 2) which are outlined below:

Safety Policy and Objectives

1. Management commitment and responsibility
2. Safety accountabilities
3. Appointment of key safety personnel
4. Coordination of emergency response planning
5. SMS documentation

Safety Risk Management

6. Hazard identification
7. Safety risk assessment and mitigation

Safety Assurance

8. Safety performance monitoring and measurement
9. Management of change
10. Continuous improvement of the safety measurement system (SMS)

Safety Promotion

11. Training and education
12. Safety communication.

ICAO SAFETY MANAGEMENT SYSTEM MODEL			
4 MAJOR ELEMENTS			
Safety Policy & Objectives	Safety Risk Management	Safety Assurance	Safety Promotion
12 SUB-ELEMENTS			
Management Commitment & Responsibility	Hazard Identification	Safety Performance Monitoring & Measurement	Training & Education
Safety Accountabilities	Safety Risk Assessment & Mitigation	The Management of Change	Safety Communication
Appointment of Key Safety Personnel		Continuous Improvement of the SMS	
Coordination of the Emergency Response Plan			
SMS Documentation			

Figure 3.1: ICAO SMS Model
(Constructed from ICAO, 2009)

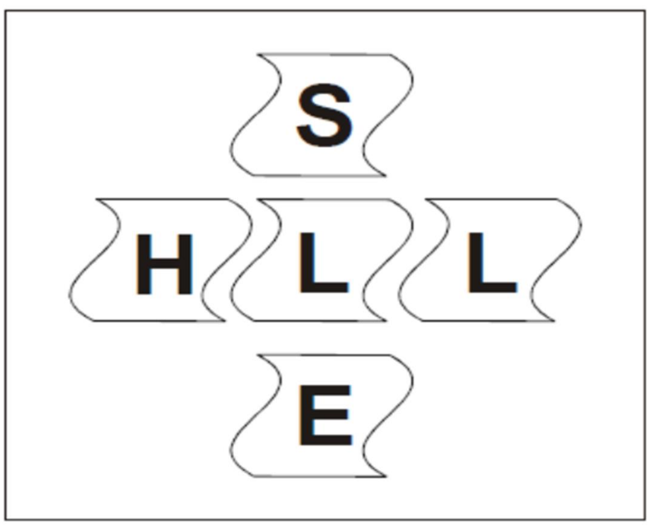

Figure 3.2: SHELL Model
Source: (ICAO, 2009)

Underpinning ICAO's SMS model (Figure 3.1) is the concept of safety that revolves around Professor James Reason's accident causation model (Figure 3.8) and the SHELL model depicted in Figure 3.2 (ICAO, 2009, pp. 2-5, 2-6). The concept and understanding of the organisational accident was accepted industry-wide as a result of Reasonǿs chain of accident causation. This model provides a means for understanding how aviation (or any other production system) operates successfully or drifts into failure. According to this model, accidents require the coming together of a number of enabling factorsð each one necessary, but in itself not sufficient to breach system defences. Because complex systems such as aviation are extremely well-defended by layers of defences, in-depth, single-point failures are rarely consequential in the aviation system. Equipment failures or operational errors are never the cause of breaches in safety defences, but rather the triggers. Breaches in safety defences are a delayed consequence of decisions made at the highest levels of the system, which remain dormant until their effects or damaging potential are activated by specific sets of operational circumstances. Under such specific circumstances, human failures or active failures at the operational level act as triggers of latent conditions conducive to facilitating a breach of the systemǿs inherent safety defences. In the concept advanced by the Reason model, all accidents include a combination of both active and latent conditions.

The SHELL model derives its name from the initial letters of its five components:

a) Software (S): (procedures, training, support, etc.)
b) Hardware (H): (machines and equipment)
c) Environment (E): (the operating circumstances in which the rest of the liveware-hardware-software [L-H-S] system must function)
d) Liveware (L): (humans in the centre of the system interacting with other parts, including other humans)
e) Liveware (L): (humans in the workplace).

The SHELL model facilitates the visualisation of the interrelationships among the various components and features of the aviation system and places an emphasis on the individual humanǿs interfaces with the other components and features of the system.

3.4.2 Civil Aviation Safety Authority (CASA) SMS Model

Legislation for the implementation of an SMS for regular public transport (RPT) Air Operator Certificate (AOC) holders in Australia was introduced by the Civil Aviation Safety Authority (CASA) in 2009 with the associated guidance material for SMSs published in the following four Civil Aviation Advisory Publications (CAAPs):

- SMS-1(0) ï Safety Management Systems for Regular Public Transport Operations, dated January 2009.
- SMS-2(0) ï Integration of Human Factors (HF) into Safety Management Systems, dated January 2009.
- SMS-3(0) ï Non-Technical Skills Training and Assessment for Regular Public Transport Operations, dated January 2009.
- SMS 4-(0) ï Guidance on the establishment of a Flight Data Analysis Program (FDAP) ï Safety Management Systems, dated August 2011.

The Civil Aviation Safety Authority (CASA)ôs SMS model (Figure 3.3) is largely modelled after the ICAOôs SMS model and consists of four major components (CASA, 2009):

1) Safety policy, objectives and planning
2) Safety risk management
3) Safety training and promotion
4) Safety assurance.

An effective SMS needs to be driven from the top of any organisation with the ultimate responsibility resting with the Chief Executive Officer (CEO). As part of the approval process for an SMS, CASA requires that the SMS manual shows how the following elements are measured and demonstrated in practice:

1) Management commitment and responsibility
2) Safety accountabilities of managers
3) Appointment of key safety personnel
4) SMS implementation plan
5) Third-party interface ï contracted activities
6) Coordination of the emergency response plan
7) Documentation.

It is also worthwhile to note that confidentiality in reporting and a just culture are two very crucial pieces in any SMS to build a level of trust in the system. Without adequate protection to ensure the integrity of these two elements, it is highly likely that safety issues will not be reported by staff and, consequently, the SMS will be ineffective. A just culture is defined as:

> an organisational perspective that discourages blaming the individual for an honest mistake that contributes to an accident or incident. Sanctions are only applied when there is evidence of a conscious violation or intentional reckless or negligent behaviour. (CASA, 2009, p. 6)

The process of risk management involves establishing an appropriate infrastructure and culture and applying a logical and systematic method of establishing the context, identifying, analysing, evaluating, treating, monitoring and communicating risks associated with any activity, function or process in a way that will enable organisations to minimise losses and maximise gains (CASA, 2009, p. 27).

Broadly speaking, the objective of risk management is to eliminate risk where practicable or to reduce the risk (a combination value derived from probability and consequence) to acceptable levels, and to manage the remaining risk in order to avoid or mitigate any possible undesirable outcome of the particular activity. Risk management is therefore integral to the development and application of an effective safety management system (SMS). It is thought that organisations pursuing a proactive strategy for safety risk management believe that the risk of accidents or incidents can be minimised by identifying vulnerabilities and by taking the necessary actions to reduce the risk of adverse consequences arising from them (CASA, 2009, p. 28).

The Civil Aviation Safety Authority (CASA) recognises that there is no such thing as absolute safety and that risk management systems are often premised on the concept of risk that is as low as reasonably practicable (ALARP). This concept means that a risk is low enough that attempting to make it lower, or the cost of assessing the improvement gained in an attempted risk reduction, would actually be more costly than any cost likely to come from the risk itself (CASA, 2009, p. 4). In applying this concept, there is an acceptance that not all risk can or should be eliminated and that there are practicable limits to which the aviation industry is able to go as well as an extent to which the industry and the community will pay to reduce adverse risks.

CASA SAFETY MANAGEMENT SYSTEM MODEL			
4 MAJOR ELEMENTS			
Safety Policy, Objectives & Planning	Safety Risk Management	Safety Assurance	Safety Promotion
15 SUB-ELEMENTS			
Management Commitment & Responsibility	Hazard Identification Process	Safety Performance Monitoring & Measurement	Training & Promotion
Safety Accountabilities of Managers	Risk Assessment & Mitigation Process	Internal Safety Investigation	Safety Communication
Appointment of Key Safety Personnel		The Management of Change	
SMS Implementation Plan		Continuous Improvement of the Safety System	
Third Party Interface			
Coordination of the Emergency Response Plan			
Documentation			

Figure 3.3: CASA SMS Model
(Constructed from CASA, 2009)

3.4.3 Civil Aviation Authority of Singapore (CAAS) SMS Model

The Civil Aviation Authority of Singapore (CAAS) noted, as a consequence of the nature of the aviation industry, that the total elimination of accidents or serious incidents is unachievable (CAAS, 2006, p. 2). It further stated that no human endeavour or human-made system can be free from risk and error and, therefore, failures will be expected to occur despite the most accomplished prevention efforts (CAAS, 2006, p. 2). However, the system must seek to understand and control such risks and errors (CAAS, 2006, p. 2). The traditional approaches to accident prevention have focused primarily on outcomes and unsafe acts by operational personnel and the safety improvement measures introduced usually exclusively address the identified safety concern (CAAS, 2006, p. 2). The organisational, human factor (HF) and environmental contexts in which errors were made were often neglected: therefore, the measures adopted often addressed only the symptoms (CAAS, 2006, p. 2). Accident prevention in the 1950s concentrated primarily on technical factors with the recognition that human performance issues or human factors (HF) played a part gaining momentum in the 1970s (CAAS, 2006, p. 2). Safety thinking in the 1990s evolved to the point of widespread acknowledgement that organisational factors played a significant role in the performance of human beings and, therefore, they were an important issue in risk and error management (CAAS, 2006, p. 2).

The study of accident causation today focuses on organisational processes, latent conditions, workplace conditions, human factors (HF) and the adequacy of defences as well as on active failures. Today, SMSs seek to enhance the organisational approach to managing a safe and successful aviation operation (CAAS, 2006, p. 2). Safety cannot be achieved by simply introducing rules or directives concerning the procedures to be followed by operational employees. It must encompass most of the activities of the organisation (CAAS, 2006, p. 2). The SMS is a systematic, explicit and comprehensive process for the management of safety risks, which integrates operations and technical systems with financial and human resource management, for all activities related to an enterprise (CAAS, 2006, p. 29). The SMS process aims to improve the safety of an enterprise as a whole, by identifying and correcting any potential problems/hazards that could contribute to a reduction of safety margins (CAAS, 2006, p. 29). Todayös systems are predominantly reactive in nature and SMSs are needed to move to more proactive processes (CAAS, 2006, p. 29). In the final analysis, the primary reason for the introduction of SMSs is to improve the existing levels of aviation safety through a systematic process of hazard and risk management (CAAS, 2006, p. 3). The CAASös Advisory Circular AC 1-3(2) recommended that all Singapore AOC holders and Singapore Airworthiness Requirements (SAR)-145-approved maintenance organisations (AMOs), other than SAR-145 Subpart D organisations, initiate the implementation of an SMS with effect from 20 December 2006. The objectives of the SMS must include the following:

- Identifies safety hazards, assesses, controls and mitigates risks.
- Ensures that remedial actions necessary to maintain an acceptable level of safety are implemented.

- Provides for continuous monitoring and regular assessment of the safety level achieved.
- Aims to make continuous improvement to the overall level of safety.

The framework of the CAAS SMS model must include, as a minimum, the following 12 elements:

Safety Policy and Objectives

1) Management commitment and responsibility

2) Safety accountabilities of managers

3) Appointment of key safety personnel

4) Emergency response planning

5) Documentation and records

Safety Risk Management

6) Hazard identification processes

7) Risk assessment and mitigation processes

Safety Assurance

8) Safety performance monitoring and measurement

9) Management of change

10) Continuous improvement and audit

Safety Promotion

11) Training and education

12) Safety communication.

A model of the CAASôs SMS framework is shown in Figure 3.4. As previously stated, according to the CAAS, safety cannot be achieved by simply introducing rules or directives concerning the procedures to be followed by operational employees: it encompasses most of the activities of the organisation. For this reason, safety management must start from senior management, and the effects on safety must be examined at all levels of the organisation. An SMS is a systematic, explicit and proactive process for managing safety that integrates operations and technical systems with financial and human resource management to achieve safe operations with as low as reasonably practicable (ALARP) risk.

The system is systematic in that safety management activities are carried out in accordance with a predetermined plan, and applied in a consistent manner throughout the organisation. It is proactive as it takes an approach that emphasises prevention, through hazards identification and risk control and mitigation measures, before events occur that affect safety. It is also explicit, in that all safety management activities are documented, visible and performed as an essential component of management activities. People, procedures, practices and technology are needed to monitor and improve the safety of the aviation transportation system.

Safety management may be also described as the systematic application of specific technical and managerial skills to identify and control hazards and related risks. By identifying, assessing and eliminating or controlling safety-related hazards and risks, acceptable levels of safety will be achieved (CAAS, 2008, pp. 2-3).

CAA SINGAPORE SAFETY MANAGEMENT SYSTEM MODEL			
4 MAJOR ELEMENTS			
Safety Policy & Objectives	Safety Risk Management	Safety Assurance	Safety Promotion
12 SUB-ELEMENTS			
Management Commitment & Responsibility	Hazard Identification & Process	Safety Performance Monitoring & Measurement	Training & Education
Safety Accountabilities of Managers	Risk Assessment & Mitigation Process	Management of Change	Safety Communication
Appointment of Key Safety Personnel		Continuous Improvement and Audit	
Emergency Response Planning			
Documentation & Records			

Figure 3.4: CAAS SMS Model
(Constructed from CAAS, 2006)

3.4.4 United Kingdom Civil Aviation Authority (CAA) SMS Model

UNITED KINGDOM CAA SAFETY MANAGEMENT SYSTEM MODEL			
4 MAJOR ELEMENTS			
Safety Policy & Objectives	Safety Risk Management	Safety Assurance	Safety Promotion
13 SUB-ELEMENTS			
Management Commitment & Responsibility	Hazard Identification Process	Safety Performance Monitoring, Measurement & Review	Training & Education
Safety Accountabilities	Risk Assessment & Mitigation Process	The Management of Change	Safety Communication
Appointment of Key Safety Personnel	Internal Safety Investigation	Continuous Improvement of the Safety System	
Coordination of the Emergency Response Plan			
SMS Documentation			

Figure 3.5: UK CAA SMS Model
(Constructed from CAA [UK], 2010)

According to the UK Civil Aviation Authority (CAA), there are three essential prerequisites for a safety management system (SMS), namely, a comprehensive corporate approach to safety, an effective organisation for delivering safety and systems to achieve safety oversight. The fundamental requirement of safety management is a positive safety culture. This positive safety culture will have a direct impact on the strength and success of a companyôs safety performance. Safety culture in an organisation can be described as the way in which it conducts its business and particularly in the way that it manages safety. Safety culture emanates from the communicated principles of top management and results in all staff exhibiting a safety ethos which transcends departmental boundaries. The measurement of safety culture can be through informal or formal staff surveys, or by observations conducted in safety-related work areas.

Safety must be actively managed from the very top of a company and safety management must be seen as an integral strategic aspect of business management. Equally, every level of management must be given safety accountability with an emphasis on the contribution of the staff at and below supervisor level (CAA [UK], 2002, pp. 1-3).

The framework of the UK CAAôs SMS (CAA [UK], 2010), as shown in Figure 3.5, consists of four key components and 13 elements, namely:

Safety Policy and Objectives

1) Management commitment and responsibility
2) Safety accountabilities
3) Appointment of key safety personnel
4) Coordination of emergency response planning
5) SMS documentation

Safety Risk Management

6) Hazard identification processes
7) Risk assessment and mitigation processes
8) Internal safety investigation

Safety Assurance

9) Safety performance monitoring, measurement and review
10) Management of change
11) Continuous improvement of the safety system

Safety Promotion

12) Training and education
13) Safety communication.

3.4.5 Transport Canada (TC) SMS Model

Canada is a member state of the ICAO and therefore has to mandate the SMS implementation. Notwithstanding this obligation, Transport Canada (TC) notes that the aircraft accident rate which had previously been improving continuously since the end of World War II has levelled off and is now essentially stable (Transport Canada [TC], 2012a). As the industry grows and departures increase, the total number of accidents will also increase. While the current rate of accidents is at an all-time low, it is assumed that any appreciable increase in the total number of accidents would be unacceptable to the general public.

Therefore, to avoid this situation, Transport Canada (TC) will need to reduce the accident rate even further (Transport Canada [TC], 2012a). The steady improvement in the accident rate was considerably attributable to improvements to technology, such as the introduction of more reliable engines and navigation systems. However, the majority of todayøs accidents can be attributed to human or organisational factors. With a few notable exceptions, there is little opportunity for technological solutions for these types of accidents. Safety management systems (SMSs), on the other hand, offer the most promising means of preventing these types of accidents (Transport Canada, 2012a):

> Safety management systems (SMS[s]) help companies identify safety risks before they become bigger problems. Transport Canada regulations require the aviation industry to put safety management systems in place as an extra layer of protection to help save lives. (Transport Canada, 2012b, para. 1)

TRANSPORT CANADA SAFETY MANAGEMENT SYSTEM MODEL					
6 MAJOR ELEMENTS					
Safety Management	Documentation	Safety Oversight	Training	QA Program	Emergency Response Plan
17 SUB-ELEMENTS					
Safety Policy	Identification & Maintenance of Applicable Regulations	Reactive Processes	Training Awareness & Competence	Operational Quality Assurance	Emergency Preparedness & Response
Non Punitive Safety Reporting System	SMS Documentation	Proactive Processes			
Roles, Responsibilities & Employee Involvement	Records Management	Investigation & Analysis			
Communication		Risk Management			
Safety Planning, Objectives & Goals					
Performance Measurement					
Management Review					

Figure 3.6: Transport Canada SMS Model
(Constructed from Transport Canada, 2008)

A model of Transport Canada (TC)ôs SMS model is shown above in Figure 3.6: it consists of six key components and 17 elements, namely:

Safety Management Plan

1) Safety policy
2) Non-punitive safety reporting policy
3) Roles, responsibilities and employee involvement
4) Communication
5) Safety planning, objectives and goals
6) Performance measurement
7) Management review

Documentation

8) Identification and maintenance of applicable regulations
9) SMS documentation
10) Records management

Safety Oversight

11) Reactive processes
12) Proactive processes
13) Investigation and analysis
14) Risk management

Training

15) Training, awareness and competence

Quality Assurance Program

16) Operational quality assurance

Emergency Response Plan

17) Emergency preparedness and response.

The key generic features of an effective SMS are highlighted by Transport Canada (TC) in their model which is depicted on Figure 3.7.

Figure 3.7: Key Generic Features of an Effective SMS
Source: (Transport Canada [TC], 2008)

Legend to Figure 3.7

A	Safety Management Plan
B	Documentation

C	Safety Oversight
D	Training
E	Quality Assurance Program
F	Emergency Response Plan

3.5 Key SMS Features

According to Bayuk (n.d.), there are four key SMS features, namely:

- ✓ Top management commitment to safety: This is an important attribute as the attitudes and actions of management can significantly influence the culture of the entire workforce. Therefore, it is critical that the organisationǿs leaders commit to the success of an SMSǿs implementation (Bayuk, n.d.).

- ✓ A proactive hazard identification process and reporting structure: The continuing prompt identification and reporting of hazards can potentially save a significant amount of time and resources at a later stage (Bayuk, n.d.).

- ✓ Timely and appropriate actions taken to manage risks to a level that is as low as reasonably practicable (ALARP): A system must be in place to control logical approaches to respond to known risks and to mitigate the risks to a level which allows for continued safe operation (Bayuk, n.d.).

- ✓ A robust change management program to evaluate changes and safety actions: The continuing appraisal of the impacts of risk management actions is necessary to ensure a closed-loop process for determining if further remedial activities are required (Bayuk, n.d.).

3.6 Comparison of SMS Models

Table 3.1 provides a comparison of the ICAO SMS model against the SMS models of CASA, CAAS, UK CAA and Transport Canada (TC). The differences are highlighted between the SMS model adopted by aviation regulators from different countries and the ICAO model. It can be seen that most of the SMS models, with the exception of that of Transport Canada (TC), match quite closely to the ICAO SMS model.

Table 3.1: Comparison of SMS Models

	SMS ELEMENTS	ICAO SMS Model	CASA SMS Model	CAAS SMS Model	UK CAA SMS Model	TC SMS Model
1	**SAFETY POLICY & OBJECTIVES**	Part of ICAO Model	Part of CASA Model	Part of CAAS Model	Part of UK CAA Model	Included in TC Model but under a different heading - **Safety Management**
1.1	Management Commitment & Responsibilities	Part of ICAO Model	Part of CASA Model	Part of CAAS Model	Part of UK CAA Model	Included in TC Model but under a different heading - **Safety Management**
1.2	Safety Accountabilities	Part of ICAO Model	Part of CASA Model	Part of CAAS Model	Part of UK CAA Model	Included in TC Model but under a different heading - **Safety Management**
1.3	Appointment of Key Personnel	Part of ICAO Model	Part of CASA Model	Part of CAAS Model	Part of UK CAA Model	Included in TC Model but under a different heading - **Safety Management**
1.4	SMS Implementation Plan	Part of ICAO Model	Part of CASA Model	Not Part of CAAS Model	Not Part of UK CAA Model	Included in TC Model but under a different heading - **Safety Management**
1.5	Coordination of Emergency Response Palnning	Part of ICAO Model	Part of CASA Model	Part of CAAS Model	Part of UK CAA Model	Included in TC Model but under a different heading - **Emergency Response Plan**
1.6	SMS Documentation	Part of ICAO Model	Part of CASA Model	Part of CAAS Model	Part of UK CAA Model	Included in TC Model but under a different heading - **Documentation**
2	**SAFETY RISK MANAGEMENT**	Part of ICAO Model	Part of CASA Model	Part of CAAS Model	Part of UK CAA Model	Included in TC Model but under a different heading - **Safety Oversight**
2.1	Hazard Identification	Part of ICAO Model	Part of CASA Model	Part of CAAS Model	Part of UK CAA Model	Included in TC Model but under a different heading - **Safety Oversight**
2.2	Safety Risk Assessment & Mitigation	Part of ICAO Model	Part of CASA Model	Part of CAAS Model	Part of UK CAA Model	Included in TC Model but under a different heading - **Safety Oversight**
3	**SAFETY ASSURANCE**	Part of ICAO Model	Part of CASA Model	Part of CAAS Model	Part of UK CAA Model	Included in TC Model but under a different heading - **Safety Oversight**
3.1	Safety Performance Monitoring & Measurement	Part of ICAO Model	Part of CASA Model	Part of CAAS Model	Part of UK CAA Model	Included in TC Model but under a different heading - **Safety Oversight**
3.2	Internal Safety Investigations	Part of ICAO Model	Part of CASA Model	Not Part of CAAS Model	Included in UK CAA Model but classified to a new Heading - Safety Risk Management	Included in TC Model but under a different heading - **Safety Oversight**
3.3	The Management of Change	Part of ICAO Model	Part of CASA Model	Part of CAAS Model	Part of UK CAA Model	Not Part of TC Model
3.4	Continuous Improvement of the SMS	Part of ICAO Model	Part of CASA Model	Part of CAAS Model	Part of UK CAA Model	Not Part of TC Model
3.5	Audit	Not Part of ICAO Model	Not Part of CASA Model	Part of CAAS Model	Not Part of UK CAA Model	Included in TC Model but under a different heading - **Quality Assurance Program**
4	**SAFETY PROMOTION**	Part of ICAO Model	Part of CASA Model	Part of CAAS Model	Part of UK CAA Model	Not Part of TC Model
4.1	Training & Education	Part of ICAO Model	Part of CASA Model	Part of CAAS Model	Part of UK CAA Model	Included in TC Model but under a different heading - **Training**
4.2	Safety Communication	Part of ICAO Model	Part of CASA Model	Part of CAAS Model	Part of UK CAA Model	Included in TC Model but under a different heading - **Safety Management**

3.7 Benefits of SMSs

The benefits to be gained with the implementation of an effective SMS are argued by CAAS, CASA, UK CAA and Transport Canada (TC) in their respective SMS documents; albeit in some cases, the stated benefits have not been explained exactly in terms of how the SMS contributes to safety outcomes. For example, CAAS claimed that, through the implementation of SMSs, regulatory requirements can be exceeded with simultaneous bottom line and productivity gains (CAAS, 2008, p. 3). No corresponding reasons or evidence have been provided by CAAS to demonstrate how this stated benefit is achieved. Notwithstanding the former point, the information in Table 3.2 suggests that, in most cases, the aviation regulators and other authors have provided supporting reasons for their claims of the benefits of a safety management system (SMS).

Table 3.2: Benefits of a SMS

Benefits of a SMS		How is This Benefit Achieved	Reference
1	Improve existing levels of aviation safety	Through a systematic process of hazard and risk management	Civil Aviation Authority Singapore, 2008, p. 3.
		SMS establishes processes to improve communication about these risks and take action to minimize them. This approach will subsequently improve an organisation's overall level of safety	Bayuk, n.d.
		An effective SMS may produce reduction in incidents and accidents	Civil Aviation Safety Authority, 2009a, p. 50.
		Continuous improvement of operational processes as SMS allows for lessons learned to be incorporated into the system and lead to superior operations	Bayuk, n.d.
2	Minimises the direct and indirect costs from accidents and incidents	The decrease in accidents and incidents will translate to a reduction of the direct and indirect costs normally associated with aviation mishaps such as fines, repair costs, damage claims and increased insurance premiums.	Bayuk, n.d.
		This stated benefit of SMS is not accompanied by any supporting information to elaborate on how it is achieved	Civil Aviation Authority Singapore, 2008, p. 3.
		Improved communication and risk mitigation will prevent many accidents from ever occurring, thus potentially avoiding incident investigation costs and operational disruptions	Bayuk, n.d.
		Reduce direct and indirect costs	Civil Aviation Safety Authority, 2009a, p. 50
		Improved communication and risk mitigation will prevent many accidents from ever occurring, thus potentially avoiding incident investigation costs and operational disruptions	Bayuk, n.d.
		Reduce direct and indirect costs	Civil Aviation Safety Authority, 2009a, p. 50
3	Reduction in insurance rate	This stated benefit of SMS is not accompanied by any supporting information to elaborate on how it is achieved	Civil Aviation Authority Singapore, 2008, p. 3.
			Civil Aviation Safety Authority, 2009a, p. 50.
4	Gain safety recognition by the travelling public	This stated benefit of SMS is not accompanied by any supporting information to elaborate on how it is achieved	Civil Aviation Authority Singapore, 2008, p. 3
			Civil Aviation Safety Authority, 2009a, p. 50.
		Establishing a marketable safety record as a record of consistently safe operations can be used to attract new business and investment	Bayuk, n.d.

Benefits of a SMS		How is This Benefit Achieved	Reference
5	Proof of due diligence in event of legal or regulatory safety enquiries	This stated benefit of SMS is not accompanied by any supporting information to elaborate on how it is achieved	Civil Aviation Authority Singapore, 2008, p. 3
			Civil Aviation Safety Authority, 2009a, p. 50
6	Improved working environment resulting in better productivity and morale	This stated benefit of SMS is not accompanied by any supporting information to elaborate on how it is achieved	Civil Aviation Authority Singapore, 2008, p. 3
		If the firm can be spurred by the regulator to invest in more systematic planning than firms would otherwise choose, the resulting plans and procedures that the firms adopt in response to implementing a safety based management system are likely to be more cost-effective than procedures or plans that the regulator might impose on them. Since the SMS addresses complex interactions that can be affected by systemic defects, human, organisational and management factors, the decision making that takes place at the operator level may result in a greater compliance as resulting plans and standards are developed by operators. By giving operators discretion in planning and creating their own management systems for managing safety there is more room for adaptive responses and innovation	Civil Aviation Safety Authority, 2008
		SMS improves employee morale and productivity by promoting communication between management and the rest of the organisation, thus preventing disenfranchisement and lifts morale	Bayuk, n.d.
		The increase in the system's level of safety leads to a reduction in material losses and enhances productivity which makes the case that safety is good for business	Bayuk, n.d.
		SMS improves employee morale as a result of employees being empowered and seeing results through the SMS	Civil Aviation Safety Authority, 2008
7	Improved Safety with continued growth	With a logical prioritisation of safety needs, SMS emphasizes risk mitigation actions that provide the biggest impact on both safety and the bottom line	Bayuk, n.d.
		Improvements on existing levels of aviation safety in the face of continued growth are achievable if operators develop and implement their own SMS which fits the size and complexity of their operation	Civil Aviation Safety Authority, 2009a, p. 50
		The tangible savings for operators as a result of knowing the operational risks and preventing incidents translates into substantial savings	Civil Aviation Safety Authority, 2008

Benefits of a SMS		How is This Benefit Achieved	Reference
8	Better scheduling and resource utilisation	Effective hazard reporting in SMS allows proactive scheduling of maintenance tasks when resources are available and increasing the likelihood that maintenance is performed on time and more efficiently. In other words, maintenance scheduling and resource utilization become more efficient	Bayuk, n.d.
9	Solid commitment ensures that safety management is accorded sufficient resources and attention.	Regardless of the size, complexity, or type of operation, there is no doubt that senior management plays a major role in determining the company's safety culture. Without the wholehearted commitment of management, any safety program will be ineffective. Safety management will succeed to the degree that senior management devotes the time, resources, and attention to safety as a core management issue.	Transport Canada, 2001, p. 8
10	Management is confident that staff understands and accept that they have important roles in ensuring safety.	Senior management commitment will not lead to positive action unless that commitment is expressed as direction in the form of a Safety Policy as required in a SMS	Transport Canada, 2001, p. 9
11	Safety data and information are available to the people who need it to do their jobs.	Management depends critically upon information to make decisions and lead the organisation. Managers and staff should be able to access and use safety information relating to the organisation's own performance. SMS requires the establishment of a system to collect and analyse safety data.	Transport Canada, 2001, p. 10
12	Staff becomes stakeholders in safety management, ensuring its effectiveness.	Safety involves everyone. A positive safety culture is invaluable in encouraging the kind of behaviour that will enhance safety. Positively re-enforcing safety conscious action sends the message that management cares about safety. The best way to establish safety as a core value is to make safety an integral part of the management plan. This is done by setting safety goals and holding managers and employees accountable for achieving those goals.	Transport Canada, 2001, p. 11
13	Clearly stated goals lead to a commitment to action which will enhance the safety of an organisation.	Establishing Safety as a Core Value	Transport Canada, 2001, p. 11

3.8 System Safety and SMSs

óSystem safetyô as defined by MIL-STD-882 is ñthe application of engineering and management principles, criteria, and techniques to achieve acceptable mishap risk, within the constraints of operational effectiveness and suitability, time, and cost, throughout all phases of the system life cycleò (New England Chapter of the System Safety Society, 2002, p. 6). The MIL-STD-882 document is used by the US Department of Defense (DoD) to provide a standard, generic method for the identification, classification and mitigation of hazards (Department of Defense [DoD] Standard Practice [US] 2012).

The traditional safety approach is via system safety and, as such, the primary focus is on the safety implications of technical aspects and components of the system under consideration, somewhat at the expense of the human component, mainly due to the engineering roots of this approach (ICAO, 2009, p. 4-1). On the other hand, SMSs build upon the dogma of system safety (hazard identification and safety risk management), and expand the field of perspective to include human factors (HF) and human performance as key safety considerations during system design and operation (ICAO, 2009, p. 4-1).

A major difference between SMSs and system safety is that SMSs take a proactive approach to safety management and go beyond prescriptive audits and checklist-based inspections to develop procedures and indicators that anticipate safety risks (Bayuk, n.d.).

In order to verify SMS performance, the civil aviation authority of the state has to conduct oversight of the organisationôs performance on a periodic basis, during the course of activities aimed at delivery of services. This would prove to be difficult if not impossible in practice, hence the reason for the safety performance indicators and safety performance targets of a safety management system (SMS). While acceptance and compliance oversight are prescriptive-based, oversight of safety performance indicators and targets is performance-based (ICAO, 2009, p. 6-15).

The responsibility for a safe operation is spread throughout the different levels of the entire organisational structure in safety management systems (SMSs). Such an approach increases the likelihood of more people watching out for safety issues and reporting them, thus reducing the chance of a hazard going undetected. This approach follows Reasonôs concept of the accident causation model as shown in Figure 3.8.

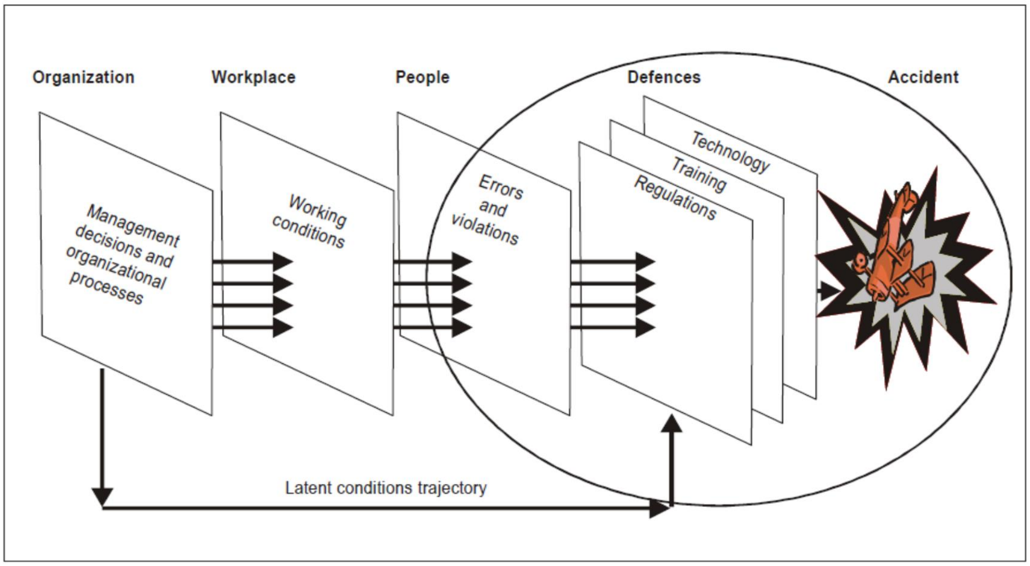

Figure 3.8: Concept of Accident Causation
Source: (ICAO, 2013c, p. 2-3)

The implementation of every SMS will create its own customised set of defences or layers that coordinate to craft the safety culture. Each layer of defence has holes that symbolise the potential for a safety hazard to go undetected, because the layer may not be designed to manage that type of hazard or it may simply be missed, due to human error. Conversely, when these layers are combined by SMS principles, this makes it much harder and less likely for a hazard to pass through all the defences without being identified and mitigated.

Commonalities between an SMS and a quality management system (QMS) are quite substantial as both require planning, performance monitoring, communication and the participation of all employees.

3.9 Safety Management and Quality Management Systems

The primary document recommended by ICAO to be used by all contracting states in developing their SMSs is the ICAO SMS manual, Document 9859. The Standard commonly used for and referred to in the development of a QMS within the aviation industry is ISO 9000 or its equivalent designed for the aerospace industry, AS 9000.

The global adoption of the ISO 9000 standards for a QMS may be attributable to a number of factors but, mainly, it stems from the initial requirement by a number of major purchasers that their suppliers must hold ISO 9001 certification. In addition to benefits for several stakeholders, a number of studies have identified significant financial benefits for ISO 9001-certified organisations. A survey by the British Assessment Bureau in 2011 indicated that 44% of their certified clients had won new business (British Assessment Bureau, 2011).

The view of the Civil Aviation Authority of Singapore (CAAS) is that an SMS differs from a QMS in that it focuses on the safety, human and organisational aspects of an operation, that is, 'safety satisfaction'. A QMS, on the other hand, focuses on the product or service of an operation, that is, customer or 'specification satisfaction'. Safety management results in the design and implementation of organisational processes and procedures to identify hazards as well as controlling or mitigating risks to within an acceptable level in aviation operations.

Quality management techniques provide a structured process for ensuring that organisational processes and procedures achieve their intended product specifications, service specifications or customer expectations. Notwithstanding the former, the construct of an SMS is quite similar to that of a QMS in that they both have the same procedural principles and objectives. From an implementation perspective, the goal is to integrate an organisation's safety policy and objectives with its quality policies. Conversely, the coverage of quality policies should be fundamentally based upon quality in support of safety. Safety objectives should receive primacy where conflicts are identified (CAAS, 2008).

The CAAS also stated that a QMS is the main supporting structure for a safety management system (SMS) (CAAS, 2008, p. 34). An SMS is a natural progression from traditional techniques, based on modern understanding of the nature of organisational accidents and how they occur. An SMS has much in common with modern quality assurance practices, but places even more emphasis on proactive hazard identification and risk assessment. It includes areas of the organisation that may not be directly involved with day-to-day flight or maintenance operations, but nevertheless have the potential to affect aviation safety (CAAS, 2010).

The Civil Aviation Safety Authority (CASA) states that an SMS goes beyond a traditional QMS by focusing on the safety, human and organisational aspects of an operation. Furthermore, CASA adds that within an SMS, there is a distinct focus on operational safety and the human element in the system, thus underlining the importance of integrating human factors (HF) through all parts of the safety management system (SMS) (CASA, 2009, p. 10).

A notable difference between an SMS and a QMS is that an SMS looks at the enterprise as a whole, whilst a QMS tends to be managed usually at a certificate or divisional level, for example, setting up a separate quality system for flight operations and engineering. The majority of SMS activity will continue to be directed toward particular specialist functions; the system is also concerned with how all relevant functions are integrated. To a large extent, the effectiveness of SMSs relies on the corporate culture. The aim of SMSs is to achieve a culture wherein each individual contributes to and is responsible for safety, and where the reporting of safety concerns is actively encouraged (CAAS, 2010).

Other than an SMS and a QMS, another array of different and separate management systems co-exist within an organisation which will inevitably pose a challenge for many organisations. For example, there may be a requirement for a Human Factor and Error Management System (HFEM), Environment Management System (EMS), Occupational Health and Safety Management System (OHSMS), etc.

The view of the CAAS is that aviation organisations should, where appropriate, consider integrating their management systems for quality, safety, HFEM, security, occupational health and environmental protection. Apart from internal integration of an organisationĝs SMS components with related control systems, such integration should be coordinated with other organisations or contractors whereby this interface with their relevant SMS or control system is necessary during the provision of services (CAAS, 2008).

Without a clear and proper understanding of the underlying similarities and differences between an SMS and a QMS, the potential for misunderstanding is high as alluded to by McNeely (2010). An often repeated statement heard is ñwe already have a quality management system in place, and do not need another such as [an] SMSò (McNeely, 2010). It has been argued that safety is an unspoken and unwritten quality expectation of customers and the two cannot be separated. Having a quality product or service, as defined by the ISO standards, may still not be equivalent to having a safe product or service. The problems faced by Toyota, as described below, clearly accentuate this point (McNeely, 2010).

Part of the confusion stems from the adoption of some of the same types of tools and techniques used in quality management to manage the safety system. Trade association presidents and regulators state that SMSs are a businesslike approach to managing safety and this is correct. However, many people falsely assume this to mean that processes designed to produce a quality product, that is, processes that repeatedly do the same thing, without variation, equate to repeatedly producing a safe product. In Toyotaøs case, the accelerator parts were manufactured to a specification, albeit an incorrect one: the quality system would detect any variance of this process, and adjust the process to bring the production back in line with the specification. In effect, Toyota had a quality product. It was produced as designed, and produced repeatedly without variation outside of established limits.

However, Toyota did not have a safe product and, as indicated above, did not connect the dots between failures of the product during use, to failures of the production process. Because QMSs measure types of data points geared towards production costs and sales, some people believe these same types of measures with a õbusinesslike approachö equate to a safety management system (SMS) (McNeely, 2010). What makes the QMS and the SMS different is how the tools and techniques are used, along with a focus on the investigation of events. Quality management systems (QMSs) do not investigate incidents or accidents for risk assessment. They audit the output of a process only for variance and then make adjustments. An SMS investigates events, looking for contributing factors from all influencing sources (McNeely, 2010).

One of the purposes of an SMS is to improve safety performance and, therefore, to reduce exposure to the risk of having an accident. It is not focused on the safety record per se. Quality management systems (QMSs) are also focused on continuous improvement, but through improving the production record rate. This is another source of confusion between the two management system concepts: improving a safety record is not the same as improving safety performance.

Many aviation companies have extremely good safety records, but are operating with risky behaviour or inadequate organisational structures, and have simply not had an accident yet. A good safety record, just like a good quality record, does not guarantee safety. Toyota has for decades been renowned for its outstanding quality: the companyøs reputation was built on its quality, yet in 2010, Toyota came face to face with a failure to connect safety to quality (McNeely, 2010).

The case study of Toyota has highlighted significant issues with the use of quality performance indicators versus safety performance indicators. Toyota managementôs attention and oversight were focused on the business bottom line, and those metrics were quality measures. Management was not focused on safety risk assessment or safety risk management which are just two of the components of an SMS, and which require management involvement (McNeely, 2010).

3.10 SMSs in Safety-Critical Industries

Besides aviation, SMSs and system safety principles have been used in many other mission-critical industries such as petroleum, nuclear, railroad, maritime and chemical. These industries demonstrate how past disasters have led to the development and adoption of critical components of safety management systems (SMSs). The progression of system safety has been predicated on the need to avoid loss of life, injuries and financial consequences experienced by the various industries discussed here. The traditional approach to the safety regulation of industry is one that is reactive and prescriptive. Usually, it is in response to a significant safety failure and only addresses the issues that directly led to the failure. Although this has led to an improved level of safety, the current rate of growth in the aviation industry in particular requires a more systematic approach. During its early years, commercial aviation was a loosely regulated activity characterised by underdeveloped technology; lack of a proper infrastructure; limited oversight; an insufficient understanding of the hazards underlying aviation operations; and production demands incommensurate with the means and resources actually available to meet such demands. Therefore, it is hardly surprising that the early days of commercial aviation were characterised by a high frequency of accidents; that the overriding priority of the early safety process was the prevention of accidents; and that accident investigation was the principal means of prevention. In those early days, accident investigation, hampered by the absence of other than basic technological support, was a daunting task (ICAO, 2009, p. 2-2). In fact, in todayôs dynamic industries with increasingly complex production processes and high volume operations, prescriptive regulations become less effective because they primarily seek to prevent the reoccurrence of failures. In many industries, prescriptive measures have been replaced by SMS processes, which are better suited for these dynamic systems (Bayuk, n.d.).

3.10.1 Petroleum Industry

3.10.1.1 Piper Alpha Oil Rig Accident

A good example of a change from prescriptive safety to an SMS approach is the example of the Piper Alpha oil rig accident. Piper Alpha was a large North Sea oil platform that started production in 1976. It produced oil from 24 wells and, in its early life, had also produced gas from two wells. It was connected by an oil pipeline to Flotta and by gas pipelines to two other installations. In 1988, Piper Alpha was operated by Occidental Petroleum (Caledonia) Ltd, a wholly owned subsidiary of Occidental Petroleum Corporation. On 6 July 1988, a massive leakage of gas condensate on Piper Alpha ignited causing an explosion which led to large oil fires. The heat ruptured the riser of a gas pipeline from another installation which produced a further massive explosion and fireball that engulfed the Piper Alpha platform. This happened in just 22 minutes. The scale of the disaster was enormous (Oil & Gas UK, n.d.). The fire caused 167 deaths, loss of oil production and an insurance payout equivalent to US$2.8 billion. The public inquiry found the management company directly responsible for a series of preventable failings and errors. The report recommended a change from a prescriptive safety system to a safety risk management approach based on quantitative risk assessment. This approach assesses risk by determining the likelihood of an event and identifying the severity of the consequences. This is the basis of the safety risk management pillar of safety management systems (SMSs) (Bayuk, n.d.).

In his report investigating the Piper Alpha accident, Lord Cullen made 106 recommendations, all of which were accepted by industry, with many being a direct result of industry evidence. The responsibilities for implementing these recommendations were spread across the regulator and the industry. The Health and Safety Executive (HSE) was to oversee 57 recommendations with the operators responsible for 40 recommendations. Eight were for the whole industry to progress and the last recommendations was for the Standby Ship Owners Association. The Offshore Installations (Safety Case) Regulations came into force in 1992. By November 1993, a safety case for every installation had been submitted to the HSE and, by November 1995, all had had their safety case accepted by the Health and Safety Executive (HSE). The

Safety Case Regulations require the operator/owner of every fixed and mobile installation operating in UK waters to submit a safety case to the HSE, for their acceptance. The safety case must give full details of the arrangements for managing health and safety and for controlling major accident hazards on the installation. It must demonstrate, for example, that the company has an SMS in place; has identified risks and reduced them to as low as reasonably practicable (ALARP); has introduced management controls; provided a temporary safe refuge on the installation; and has made provisions for safe evacuation and rescue (Oil & Gas UK, n.d.).

3.10.2 Nuclear Industry

Safety has always been a major concern for the nuclear industry, given that the severity of any accident or incident will inevitably be catastrophic for most cases. Historically, two significant nuclear-related accidents have occurred:

(1) The Three Mile Island accident in the USA
(2) The Chernobyl disaster in the Ukraine.

These events have led to improvements in nuclear technology and in the associated safety culture required to support it effectively. In more recent times, the Fukushima accident occurred in Japan.

3.10.2.1 Three Mile Island Accident

The Three Mile Island nuclear power station is situated near Harrisburg, Pennsylvania in the USA. It had two pressurised water reactors. Reactor 1 entered service in 1974 and, at the time of the accident, Unit 2 was almost brand new. The accident to Unit 2 happened at 4 a.m. on 28 March 1979. The nuclear plantȷs reactor core was starved of coolant and about half the fuel melted, resulting in severe damage. The operators were unable to diagnose or respond properly to the unplanned automatic shutdown of the reactor. Deficient control room instrumentation and inadequate emergency response training proved to be root causes of the accident (World Nuclear Association, 2012b). Fortunately, containment of the nuclear reactor was not breached and the accident did not cause any deaths. However, the cost for the clean-up was around US$975 million and the reactor was permanently closed. The investigation called for a restructuring of the US Nuclear Regulatory Commission with more emphasis on the agencyȷs responsibilities for reactor safety. In particular, it called for improving person-to-machine interfaces and risk assessment procedures.

After this accident, the US Nuclear Regulatory Commission increased its focus on a formal risk assessment approach which has been the basis for many subsequent improvements in plant design and operation. In addition, changes were made in the area of control room operations, such as licensee training, program certification and simplified procedures to mitigate a hazard (Bayuk, n.d.). Disciplines in training, operations and event reporting that grew from the lessons of the Three Mile Island accident have made the nuclear power industry demonstrably safer and more reliable. These trends have been both promoted and tracked by the Institute for Nuclear Power Operations (INPO). To remain in good standing, a nuclear plant must meet the high standards set by INPO as well as the strict regulations of the US Nuclear Regulatory Commission.

A key indicator is the graph of significant plant events, based on data compiled by the US Nuclear Regulatory Commission. The number of significant events decreased from 2.38 per reactor unit in 1985 to 0.10 at the end of 1997. On the reliability front, the median capability factor for nuclear plantsð the percentage of maximum energy that a plant is capable of generatingð increased from 62.7% in 1980 to almost 90% in 2000. Other indicators for plants in the USA tracked by INPO and its world counterpart, the World Association of Nuclear Operators (WANO), are the unplanned capability loss factor, unplanned automatic scrams, safety system performance, thermal performance, fuel reliability, chemistry performance, collective radiation exposure, volume of solid radioactive waste and industrial safety accident rate. All are reduced, that is, improved substantially, from 1980 (World Nuclear Association, 2012b).

3.10.2.2 Chernobyl Accident

The April 1986 disaster at the Chernobyl nuclear power plant in the Ukraine was the product of a flawed Soviet reactor design coupled with serious mistakes made by the plant operators. It was a direct consequence of Cold War isolation and the resulting lack of any safety culture.

The accident destroyed the Chernobyl 4 reactor with the loss of more than 30 lives. Acute radiation syndrome (ARS) was originally diagnosed in 237 people on-site and involved with the clean-up: it was later confirmed in 134 cases. Of these, 28 people died as a result of ARS within a few weeks of the accident. Nineteen more subsequently died between

1987 and 2004 but their deaths cannot necessarily be attributed to radiation exposure. Nobody off-site suffered from acute radiation effects although a large proportion of childhood thyroid cancers diagnosed since the accident is likely to be due to the intake of radioactive iodine fallout. Furthermore, large areas of Belarus and the Ukraine, in Russia and beyond were contaminated in varying degrees.

The Chernobyl disaster was a unique event and was the only accident in the history of commercial nuclear power where radiation-related fatalities occurred (World Nuclear Association, 2012a). This was the case up until the Japanese nuclear accident at Fukushima in 2011. After Chernobyl, remedial measures to enhance nuclear safety were implemented at existing plants with similar reactors. Safety upgrades essentially removed the design deficiencies that contributed to the accident. Progress was also achieved in plant management, training of personnel, non-destructive testing and safety analysis. As a result, a repetition of the same accident scenario seems no longer practically possible. The new generation of nuclear plants is much safer, due in large part to the lessons learned from these industrial accidents. Several elements of todayọ̑s SMSs were developed as a result, and the strict safety culture of todayọ̑s nuclear industry is an excellent model for other industries that perform high-risk operations (Bayuk, n.d.).

3.10.2.3 Fukushima Accident

Following a major earthquake, a 15-metre tsunami disabled the power supply and cooling of three Fukushima Daiichi reactors, causing a nuclear accident on 11 March 2011. There have been no deaths or cases of radiation sickness from the nuclear accident, but over 100,000 people had to be evacuated from their homes to ensure this. A national Nuclear Accident Independent Investigation Commission (NAIIC) was subsequently set up with one of its tasks being to provide suggestions including the ñre-examination of an optimal administrative organisationò for nuclear safety regulation based on its investigation of the accident. The NAIIC reported in July 2012, harshly criticising the government, the plant operator and the countryọ̑s national culture. After conducting 900 hours of public hearings, interviews with more than 1,100 people and visiting several nuclear power plants, the commissionọ̑s report concluded that the accident was a man-made disaster, the result of collusion between the government, the regulators and Tokyo Electric Power Co (Tepco). The report said that the root causes were the organisational and regulatory systems that supported faulty rationales for decisions and actions. The NAIIC criticised the regulator for insufficiently maintaining independence from the industry in developing and enforcing safety regulations, the government for inadequate emergency preparedness and management, and the plant operator, Tepco, for its poor governance and lack of safety culture. The report called for fundamental changes across the industry, including the government and regulators, to increase openness, trustworthiness and the focus on protecting public health and safety.

The fundamental causes were found to be in the ingrained conventions of Japanese culture including a reflexive obedience, reluctance to question authority, a devotion to sticking with the program, groupism and insularity. The mindset of government and industry had led the country to avoid learning the lessons of the previous major nuclear accidents at Three Mile Island and Chernobyl. The consequences of negligence at Fukushima stand out as catastrophic, but the mindset that supported it can be found across Japan. The NAIIC reported that Tepco had been aware since 2006 that Fukushima Daiichi could face a station blackout if flooded, as well as the potential loss of ultimate heat sink in the event of a major tsunami. However, the regulator, Nuclear & Industrial Safety Agency (NISA), gave no instruction to the company to prepare for severe flooding, and even told all nuclear operators that it was not necessary to plan for station blackout. During the initial response to the tsunami, this lack of readiness for station blackout was compounded by a lack of planning and training for severe accident mitigation. Plans and procedures for venting and manual operation of emergency cooling were incomplete and their implementation in emergency circumstances proved very difficult as a result. The regulator, NISA was also criticised for its ñnegligence and failure over the yearsò to prepare for a nuclear accident in terms of public information and evacuation, with previous governments equally culpable. Tepcoôs difficulty in mitigation was then compounded by government interference which undermined NISA (World Nuclear Association, 2013).

3.10.3 Maritime Industry

Several maritime accidents in the 1980s and 1990s led to a push for a uniformly applicable formal safety management approach. These were manifestly caused by human errors, with management faults also identified as contributing factors.

3.10.3.1 Herald of Free Enterprise Accident

The most notable accident is the flooding and subsequent capsize of the roll-on/roll-off passenger ferry, *Herald of Free Enterprise*, on 6 March 1987, that resulted in the loss of 193 lives. In a public court inquiry into the loss of the *Herald of Free Enterprise*, the investigating judge famously described the management failures as ñthe disease of sloppinessò. In response to this accident, at its 16th assembly in October 1989, the International Maritime Organization (IMO) adopted resolution A.647(16), óGuidelines on Management for the Safe Operation of Ships and for Pollution Preventionô. The purpose of these guidelines was to provide those responsible for the operation of ships with a framework for the proper development, implementation and assessment of safety and pollution prevention management in accordance with good practice. The objective was to ensure safety, to prevent human injury or loss of life, and to avoid damage to the environment, in particular, the marine environment, and to property. The guidelines were based on general principles and objectives so as to promote the evolution of sound management and operating practices within the industry as a whole. They recognised the importance of the existing international instruments as the most important means of preventing maritime casualties and pollution of the sea and included sections on management and the importance of a safety and environmental policy.

After some experience in the use of the guidelines, in 1993, the IMO adopted the óInternational Management Code for the Safe Operation of Ships and for Pollution Preventionô (the ISM Code). In 1998, the ISM Code became mandatory. The code establishes safety management objectives and requires an SMS to be established by ñthe Companyò which is defined as the shipowner or any person, such as the manager or bareboat charterer, who has assumed responsibility for operating the ship. The company is then required to establish and implement a policy for achieving these objectives. This includes providing the necessary resources and shore-based support. Every company is expected ñto designate a person or persons ashore having direct access to the highest level of managementò. The procedures required by the code should be documented and compiled in a Safety Management Manual, a copy of which should be kept on board (International Maritime Organization [IMO], n.d.).

3.10.4 Chemical Industry

3.10.4.1 Esso Longford Gas Plant Accident

Esso Australiaȣs gas plant at Longford in Victoria suffered a major fire in September 1998. The consequence of this accident was the death of two men and disruptions to the stateȣs gas supply for two weeks. What happened was that a warm liquid system failed, allowing a metal heat exchanger to become intensely cold and therefore brittle. When operators tried to reintroduce warm lean oil, the vessel fractured and released a large quantity of gas which found an ignition source and exploded.

In the analysis of the findings of the Royal Commission into the accident, the following lessons were identified which are applicable to hazardous industries generally (Hopkins, n.d.):

1) Operator error is not an adequate explanation for major accidents.
2) Systematic hazard identification is vital for accident prevention.
3) Auditing must be good enough to identify the bad news and ensure it gets to the top.
4) Reliance on lost-time injury data in major hazard industries is itself a major hazard.
5) Good reporting systems must specify relevant warning signs. They must provide feedback to reporters and an opportunity for reporters to comment on feedback.
6) Alarm systems must be carefully designed so that warnings of trouble do not get dismissed as normal (normalised).
7) Senior management must accept responsibility for the management of hazardous processes.
8) A safety case regime should apply to all major hazard facilities.

Chapter 4 Australia's State Safety Program and SMS Implementation

4.1 Australia's State Safety Program

AustraliaØs support for the efforts of the ICAO to establish safety programs for its member states to better ensure effective integration of aviation safety standards and practices has been demonstrated by building on the approach endorsed by ICAO to have air transport operators, airports, air navigation and maintenance service providers, and other critical aviation operations establish comprehensive SMSs to guide the management of the range of activities involved in ensuring safety (Department of Infrastructure and Transport, 2011, p. v).

AustraliaØs State Support Program (SSP) plays an important part in identifying, monitoring and maintaining the effectiveness of the various elements of AustraliaØs safety systems and outlines the steps needed to respond to safety challenges in the future. The Civil Aviation Safety Authority (CASA) is amongst a number of Australian government agencies charged with the responsibilities for aviation safety. These agencies include the Department of Infrastructure and Transport, Airservices Australia, the Australian Transport Safety Bureau (ATSB), the Department of Defence, the Bureau of Meteorology (BoM) and the Australian Maritime Safety Authority (AMSS). Annexes 1, 6, 8, 11, 13 and 14 to the Convention on International Civil Aviation include the requirement for contracting states to establish a state safety program (SSP) so as to achieve an acceptable level of safety in civil aviation (Department of Infrastructure and Transport, 2011, p. 1).

A SSP is best described as a management system employed by each state for its management of safety. State safety programs (SSPs) are defined as integrated sets of regulations and activities aimed at improving safety including specific safety activities that must be performed by the state. They also include regulations and directives to support fulfilment of the stateØs responsibilities concerning safe and efficient delivery of aviation activities in the state (Department of Infrastructure and Transport, 2011, p. 1). The SSP combines the elements of both prescriptive- and performance-based approaches to the management of aviation safety and incorporates four key components:

1. State safety policy and objectives
2. State safety risk management
3. State safety assurance
4. State safety promotion.

Each SSP provides the monitoring and governance framework within which operators and service providers establish and maintain a safety management system (SMS). Member states of the ICAO are responsible, under the SSP, for the acceptance and oversight of service providersô safety management systems (SMSs).

Regulation of aviation safety relies on a broad approach that includes planning and accountability at an organisational level as well as appropriate technical standards with the aviation operators having a primary role in ensuring safety (Department of Infrastructure and Transport, 2011, p. 1). The ICAO has mandated that aviation operators implement satisfactory SMSs which seek to deliver a better safety culture across the board. Broadly defined as a systematic approach to managing safety risks, an SMS encompasses organisational structures, policies and procedures. It is based on the idea that safety is best achieved through strong interwoven systems, rather than individual processes or practices. It is also underpinned by a philosophy of mutual responsibility and accountability, rather than relying solely on regulatory compliance (Department of Infrastructure and Transport, 2011, p. 30).

4.2 Oversight of SMSs

The protocols employed by CASA in its oversight of SMSs are expounded, inter alia, in the Australian Governmentøs State Aviation Safety Program report and include the following components (Department of Infrastructure and Transport, 2011, p. 30):

- Qualified and trained technical staff with specific training in relation to safety management systems (SMSs).
- Documented procedures and guidance for approval, surveillance and associated safety processes.
- Licensing, certification, authorisation and approval

- Surveillance activities including regular, planned and unplanned audits and inspections, data collection and exchange, analysis, workflow management and information management.

- Conducting a six-monthly Air Operator Certificate (AOC) Holder Survey Questionnaire (AHSQ) in which AOC holders are required to provide data about their activities including types of aircraft operated, hours flown, categories of operations and factors that might impact on safety.

The AHSQ process captures hazard identification and information on emerging risks as well as operational information. This information supplements information received from other sources such as Service Difficulty Reports (SDRs) and is used to determine if there are specific safety risks or issues arising. This analysis may lead to CASA taking or requiring action to address any identified safety issues (Department of Infrastructure and Transport, 2011, p. 34).

Part of CASAõs core function is the monitoring of safety performance and identification of safety-related trends and risk factors, taking into account international safety developments. This includes risk review meetings at all levels of the organisation, including a safety review meeting involving all CASA executives during which domestic and international trends are discussed and decisions on changes to CASAõs activities are made (Department of Infrastructure and Transport, 2011, p. 34).

The report further adds that CASA is developing a systemic risk-based approach to surveillance activities which takes into account trend information, issues identified through surveillance information and information provided by individuals, industry or other agencies (Department of Infrastructure and Transport, 2011, p. 34). In addition, CASA has established a training and development schedule for all staff, with a particular focus on technical training for safety staff, including training in relation to SMS oversight. The internal training program provided by CASA for safety staff comprises initial, recurrent and specialist modules. This includes a comprehensive induction program for new inspectorate staff, covering generic training for all functional streams on people management, audit, systems and tools, the regulatory environment and safety management systems (SMSs).

Furthermore, CASA ensures training specific to the functional inspectorate stream (such as training on airworthiness, aerodromes and dangerous goods) is provided to staff on a systematic basis (Department of Infrastructure and Transport, 2011, p. 36).

The aim of CASA is to achieve an informed and safety-motivated aviation community which addresses its safety responsibilities based on the analysis of emerging issues in the industry. In playing its part to support this effort and approach, CASA provides a range of educational and promotional material to the industry and the public including information about CASA programs and safety publications in a variety of forms and seminars. An active group of aviation safety advisors is also available to CASA to provide assistance and advice, which gives effect to CASA's mandate under the *Civil Aviation Act 1988* to encourage a greater commitment to high aviation safety standards and a better understanding of the need to comply with aviation safety requirements. In addition, CASA regularly publishes the magazine *Flight Safety Australia* and has developed a range of support tools for industry and its technical staff to ensure better understanding and integration of SMS principles. These include (Department of Infrastructure and Transport, 2011, p. 37)

- A dedicated Safety Systems Branch which provides oversight and management of CASA's Safety Program
- Publicly available guidance information on SMSs, including a toolkit for operators comprising documents and DVDs covering best practice, requirements of organisations, and CASA's approach to SMS surveillance.

A key part of CASA's regulatory function includes communication with stakeholders and industry representatives through a variety of forums. These include the Standards Consultative Committee, Sport Aviation Safety Forum, Regional Aviation Safety Forum and online discussion forums. Many service providers and industry associations are represented on these forums. Furthermore, CASA publishes guidance material to support the regulatory development and implementation processes. The reporting of aviation accidents, serious incidents and certain other safety occurrences to the ATSB is mandated through the *Transport Safety Investigation Act 2003* and *Transport Safety Investigation Regulations 2003*. Aviation safety accidents and other safety occurrences are categorised into 'immediately reportable' matters and 'routine reportable' matters. In addition to the mandatory reporting of accidents and other safety occurrences, Australia has also established a voluntary confidential reporting scheme for aviation, REPCON, which allows any person who has an aviation safety concern to report it to the ATSB confidentially (Department of Infrastructure and Transport, 2011, p. 31).

4.3 Implementation and Administration of SMSs for RPT Operators

In September 2008, the Senate Committee on Rural and Regional Affairs and Transport presented a report on the administration of CASA and related matters. This report made three recommendations which included an Australian National Audit Office (ANAO) audit of CASA with the objective being ñto assess CASAôs implementation and administration of an SMS approach to regulating aircraft operatorsò (ANAO, 2010, p. 13). A review of the ANAO audit report is relevant to this study because it will help in the understanding of the influences that the regulator may have on SMS implementation for regular public transport (RPT) operators.

4.4 Phased Introduction of SMS Requirements

The ICAO Safety Management Manual (SMM) introduced a proposal for SMS implementation to be carried out using a phased approach with the aim identified as being three-fold (ANAO, 2010, p. 42):

1) To provide a more manageable series of steps for operators to follow in implementing an SMS, including the allocation of resources;
2) To effectively manage the workload associated with the SMS implementation; and
3) To provide a robust SMS and not ñmerely an empty shell (that is, ñticking the appropriate boxesò)ò.

The principles-based approach outlined in the ICAO SMM proposed four SMS implementation phases, each phase encompassing one or more component, and introducing specific elements of the ICAO SMS model as shown in Figure 3.1. The four phases are (ANAO, 2010, p. 42):

- Phase 1: Planning SMS implementation ï how the SMS will be developed, including establishing an accountability framework and developing a gap analysis and implementation plan;

- Phase 2: Reactive safety management processes ï implementing and correcting potential deficiencies in existing safety management processes;
- Phase 3: Proactive and predictive safety management processes ï developing forward-looking safety management processes to enable an operator to identify and respond to hazards based on reactive, proactive and predictive safety data; and
- Phase 4: Operational safety assurance ï periodic monitoring, feedback and continuous improvement of the safety management system (SMS).

In addition to providing guidance on the distribution of elements across the three phases, the Civil Aviation Advisory Publication (CAAP) SMS-1(0) provided a suggested implementation time frame for each of the three phases as shown in Figure 4.1.

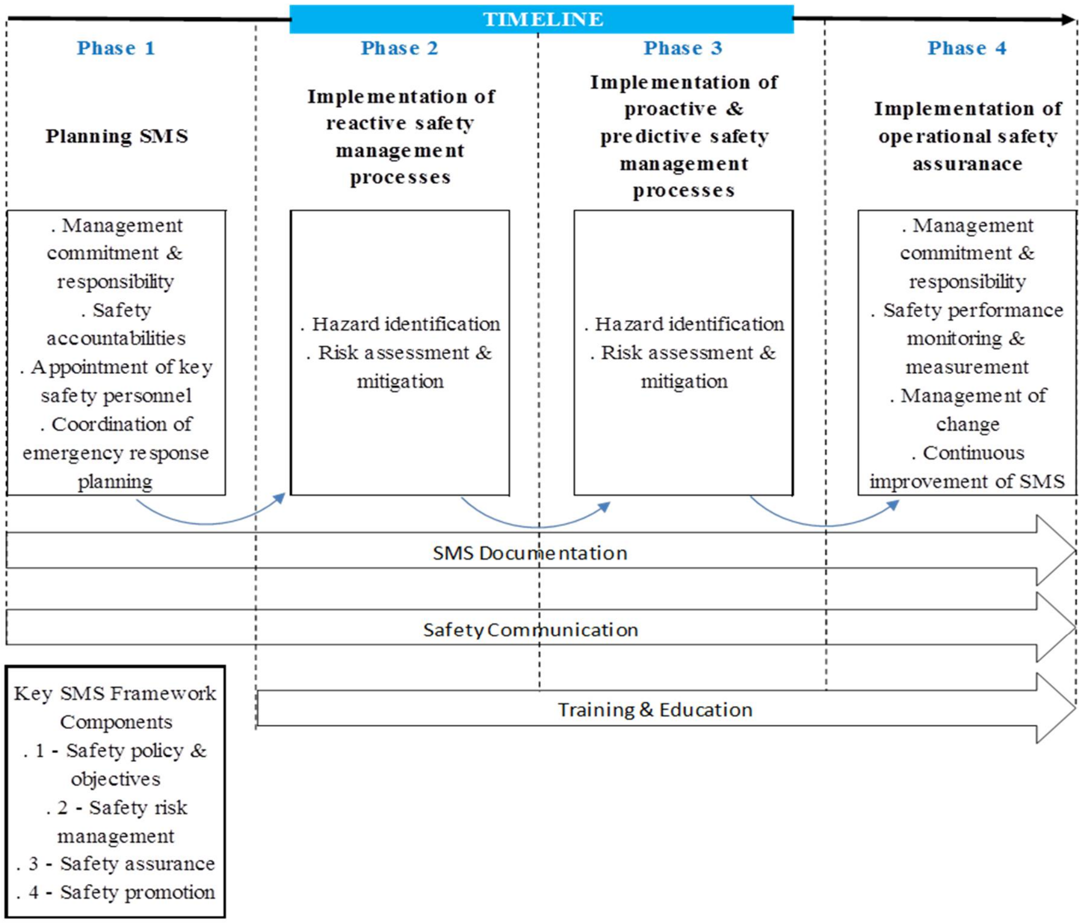

Figure 4.1: ICAO Phased SMS Implementation Approach
Source: (ANAO, 2010, p. 43)

4.5 CASA's Three-Phase Approach to SMS Implementation

The first step undertaken by CASA to meet its international obligations with the regulation of operatorsô SMS implementation was to change the relevant regulations to require RPT operators to use an SMS that has CASA approval (ANAO, 2010, p. 14). The associated regulatory changes came into effect in January 2009; however, operators were not required to have an SMS that was acceptable to CASA immediately from January 2009 (ANAO, 2010, p. 14). Instead, CASA allowed operators to adopt a phased approach to implementing an SMS in order to allow each RPT operator to plan for and implement an SMS in a timely, effective way, thus easing the burden placed on affected operators and CASA itself (ANAO, 2010, p. 14).

The implementation approach adopted by CASA was similar to the method suggested by ICAO in the Safety Management Manual (ANAO, 2010, p. 43). However, unlike the

ICAO proposal, CASA structured its implementation phases around three safety management strategies, namely reactive, proactive and predictive strategies (ANAO, 2010, pp. 43-44).

The resultant reactive, proactive and predictive processes are in accordance with the definitions in the ICAO Safety Management Manual. The reactive processes involve responding to events that have already occurred, such as accidents and incidents. The proactive processes aim to identify safety risks through the analysis of organisational activities while the predictive processes rely on the collection of routine operational data and attempt to identify safety incidents that have not yet occurred (ANAO, 2010, p. 43).

Distributed across each of the three phases were SMS elements of increasing complexity. In support of the phased approach, the first SMS CAAP issued by CASA in January 2009 provided guidance to operators on how to adopt a transitional SMS implementation and outlined a suggested approach that encompassed the SMS implementation components and elements required under the amended Civil Aviation Orders (CAOs). In this context, the approach suggested by CASA was similar to the ICAO SMS framework in terms of the allocation of key elements across various phases (ANAO, 2010, p. 44). Figure 4.2 illustrates the three-phased transitional approach suggested by CASA in relation to the four SMS implementation components and associated elements required under the amended Civil Aviation Orders (CAOs).

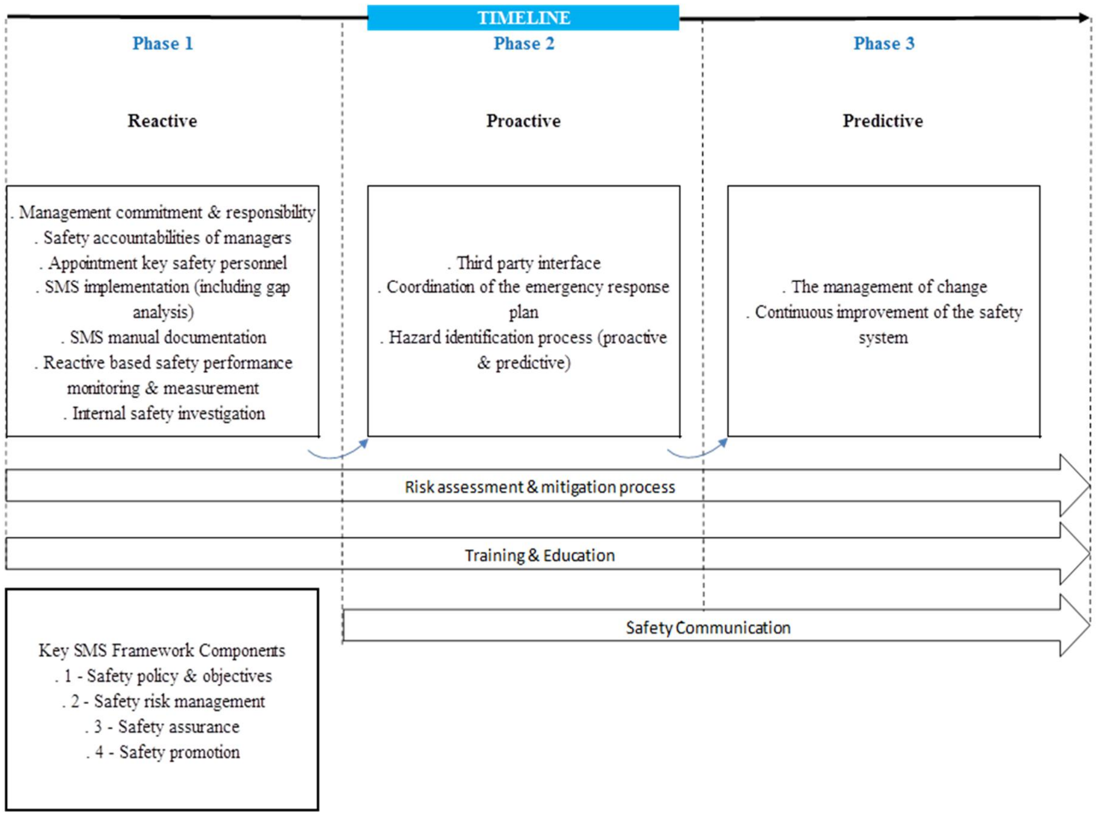

Figure 4.2: Phased SMS Implementation Approach Suggested to Operators by CASA
Source: (ANAO, 2010, p. 44)

Table 4.1: Timeline for Phased SMS Implementation Originally Proposed by CASA
Source: (ANAO, 2010, p. 45)

Phase	CAO 82.3 transition (low capacity regular public transport operators)	CAO 82.5 transition (high capacity regular public transport operators)
Implementation Plan	6 months from effective CAO amendment	
Phase 1 completion	01-February-2010	01-July-2009
Phase 2 completion	01-July-2010	01-February-2010
Phase 3 completion	01-February-2011	01-July-2010
Notes		

A. The time period between the Phase 1 and Phase 2 proposed completion dates for CAO 82.3 and CAO 82.5 operators is five months and seven months respectively.

B. Time period between the Phase 2 and Phase 3 proposed completion dates for CAO 82.3 and CAO 82.5 operators is seven months and five months respectively.

Table 4.1 shows the original timeline for SMS implementation that was developed by CASA with different durations for each of the SMS implementation phases according to whether the operator was a HCRPT or a LCRPT operator (ANAO, 2010, p. 45). Additional time was provided to LCRPT operators to address the elements in each SMS implementation phase as this was seen to be reflective of the operational difficulties faced by the small and medium-sized businesses which tend to operate in regional and remote parts of Australia (ANAO, 2010, p. 45). The additional period for compliance provided to LCRPT operators is to accommodate the additional need for these operators to seek advice, checking and reassurance from CASA that the activities being implemented align with the requirements of a safety management system (SMS) (ANAO, 2010, p. 45). Over and above the provision of differing phase durations, CASA also recognises that the diverse size and complexities of RPT operations may, in turn, require a certain degree of flexibility with an operatorôs SMS implementation approach. This is also consistent with ICAOôs SMS framework which states that the SMS should be ñcommensurate with the size of the organisation and the complexity of the services providedò (ANAO, 2010, p. 46). In this regard, the guidance material provided by CASA in the CAAPs advised that operators needed to give consideration to their individual requirements when adopting the recommendations provided against each of the SMS elements and sub-elements (ANAO, 2010, p. 46).

Civil Aviation Orders (CAOs) 82.3 and 82.5 were amended to require LCRPT operators to adopt a staged approach to their submission to CASA of their SMS implementation plan. Section 1AA of CAO 82.3 required relevant operators to submit an SMS Implementation Plan by 1 July 2009, seven months before the planned Phase 1 SMS implementation date of 1 February 2010 (ANAO, 2010, p. 47).

In addition, CASA also allowed both LCRPT and HCRPT operators the option of adopting a phased approach to the implementation of a safety management system (SMS). Sub-paragraph 2.1(a) in both the amended CAOs noted that guidance on what CASA would consider when determining whether to approve an SMS was contained in the CAAP SMS Package (ANAO, 2010, p. 47).

As it eventuated, seven of the 18 HCRPT operators or 20% of all RPT operators opted not to use a phased approach to implementing their respective safety management system (SMS). The remaining 11 HCRPT operators and all 17 LCRPT operators elected to adopt a phased implementation approach (ANAO, 2010, pp. 47-48). On 30 June 2009, CASA further extended the time frame from 1 July 2009 to 2 November 2009 for HCRPT operators to achieve an approved safety management system (SMS). The reason this extension was granted was due to confusion amongst RPT operators regarding the date that safety manuals were required to be submitted to CASA: many operators assumed that 1 July 2009 was the due date for safety manual submission to CASA, as opposed to being the date by which the SMS needed to be approved and in place. On 19 October 2009, one operator received approval for an additional extension to 2 December 2009 as the due date for having an approved SMS in place (ANAO, 2010, p. 48).

This new time frame was conditional on operators submitting a proposed SMS manual to CASA by 31 July 2009. However, similar to the amended CAOs, the approval for the new time frame was drafted in such a way that it allowed CASA to vary the date for submitting a proposed SMS beyond 31 July 2009 (ANAO, 2010, p. 48).

4.6 Expected Time Frame for Full SMS Implementation

The SMS approval instruments developed by CASA reflected the phased transition to full SMS implementation for each approved safety management system (SMS). In effect, the approval instrument listing CASAôs approval of an operatorôs proposed SMS incorporated a requirement for the operator to subsequently demonstrate safety management capability in relation to the elements of the approved SMS over a phased period of time. Table 4.2 summarises the specified dates for the completion of all three transition phases for the 35 RPT operators who had their SMSs approved by CASA under CAOs 82.3 and 82.5. In this respect, completion of each phase involves the relevant operator demonstrating its capability in relation to each SMS element encompassed by a phase to CASAôs satisfaction on or before the specified date (ANAO, 2010, p. 49).

Table 4.2: General Dates Specified for Demonstrating Safety Management Capability to CASA in Relation to Each Element of an Approved SMS
Source: (ANAO, 2010, p. 49)

Phases	High capacity operators	Low capacity operators
Phase 1 elements	02-November-2009	01-February-2010
Phase 2 elements	29-April-2010	01-August-2010
Phase 3 elements	29-October-2010	01-February-2011

Notes

A. Phase 1 elements for one operator were required by 2 December 2009.
B. The date for demonstrating capability in relation to Phase 2 elements is the earlier of six months after the date of the approval instrument approving an operator's proposed SMS or the Phase 2 date specified in the relevant operator's SMS Implementation Plan. Three high capacity operators had alternative Phase 2 dates of 25 May 2010, 11 May 2010 and 6 May 2010 respectively.
C The date for demonstrating capability in relation to Phase 2 elements is the earlier of six months after commencement of the approval instrument approving an operator's proposed SMS or the Phase 2 date specified in the relevant operator's SMS Implementation Plan. One low capacity operator had an alternative Phase 2 date of 25 July 2010.
D. The date for demonstrating capability in relation to Phase 3 elements is the earlier of 12 months after the date of the approval instrument approving an operator's proposed SMS or the Phase 3 date specified in the relevant operator's SMS Implementation Plan. Three high capacity operators had alternative Phase 3 dates of 25 November 2010, 11 November 2010 and 6 November 2010 respectively.
E. The date for demonstrating capability in relation to Phase 3 elements is the earlier of 12 months after commencement of the approval instrument approving an operator's proposed SMS or the Phase 3 date specified in the relevant operator's Implementation Plan. One low capacity operator had an alternative Phase 3 date of 25 January 2011.

4.7 Delays with Full SMS Implementation

The phase dates for SMS implementation specified in the approval instruments issued by CASA to the RPT operators deviated from the dates that were proposed in CAAP SMS-1(0) issued by CASA in January 2009. In this regard, the time frames for completing all three phases for HCRPT operators and one of the three phases for LCRPT operators were extended beyond the dates suggested in CAAP SMS-1(0) (ANAO, 2010, p. 50). Consequently, based on the phased implementation reflected in the approval instruments, full SMS implementation for both HCRPT and LCRPT operators using an approved SMS at that time would potentially not occur until February 2011. This was more than two years after both the amended CAOs took effect and the date mandated by ICAO (ANAO, 2010, p. 50).

A schematic of the SMS implementation timeline is shown in Figure 4.3. The schematic illustrates the significant periods of delay between when ICAO first proposed the changed obligations regarding SMSs and their adoption in March 2006 as well as when the amended CAOs introducing an SMS requirement for Australian RPT operators took effect in January 2009. In addition, it shows when the CAO amendments (that required RPT operators to establish and maintain an appropriate organisation with a sound and effective management structure that uses a SMS approved by CASA) took effect on 31 January 2009 and the potential completion of all three phases of SMS implementation, including operatorsô demonstrated SMS capability (ANAO, 2010, p. 50).

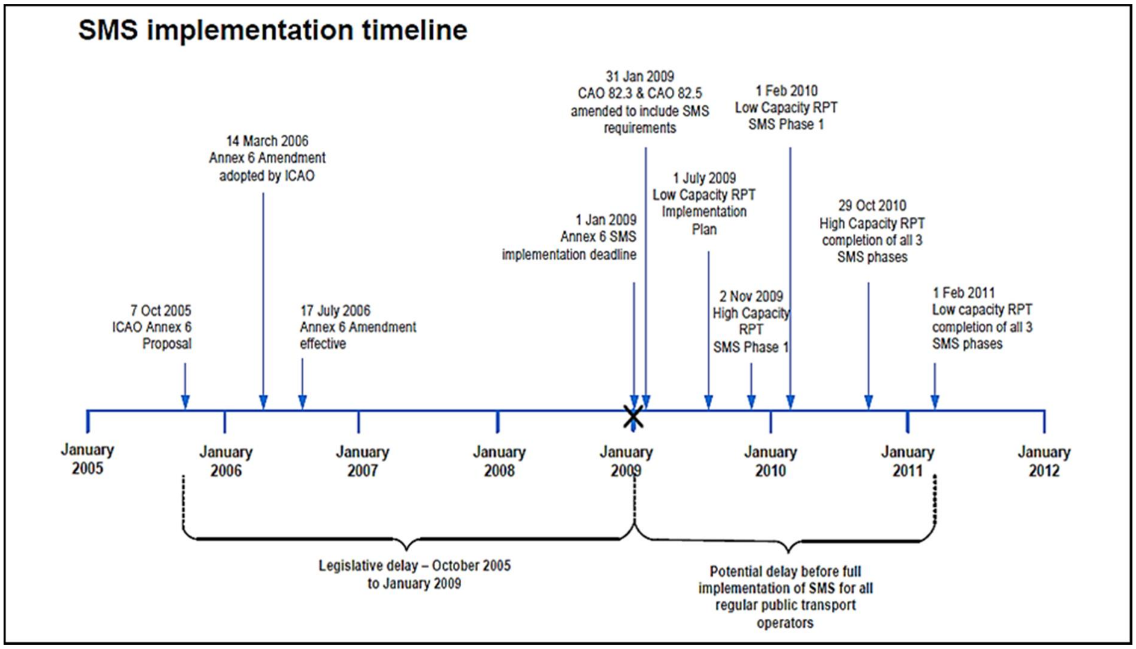

Figure 4.3: SMS Implementation Timeline
Source: (ANAO, 2010, p. 51)

Notwithstanding the delays with the SMS implementation plan for some operators, CASA reported to the ANAO in June 2010 that there had been no impact on the regulation of these affected operators. As each phase takes effect, the SMS elements are added to the overall capability of the operator. These elements are added to the requirements of the operatorôs regulatory compliance and considered in surveillance planning and surveillance conduct. The ónormalô oversight and surveillance for compliance with the existing regulatory requirements have continued throughout this process. The oversight processes will undergo a managed transition to full SMS surveillance, combined with functional surveillance, to cover all aspects of the operation (ANAO, 2010, p. 51). Under the phased approach, full SMS implementation is not scheduled to occur for the RPT operators but is in accordance with the schedule in Table 4.3. The HCRPT operators were given until October/November 2010 to have a full SMS in place while the LCRPT operators were given to February 2011 (ANAO, 2010, p. 15).

Table 4.3: General Specified Dates for Demonstrating Safety Management Capability to CASA in Relation to Each Element of an Approved SMS
Source: (ANAO, 2010, p. 15)

Phase	High capacity operators	Low capacity operators
Phase 1 elements including: internal aspects of safety policy, objectives and planning; reactive based safety performance monitoring and measurement; an SMS implementation plan; and SMS manual documentation.	02-November-2009	01-February-2010
Phase 2 elements including: proactive and predictive hazard identification, risk assessment and mitigation processes; and coordination of an emergency response plan.	29-April-2010	01-August-2010
Phase 3 elements including: the management of change; and continuous improvement of the SMS.	29-October-2010	01-February-2011
Note A: While these are the Phase dates specified in relation to most operators, CASA has agreed to alternative dates for some operators, based upon the SMS Implementation Plan submitted by the relevant operators. For high capacity operators, the latest specified date for demonstrating capability in relation to Phase 2 elements is 25 May 2010 and 25 November 2010 for Phase 3 elements.		

In Phase 1, operators were required to implement SMS elements that were relatively easy to set up, including the development of an SMS manual (ANAO, 2010, p. 14). Phases 2 and 3 related to progressively more complex elements of a safety management system (SMS) (ANAO, 2010, p. 14). In conjunction with this phased approach, CASA also adopted a phased SMS approval process. In the first part, termed ÷Document Evaluationø, the focus and work involves CASA assessing, through desktop review, whether the SMS manual submitted by an operator contained the required elements, and whether these were suitable for the operator (ANAO, 2010, p. 14).

4.8 Stage One of Approval (Document Evaluation Stage)

The first group of RPT operators that were required by CASA to have an SMS totalled 35 operators. These operators comprised 18 HCRPT and 17 LCRPT operators (ANAO, 2010, p. 14). Each operator had to submit to CASA an SMS manual for assessment (ANAO, 2010, p. 14). These SMS manuals were assessed by a group of system specialists employed and trained by CASA. In addition, CASA developed a comprehensive checklist to inform the decision as to whether the SMS manual submitted by each operator should be approved (ANAO, 2010, p. 14). Notwithstanding the former, the ANAO found some shortcomings in the documentation assessment process, including instances where there was not a clear and consistent evidentiary trail to support CASAõs decision to approve the SMS manual submitted by the operator (ANAO, 2010, p. 14).

4.9 Stage Two of Approval (Capability Assessment Stage)

For operators to have their SMS approved, they needed to satisfy CASA with the condition that their SMS manual had documented and suitably described safety systems and processes that were appropriate to the operator, or that any missing/inadequate elements would be addressed in a time frame that CASA considered acceptable (ANAO, 2010, p. 15). Accordingly, CASA approval of an operatorõs SMS was not on the basis that CASA was satisfied that the SMS manual was being used by the operator and that the documented systems and processes effectively managed safety risks. Rather, these aspects were to be addressed in the second stage of CASAõs SMS approval process, referred to as ÷Capability Assessmentö (ANAO, 2010, p. 15).

By the time the ANAO audit fieldwork was completed, CASA had undertaken a capability assessment of only one operator as part of its scheduled surveillance activities. Whilst the desktop review of this operatorõs manual had not identified any shortcomings, CASAõs surveillance activities found that compliance was lacking for important elements of the SMS manual and that the planned development of an SMS had not occurred (ANAO, 2010, p. 15). Consequently, the ANAO used this sample as an example to highlight the risks involved with granting an approval based solely on a desktop evaluation of documentation (ANAO, 2010, p. 15). Subsequently, in August 2010, CASA informed the ANAO that SMS capability assessments had commenced for all RPT operators and the results of the capability assessments would provide a sound indication of the extent to which RPT operators had implemented systems and procedures tailored to their business that were designed to promote high standards of aviation safety (ANAO, 2010, p. 16).

4.10 CASA’s Compliance Approach

The compliance approach used by CASA at the time involved conducting surveillance, which consisted of operational surveillance and scheduled annual audits against the conditions of an operatorǿs Air Operator Certificate (AOC) (ANAO, 2010, p. 16). The air transport sector which includes the RPT operators is examined by CASA against nine elements, one of which is the operatorǿs safety management system (SMS). On an annual basis, a sample of the elements are selected and examined so as to provide a snapshot of the system under review, with a full audit cycle covering all nine elements for each operator taking three years to complete (ANAO, 2010, p. 16).

4.11 CASA’s SMS Approval Process

Subsequent to the audit, the ANAO made the recommendation that CASA should enhance the rigour of its desktop review of operatorsô SMSs by introducing the recommended procedures. These would provide a clearer and more consistent evidentiary trail as to the basis on which approvals are granted, particularly in circumstances where the underlying records indicated that one or more required elements were not found to be suitably present in the operatorǿs SMS documentation at the time of the assessment (ANAO, 2010, p. 18). This finding was subsequently reviewed and accepted by CASA (ANAO, 2010, p. 18).

Chapter 5 Safety Performance and Measurement

5.1 Introduction

The second research question in this thesis aimed to find out how aviation safety performance is measured and the third question sought to validate the hypothesis that SMSs improve the safety performance of commercial aviation operations.

Researchers have tried to establish the general relationship between safety performance and contributing factors such as the quality of safety management elements or the adequacy of safety climate. The positive relationships, if any, have been weak due to the general nature of the contributing factors and the high level of aggregation of the accident data (Kjellén, 2009). Kjellén (2009) further stated that good measures of safety performance should possess the following characteristics:

1) Quantifiable and permitting statistical inferential procedures
2) Valid or representative of what is to be measured
3) Provide minimum variability when measuring the same conditions
4) Sensitive to change in environmental or behavioural conditions
5) Cost of obtaining and using measures is consistent with the benefits
6) Comprehended by those in charge with the responsibility of using them.

Prior to the requirement for SMSs in aviation, the traditional approach to safety oversight by the ICAO member states primarily focused on prescriptive regulatory compliance. With the introduction of SMSs, the acceptable level of safety performance (ALoSP) concept complemented the traditional approach to safety oversight with a performance-based approach that defines actual safety performance levels within a prescribed State Safety Program (SSP) framework (ICAO, 2013c). The term óALoSPô is the acceptable level of safety performance of a state as defined by its SSP safety indicators and their associated target and alert levels (ICAO, 2013c).

5.2 Concept of Safety

The concept of aviation safety may have different connotations, such as zero accidents or serious incidents (a view widely held by the travelling public); freedom from danger or risks, that is, those factors which cause or are likely to cause harm; the attitude towards unsafe acts and conditions by employees (reflecting a safe corporate culture); the degree to which the inherent risks in aviation are ‘acceptable’; the process of hazard identification and risk management; the control of accidental loss (of persons and property); and the control of damage to the environment (ICAO, 2006b). To understand the economics of safety, a comprehension of the total costs of an accident is fundamental (ICAO, 2006b). Whilst the elimination of accidents or serious incidents remains a goal in aviation, a 100% safety rate is practically unachievable because failure and errors will occur in spite of the best efforts to avoid them. No human activity or man-made system can be guaranteed to be absolutely safe or free from risk. Therefore, ‘safety’ is a relative notion in which inherent risks are acceptable in a ‘safe’ system (ICAO, 2006b).

The air transportation industry’s future viability may well be predicated on its ability to sustain the public’s perceived safety while travelling. The management of safety is therefore a prerequisite for a sustainable aviation business (ICAO, 2006b, p. 1-2).

5.3 Measuring the Safety of the Aviation System

The primary goal of most aviation safety initiatives according to the National Aeronautics and Space Administration (NASA) is to reduce the rate of fatalities during or as a result of air travel. Thus, the most important metrics are the rates of fatal accidents per unit of air travel such as the number of passenger trips, flight legs, flight miles, etc. (National Aeronautics and Space Administration [NASA], 2009).

The annual reports of many aviation safety organisations also focus on accident rates and their trends, measured in various ways, and many other studies on aviation safety emphasise fatality and fatal accident rates (NASA, 2009). Fatality rates and fatal accident rates are the most important long-term measures of aviation safety. However, fatal accidents are rare, especially in travel on the major passenger airlines, so looking for changes in fatality rates or fatal accident rates may not give timely feedback on the potential risk of air travel with regard to the impacts of new equipment, new programs or changes in the airspace system (NASA, 2009).

Although major air disasters are rare events, less catastrophic accidents and a whole range of incidents occur more frequently. These lesser safety events may be harbingers of underlying safety problems (ICAO, 2006b). In an attempt to find a more timely indication of the effects of programs in improving safety or the impact of developments that might lead to a degradation of safety, analysts have turned to other events that they hope might elucidate changes in aviation safety (NASA, 2009). In the USA, one approach has been to monitor and study incidents involving damage to an aircraft and/or injury, but in which the levels of damage or injury do not meet the National Transportation Safety Board (NTSB) thresholds that define an accident: the hope is to more quickly detect changes that could potentially affect safety (NASA, 2009). However, none of these other indices or events to which the analysts have turned have been proven to be precursors to accidents or indicators of pending increases in fatality rates or fatal accident rates. Even changes in the rates of non-fatal accidents or incidents have not been shown to be predictive of or associated with changes in the rates of fatal accidents. Thus, a link between any of these other indicators and the safety of the aviation system is at best uncertain (NASA, 2009). Another complicating factor in understanding and improving aviation safety is that accidents rarely have a single cause but are typically the result of a sequence of events involving several malfunctions and/or mistakes (NASA, 2009).

The accident and incident data available from the Federal Aviation Administration (FAA), NTSB, the Aviation Safety Reporting System (ASRS) and the airlinesô Aviation Safety Action Programs (ASAPs) form the bulk of safety data used for measuring and analysing safety (NASA, 2009). The ASRS receives, processes and analyses voluntarily submitted incident reports from pilots, air traffic controllers, dispatchers, flight attendants, maintenance technicians and others. The ASRS grew out of the FAAôs Aviation Safety Reporting Program (ASRP) which started on 30 April 1975 (NASA, 2009).

As stated by ICAO, data-based decision making is one of the most important facets of any management system (ICAO, 2013c, p. 2-18). The quality of the data used to enable effective decision making must be considered throughout SSP and SMS development and implementation. The failure to account for the limitations of the data used in support of safety risk management and safety assurance functions will result in flawed analysis results that may lead to faulty decisions and discredit the safety management process (ICAO, 2013c, p. 2-18). The data used to support safety risk management and safety assurance processes must be acceptable as per established criteria for their intended use; be complete with no relevant data missing; provide consistent measurement of a given parameter that can be reproduced while avoiding error; be readily available for analysis;

relevant to the time period of interest and available promptly; be protected from inadvertent or malicious alteration; and be error-free (ICAO, 2013c, p. 2-18). The different types of data or information that can be used for safety data analysis include: accident investigation data; mandatory incident investigation data; voluntary reporting data; continuing airworthiness reporting data; operational performance monitoring data; safety risk assessment data; data from audit findings/reports; data from safety studies/reviews; and safety data from other states, regional safety oversight organisations or regional accident and incident investigation organisations (ICAO, 2013c, p. 2-19).

After collection of the safety data, organisations should then perform the necessary analysis to identify hazards and control their potential consequences. The results of the analysis may be used to assist in deciding what additional facts are needed, to ascertain latent factors underlying safety deficiencies, to reach valid conclusions and to monitor/measure safety trends or performance (ICAO, 2013c, p. 2-21). Safety analysis is often iterative, requiring multiple cycles. It may be quantitative or qualitative. The absence of quantitative baseline data may force a reliance on more qualitative analysis methods. The commonly used safety analysis methods used are statistical analysis, trend analysis, normative comparisons, simulation and testing, expert panel and costï benefit analysis. The acceptance of recommended safety risk control measures may be dependent on credible costï benefit analysis (ICAO, 2013c, p. 2-21).

5.4 Safety Indicators

The ICAO requires the performance-based elements within an SMS/SSP framework to include the process for safety performance monitoring and measurement at the individual product/service provider level and also at the state level. The organisation is free to select its own safety monitoring indicators and to set relevant alerts and targets that are pertinent to its own context, performance history and expectations. There are no fixed or mandatory prescribed safety indicators or alert levels or prescribed values under this SMS/SSP expectation (ICAO, 2013c).

The state and its product/service providers should have in place an SSP and an SMS, respectively. An interface needs to be in place for the aviation regulatory agencies to agree with their individual product/service providers on their SMS-related safety performance indicators and associated targets and alert settings. The regulator will also need to have a process for continuous monitoring of the individual product and service providerôs safety performance (ICAO, 2013c, p. 2-33). Furthermore, any additional new performance-based processes introduced and duly accepted/approved by the regulator should have appropriate performance indicators developed for monitoring such performance-based processes. Such process-specific indicators may be viewed as supplementary indicators to the higher-level SMS safety performance indicators (ICAO, 2013c, p. 2-33).

The two common types of safety measures in industry are accountability measures and performance indicators. Accountability measures are a means of motivating people. They relate to specific performance expectations and specific people (Strickoff, 2000, p. 36, cited in Yeun, Bates, & Murray, 2014).

5.5 Measuring the Impact of SMSs on Safety Performance

In aviation safety, the severity of the harm is described by ICAOôs definition of an accident as an occurrence resulting in fatalities, serious injuries or severe damage to the aircraft (ICAO, 2001). Therefore, aviation safety performance indicators should provide a clue to the probability of an accident (Roelen & Klompstra, 2012, cited in Yeun et al., 2014). This is somewhat opposed to the earlier view of the European Transport Safety Council (ETSC) about the appropriateness of using accident data for assessing the level of safety and for understanding the rate of safety problems in the aviation sector (European Transport Safety Council [ETSC], 2001, p. 5, cited in Yeun et al., 2014). The safety performance outcome from the introduction of performance-based elements within or supplementary to an SMS framework should not be worse than that of the existing prescriptive regulatory framework. To assess or monitor that such equivalence is indeed the case, there should be safety indicators to monitor the overall outcome of events or non-conformance occurrences of the system/process concerned for which the performance-based element will be introduced (ICAO, 2013c, p. 2-33). Comparing the pre-SMS implementation baseline performance against the post-implementation performance can show if an equivalent level of performance has been maintained. Roelen and Klompstra (2012) argued that measuring safety performance from indicators would require some time in order to be able to understand the mechanisms that determine how the indicators represent safety performance. Regardless of the theoretical and practical groundwork undertaken to set up the system, the initial period of actual implementation should really be used for interpretation.

5.6 Case Study 1

The Basic Aviation Risk Standard (BARS) audit data used for this case study is obtained with permission from the Flight Safety Foundation (FSF). The data contain audit findings from FSF and its associated auditors for 117 organisations primarily operating small to medium-sized fixed-wing aircraft, rotary-wing aircraft or a combination of both types of aircraft. The period sampled is from 2011ï 2014. A detailed breakdown of the individual operator audit findings is provided in Appendix 1. Most, if not all, the sampled population of aircraft operators do not have any regulatory requirements imposed on them to implement a safety management system (SMS). Instead, implementing an SMS is a requirement of their own customers and FSF as their auditing body.

Flight Safety Foundation (FSF) carried out the auditing of SMSs for the sample population in 2011. A total of 7,625 audit findings were reviewed and categorised into the different technical disciplines as shown in Table 5.1. The BARS audit program and their SMS model is unique to FSF and mirrors to an extent the CASA SMS model. To facilitate the analysis and use of the BARS audit data, each BARS SMS audit question is reviewed and assigned its equivalency to the CASA SMS framework elements (see Appendix 5).

A breakdown of the SMS audit findings by operation type is provided in Appendix 2.

Table 5.1: Number and Type of BARS Audit Findings (2011–2014)

Discipline	Year 2011	Year 2012	Year 2013	Year 2014	Total Number of Audit Findings	Average Number of Audit Findings
Maintenance (Airworthiness)	813	583	438	148	1982	496
Flt (Flight Operations)	1394	753	709	241	3097	774
Ground Handling	249	173	106	45	573	143
Org (SMS)	922	525	394	132	1973	493
Total	**3378**	**2034**	**1647**	**566**	**7625**	**1906**

5.6.1 Objectives

The objectives for this case study are:

1. To determine if the safety performance of the sample population improved with SMS implementation

2. To determine the correlation and effect of SMS findings on the number of accidents
3. To determine the correlation and effect of SMS findings on the airworthiness findings
4. To determine the correlation and effect of SMS findings on the flight operations findings
5. To determine the correlation and effect of SMS findings on the ground handling findings
6. To determine the correlation and effect of flight operations findings on the airworthiness findings
7. To determine the correlation and effect of flight operations findings on the ground handling findings
8. To determine the correlation and effect of airworthiness findings on the ground handling findings
9. To determine the correlation and effect of the number of audits on the number of audit findings.
10. To determine the correlation and effect of the number of audits conducted on the number of accidents

5.7 Case Study 2

A study by Yeun et al. (2014) (see Appendix 8) on aviation SMSs and the implementation of SMSs by the initial group of 35 RPT operators in Australia provided a breakdown of de-identified audit findings by the aviation regulator, categorised by numbers and technical disciplines as shown in Appendix 6.

Table 5.2[8]: CASA Safety Indicators

Number	Safety Indicator	Data Requirements
SPI-1	The number of fatal accidents	Accident data
SPI-2	The rate of fatal accidents (per 100,000 hours flown)	Accident data & activity data
SPI-3	The number of HCRPT accidents	Accident data
SPI-4	The rate of HCRPT accidents (per 100,000 hours flown)	Accident data & activity data
SPI-5	The number of LCRPT accidents	Accident data
SPI-6	The rate of LCRPT accidents (per 100,000 hours flown)	Accident data & activity data
SPI-7	The number of charter accidents	Accident data
SPI-8	The rate of charter accidents (per 100,000 hours flown)	Accident data
SPI-9	The number of aerial work accidents	Accident data
SPI-10	The rate of aerial work accidents (per 100,000 hours flown)	Accident data & activity data
SPI-11	The number of flying training accidents	Accident data
SPI-12	The rate of flying training accidents (per 100,000 hours flown)	Accident data & activity data
SPI-13	The number of private accidents	Accident data
SPI-14	The rate of private accidents (per 100,000 hours flown)	Accident data & activity data
SPI-15	The number of sports aviation accidents claims per quarter.	Claims, activity data & licence information

Table 5.2 shows the 15 safety indicators that CASA uses to monitor the health and safety of the aviation industry.

Indicators SPIs-1 through 6 are used specifically for the RPT operations and the values of these six safety indicators from 2006ï 2013 are presented in Table 5.3. In total, there were 596 SMSs, 590 airworthiness and 1,271 flight operations audit findings as well as 175 ATSB reports raised (Yeun et al., 2014).

[8] CASA Regulatory Safety Management Program Manual Version 1.0 (Not to be reproduced without written permission from CASA)

Table 5.3[9]: CASA's RPT Operations Safety Indicators (2006–2013)

Number	Safety Indicator For RPT Operations	2006	2007	2008	2009	2010	2011	2012	2013
SPI-1	The number of HCRPT fatal accidents	0	0	0	0	0	0	0	0
SPI-1	The number of LCRPT fatal accidents	0	0	0	0	1	0	0	0
SPI-2	The rate of HCRPT fatal accidents (per 100,000 hours flown)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SPI-2	The rate of LCRPT fatal accidents (per 100,000 hours flown)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SPI-3	The number of high capacity regular public transport accidents (VH registered)	1	3	3	1	2	3	0	2
SPI-4	The rate of high capacity regular public transport accidents (per 100,000 hours flown)	0.1	0.3	0.3	0.1	0.2	0.2	0.0	0.1
SPI-5	The number of low capacity regular public transport accidents (VH registered)	0	1	0	1	1	0	0	0
SPI-6	The rate of low capacity regular public transport accidents (per 100,000 hours flown)	0.0	0.6	0.0	0.9	0.9	0.0	0.0	0.0

5.7.1 Objectives

The objectives for this case study are:

- To determine if the safety performance of the sample population improved with SMS implementation
- To determine the correlation and effect of SMS findings on the number of ATSB safety reports
- To determine the correlation and effect of SMS findings on the airworthiness findings
- To determine the correlation and effect of SMS findings on the flight operations findings
- To determine the correlation and effect of flight operations findings on the airworthiness findings

[9] Unpublished data from CASA (not to be reproduced without written permission from CASA)

Chapter 6 Results of Case Studies

6.1 Case Study 1 Results

Table 6.1 lists in a descending order, from the largest to the smallest, the number of SMS audit findings for the sampled population. Furthermore, the Pareto chart in Figure 6.1 provides a graphical representation of these findings.

A limitation of the data set used in this study is a consequence of the difference between the FSF's SMS model and the CASA's SMS model used as the reference model in Case Study 1 and Case Study 2 in this thesis. The FSF's SMS model does not have the SMS element 'SMS Implementation Plan' and as such, there is no finding against this particular SMS element in the results.

Table 6.1: BARS SMS Audit Findings by CASA SMS Model Elements (2011–2014)

CASA SMS Model Elements	No of Audit Findings
The Management of Change	435
Coordination of the Emergency Response Plan	370
Management Commitment & Responsibility	364
Safety Performance Monitoring & Measurement	175
Documentation	164
Training & Education	96
Hazard Identification Process	71
Safety Communication	67
Appointment of Key Safety Personnel	65
Safety Accountabilities of Managers	54
Third-Party Interface	50
Internal Safety Investigation	36
Risk Assessment & Mitigation Process	33
Continuous Improvement of the Safety System	17
SMS Implementation Plan	0

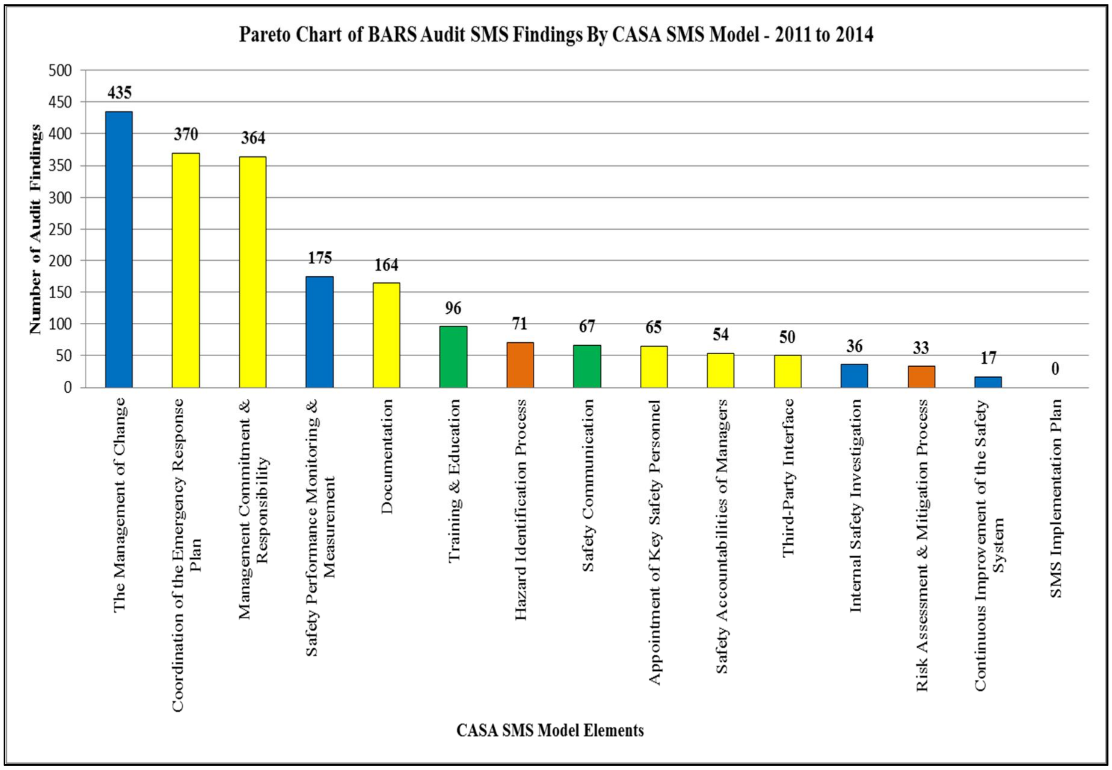

Figure 6.1: Pareto Chart of BARS SMS Findings (2011–2014)

Table 6.2 shows a breakdown of the number of audit findings made during the period between 2011 and 2014 for each of the eight regions. The results are then tabulated against the four SMS components of CASAός SMS framework model for each respective region. A map outlining the geographical boundaries of each region is shown in Figure 6.2. A graphical illustration of the results in the form of a Pareto chart is shown in Figure 6.3.

Table 6.2: SMS Audit Findings by BARS Regions

	Asia	Australia & South Pacific	Europe	Middle East	North & Central America	South America	South & East Africa	West & Central Africa	TOTAL
Safety Policy & Objectives	3	252	62	14	157	168	288	116	1060
Safety Risk Management	2	20	3	0	12	18	35	14	104
Safety Assurance	1	165	28	17	91	126	173	70	671
Safety Training & Promotion	0	33	9	4	16	25	48	27	162

Figure 6.2: BARS Region Map

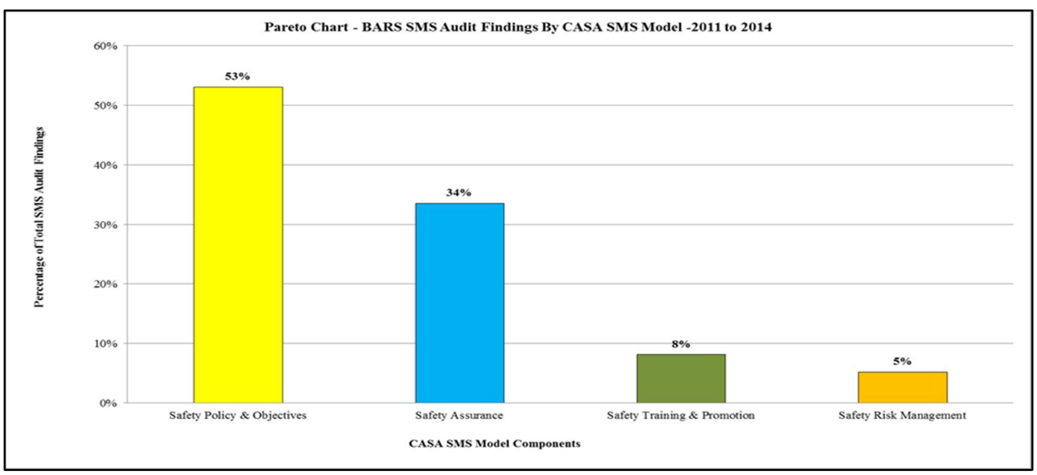

Figure 6.3: BARS SMS Findings by CASA SMS Model Components

Figures 6.4, 6.5, 6.6 and 6.7 show the breakdown by region for each of the four SMS components. It is observed that, for these four of the SMS components, the region of

South and East Africa has the highest number of findings followed by the region of Australia and South Pacific. What is unique about this observation is that for both these regions, the operators are involved with the fly-in fly-out type of operations for the mining sector and they share common safety risks that are unique to this operating environment. Further research may be necessary to investigate if this is indeed a factor but this is not within the scope of this thesis.

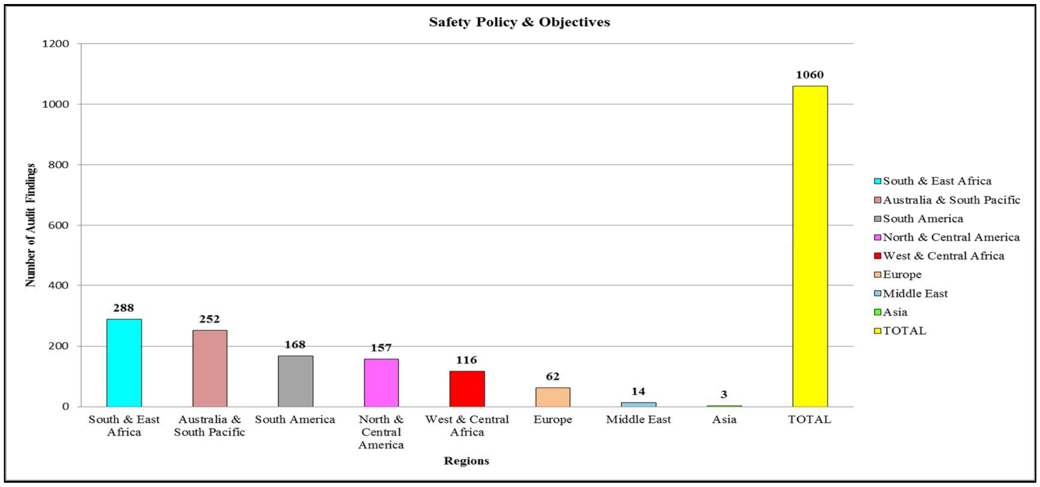

Figure 6.4: Breakdown By BARS Region – SMS Findings: Safety Policy and Objectives

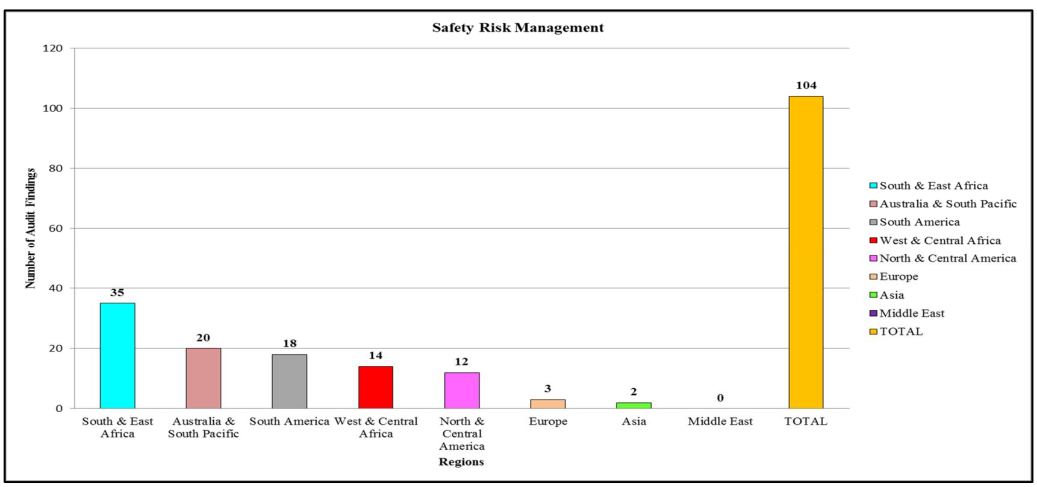

Figure 6.5: Breakdown By BARS Region – SMS Findings: Safety Risk Management

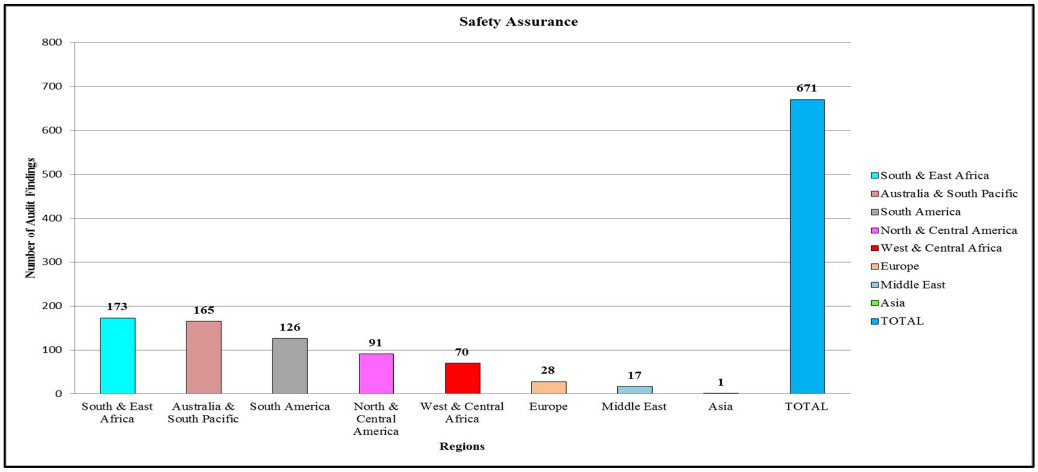

Figure 6.6: Breakdown By BARS Region – SMS Findings: Safety Assurance

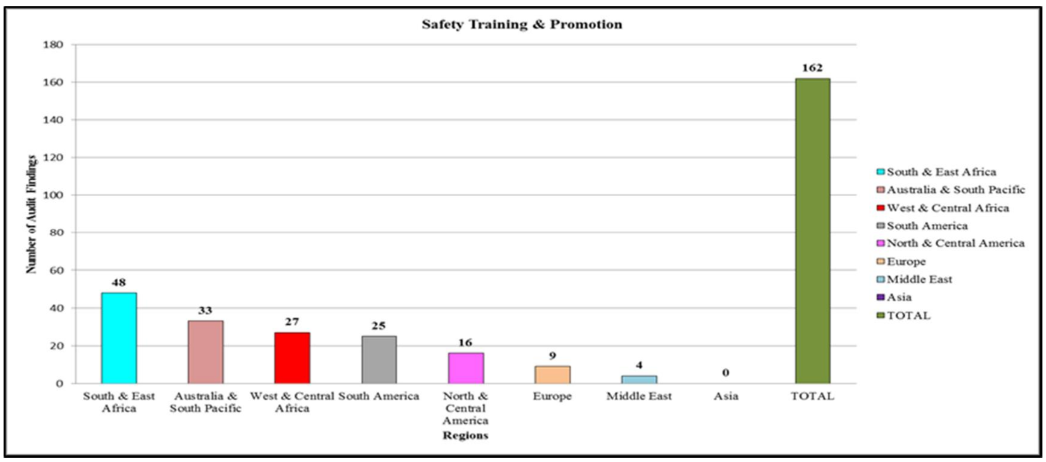

Figure 6.7: Breakdown By BARS Region – SMS Findings: Safety Training and Promotion

Table 6.3 lists the number of audits conducted for the periods from 2011ï 2014 for each of the regions. The number of audits conducted is then summed and the average number of audits conducted is calculated and presented in the extreme right column of the table. Using this information, a year-by-year comparison for airworthiness, flight operations, ground handling and SMS audits against the average number of audits conducted is computed and shown in Table 6.5.

Table 6.3 shows that the highest number of audits was conducted in 2013 but, correspondingly, in Table 6.5, it also shows the number of audit findings for all four disciplines have fallen to below average. This data point runs contrary to the expectation derived from the correlation coefficient (*r*) value of 0.737 in Table 6.8 which suggests that with more audits conducted, there is a high likelihood that there will be more audit findings found and vice versa.

A very plausible explanation for the decrease in audit findings is the improvements brought about by growing and maturing safety management systems (SMSs). Arguably, this data point supports the hypothesis that SMSs improve the safety performance of commercial aviation operations.

In 2014, 25 audits were conducted which were the least for any year in the sampling period. The finding that the number of audit findings is below average is consistent with the expectation that with fewer audits conducted, it will result in less audit findings.

Table 6.4 shows the number of audit findings for each of the four technical disciplines during the sampling period. The annual number of accidents associated with the sample population is tabulated and presented. In addition, the correlation coefficients (*r*) for SMS, airworthiness, flight operations and ground handling against the number of accidents are also calculated.

A very weak linear relationship for SMS, airworthiness, flight operations and ground handling against the number of accidents is shown in the scatter plots in Figures 6.8 to 6.11.

Table 6.6 lists the relationships and implications of the different variables of SMS, flight operations, airworthiness and ground handling to each other as derived from the scatter plots in Figures 6.12 to 6.17.

Table 6.3: BARS Audits Conducted by Region (2011–2014)

REGION	Year 2011	Year 2012	Year 2013	Year 2014	Total Number of Audits Conducted	Average Number of Audits Conducted
	Number of Audits Conducted					
Australia & South Pacific	32	27	28	7	94	24
Europe	4	2	3	2	11	3
North & Central America	7	11	9	2	29	7
South America	9	9	10	3	31	8
South & East Africa	11	11	16	9	47	12
West & Central Africa	3	3	4	2	12	3
Middle East	1	1	1	0	3	1
Asia	0	1	0	0	1	0
Total	**67**	**65**	**71**	**25**	**228**	**57**

Table 6.4: Audit Findings by Discipline versus Number of Accidents

Year	2011	2012	2013	2014
Number of SMS Audit Findings	922	525	394	132
Number of Accidents	25	37	27	26
Correlation Coefficient (*r*)	**-0.03**			
Number of Airworthiness Audit Findings	813	583	438	148
Number of Accidents	25	37	27	26
Correlation Coefficient (*r*)	**0.13**			
Number of Flight Operations Audit Findings	1394	753	709	241
Number of Accidents	25	37	27	26
Correlation Coefficient (*r*)	**-0.12**			
Number of Ground Handling Audit Findings	922	525	394	132
Number of Accidents	25	37	27	26
Correlation Coefficient (*r*)	**-0.07**			

Table 6.5: Comparison of BARS Audit Findings against the Average

Discipline	Year 2011	Year 2012	Year 2013	Year 2014
	Number of Audit Findings			
Maintenance (Airworthiness)	ABOVE AVERAGE	ABOVE AVERAGE	BELOW AVERAGE	BELOW AVERAGE
Flt (Flight Operations)	ABOVE AVERAGE	BELOW AVERAGE	BELOW AVERAGE	BELOW AVERAGE
Ground Handling	ABOVE AVERAGE	ABOVE AVERAGE	BELOW AVERAGE	BELOW AVERAGE
Org (SMS)	ABOVE AVERAGE	ABOVE AVERAGE	BELOW AVERAGE	BELOW AVERAGE

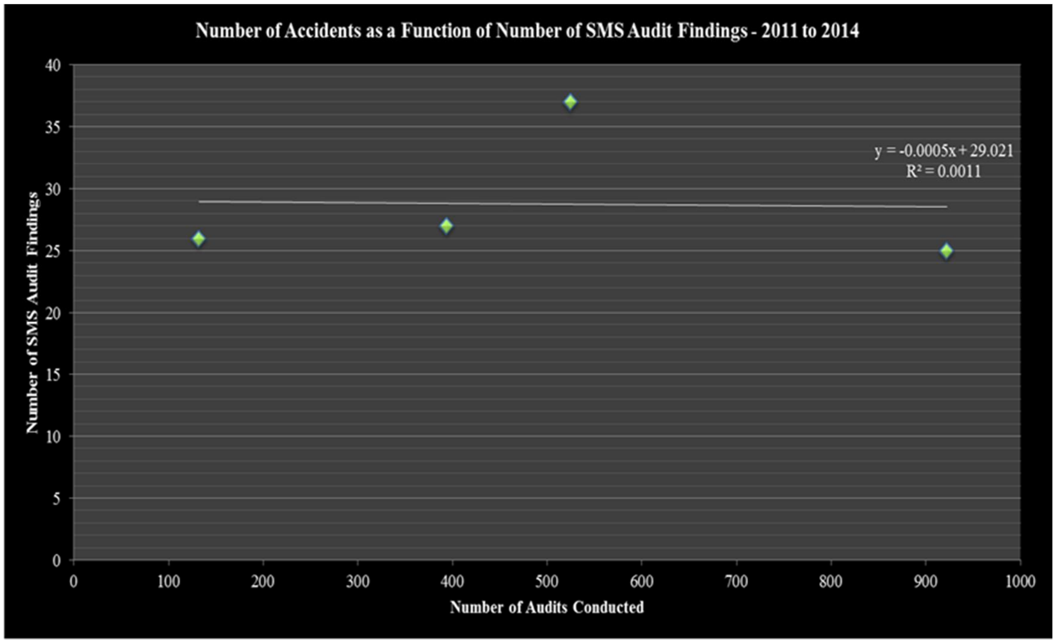

Figure 6.8: Scatter Plot: Number of Accidents as a Function of Number of SMS Audit Findings (2011–2014)

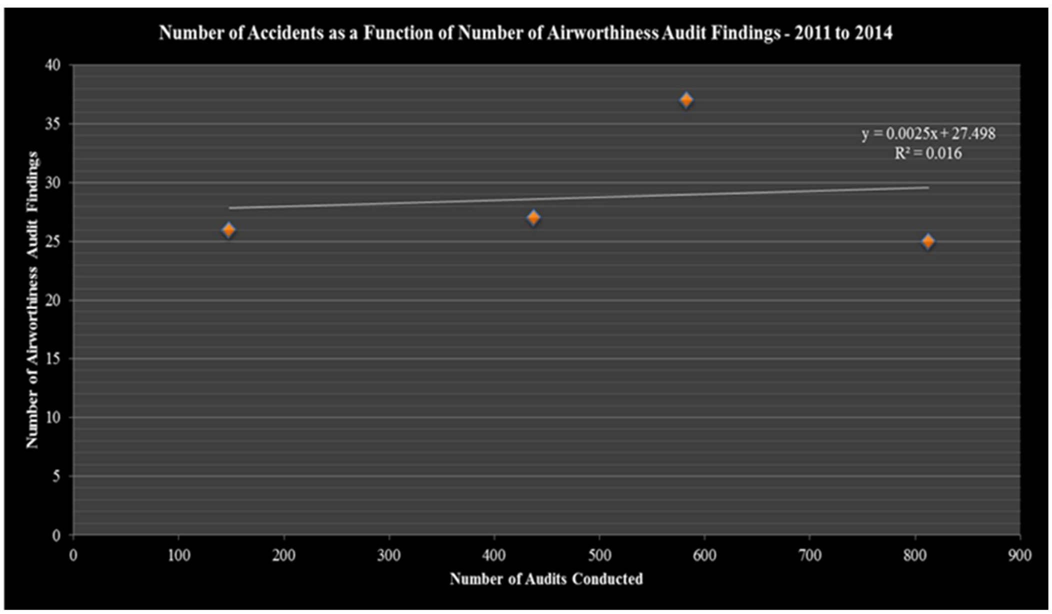

Figure 6.9: Scatter Plot: Number of Accidents as a Function of Number of Airworthiness Audit Findings (2011–2014)

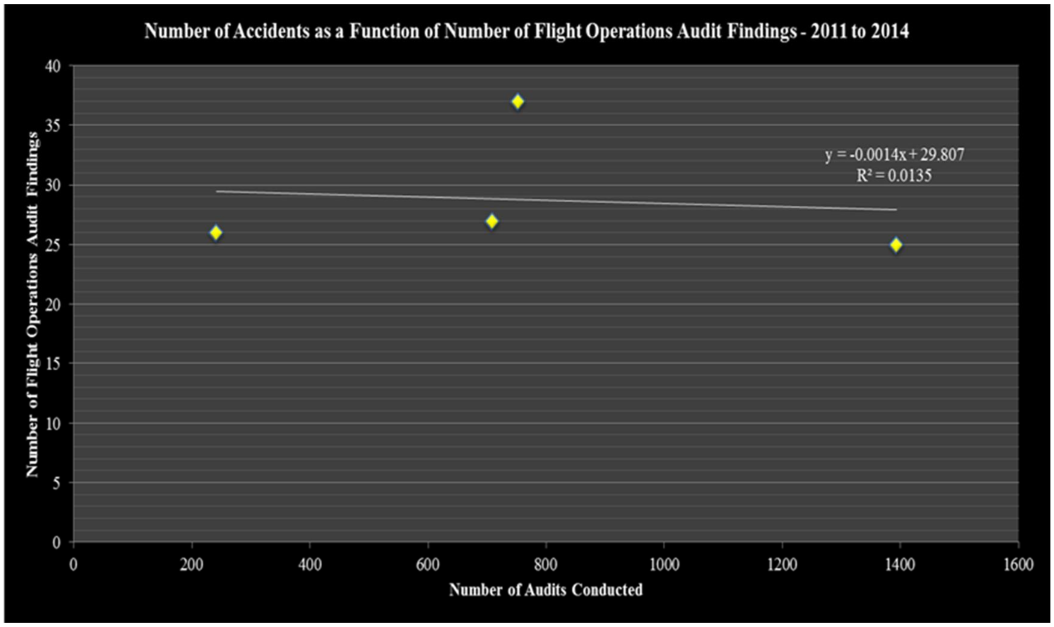

Figure 6.10: Scatter Plot: Number of Accidents as a Function of Number of Flight Operations Audit Findings (2011–2014)

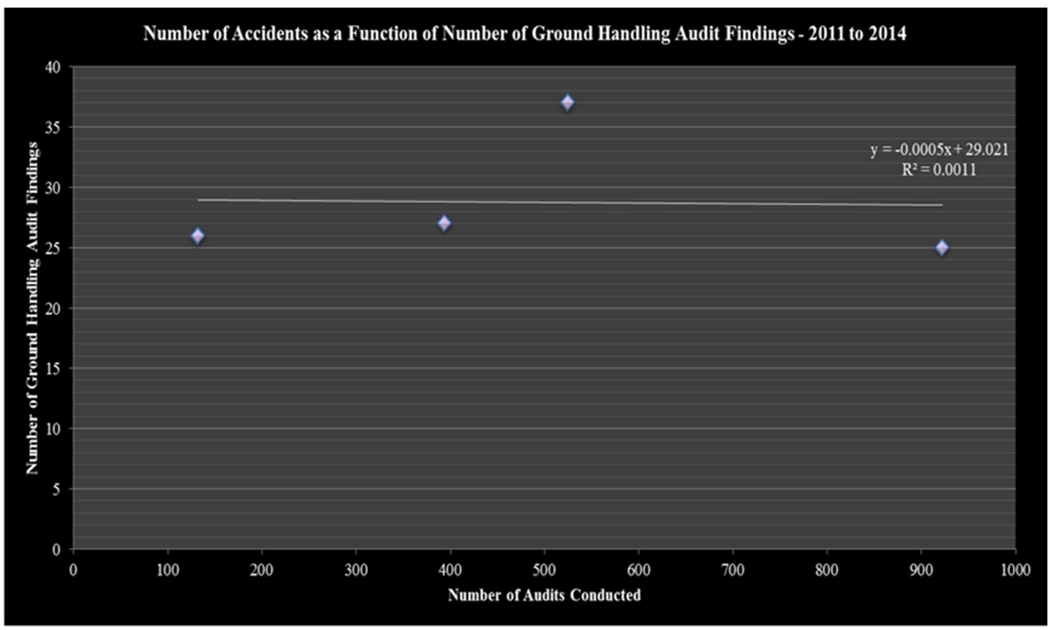

Figure 6.11: Scatter Plot: Number of Accidents as a Function of Number of Ground Handling Audit Findings (2011–2014)

Table 6.6: Correlations of SMS, Flight Operations, Airworthiness and Ground Handling Categories

Figure	Variables	R^2 Value	Correlation Coefficient (r)	Analysis	Implication
30	Number of BARS Airworthiness Audit Findings and BARS SMS Audit Findings	0.4179	0.67	Moderate positive linear relationship via a fuzzy-firm linear rule	The two variables have a moderate effect on each other, vice versa.
31	Number of BARS Flight Operations Audit Findings and BARS SMS Audit Findings	0.4537	0.75	Strong positive linear relationship via a firm linear rule	The two variables have a strong effect on each other, vice versa.
32	Number of BARS Ground Handling Audit Findings and BARS SMS Audit Findings	0.4277	0.68	Moderate positive linear relationship via a fuzzy-firm linear rule	The two variables have a moderate effect on each other, vice versa.
33	Number of BARS Flight Operations Audit Findings and BARS Airworthiness Audit Findings	0.439	0.65	Moderate positive linear relationship via a fuzzy-firm linear rule	The two variables have a moderate effect on each other, vice versa.
34	Number of BARS Ground Handling Audit Findings and BARS Airworthiness Audit Findings	0.323	0.59	Moderate positive linear relationship via a fuzzy-firm linear rule	The two variables have a moderate effect on each other, vice versa.
35	Number of BARS Ground Handling Audit Findings and BARS Flight Operations Audit Findings	0.4176	0.66	Moderate positive linear relationship via a fuzzy-firm linear rule	The two variables have a moderate effect on each other, vice versa.

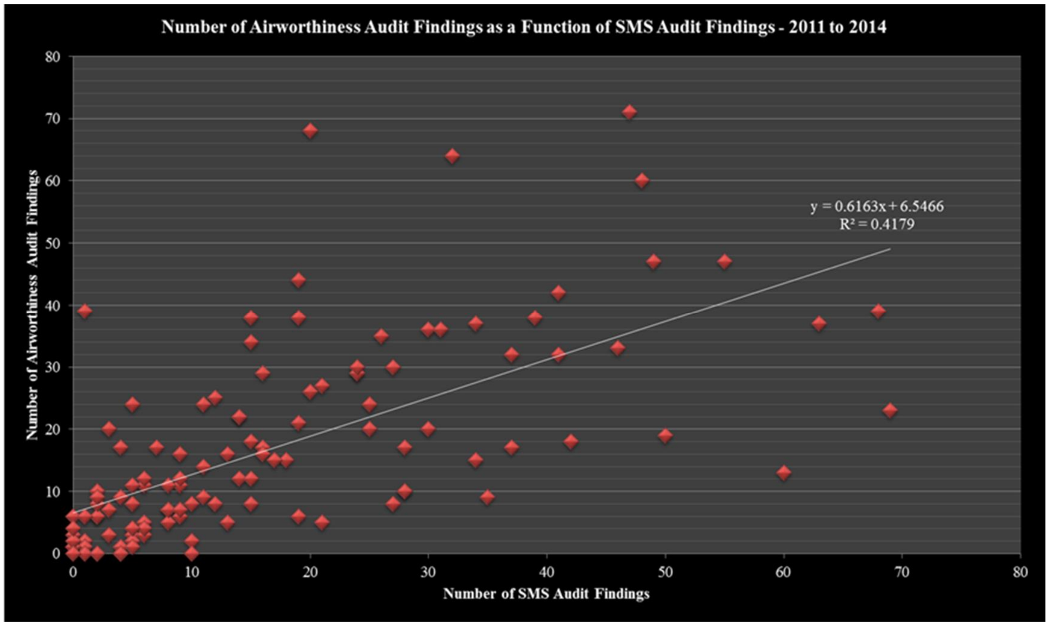

Figure 6.12: Scatter Plot: Number of Airworthiness Audit Findings as a Function of Number of SMS Audit Findings

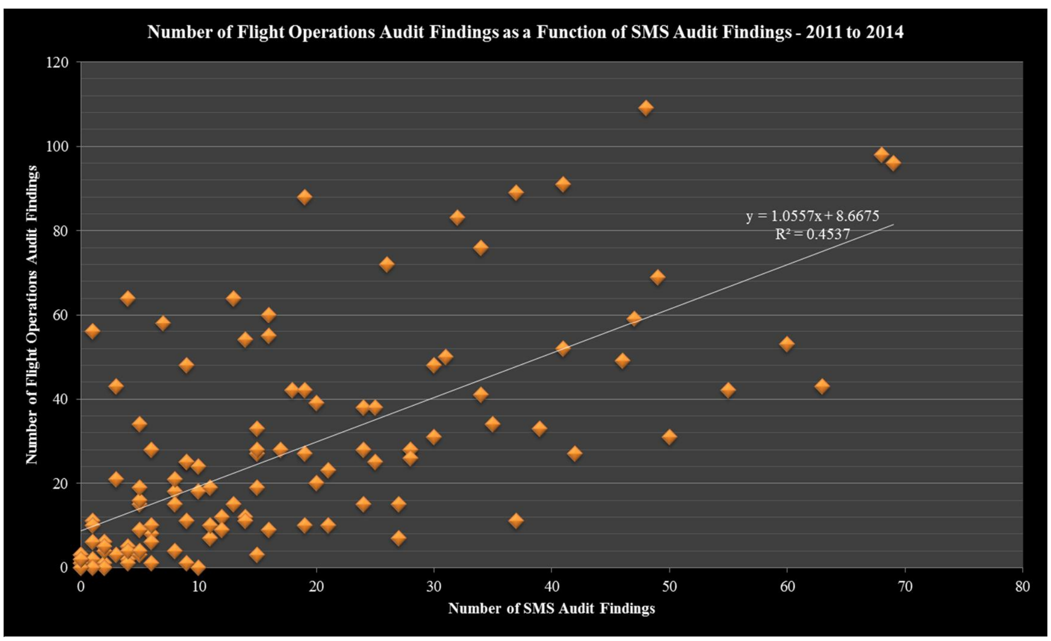

Figure 6.13: Scatter Plot: Number of Flight Operations Audit Findings as a Function of Number of SMS Audit Findings

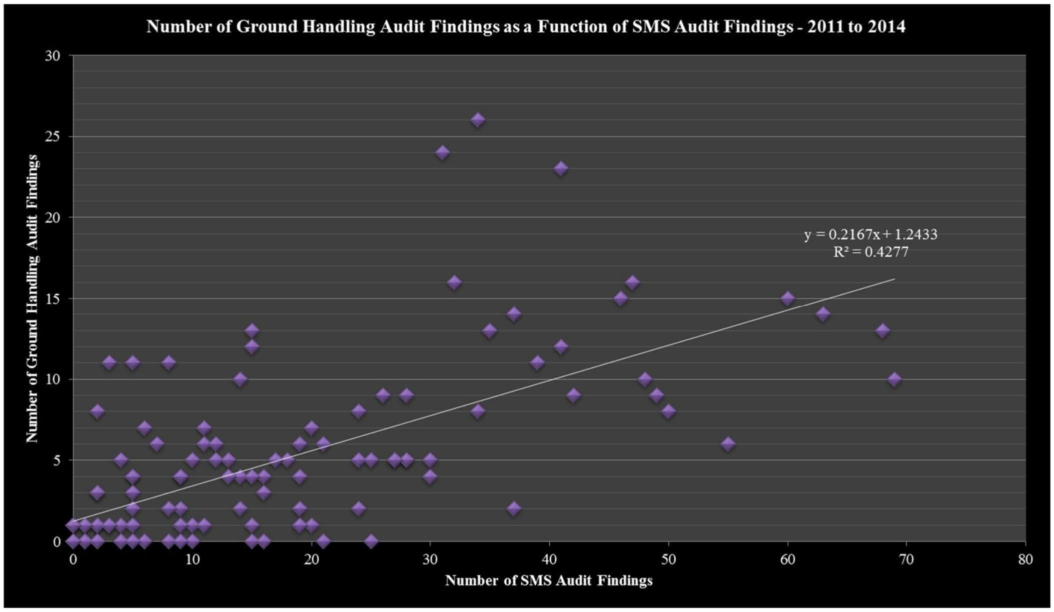

Figure 6.14: Scatter Plot: Number of Ground Handling Audit Findings as a Function of Number of SMS Audit Findings

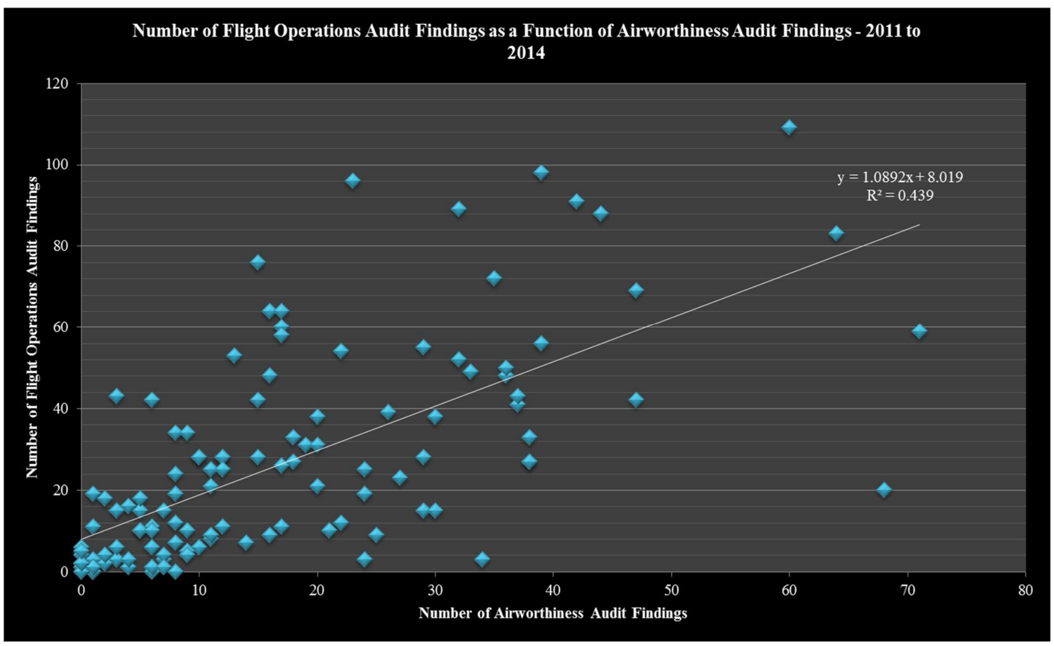

Figure 6.15: Scatter Plot: Number of Flight Operations Audit Findings as a Function of Number of Airworthiness Audit Findings

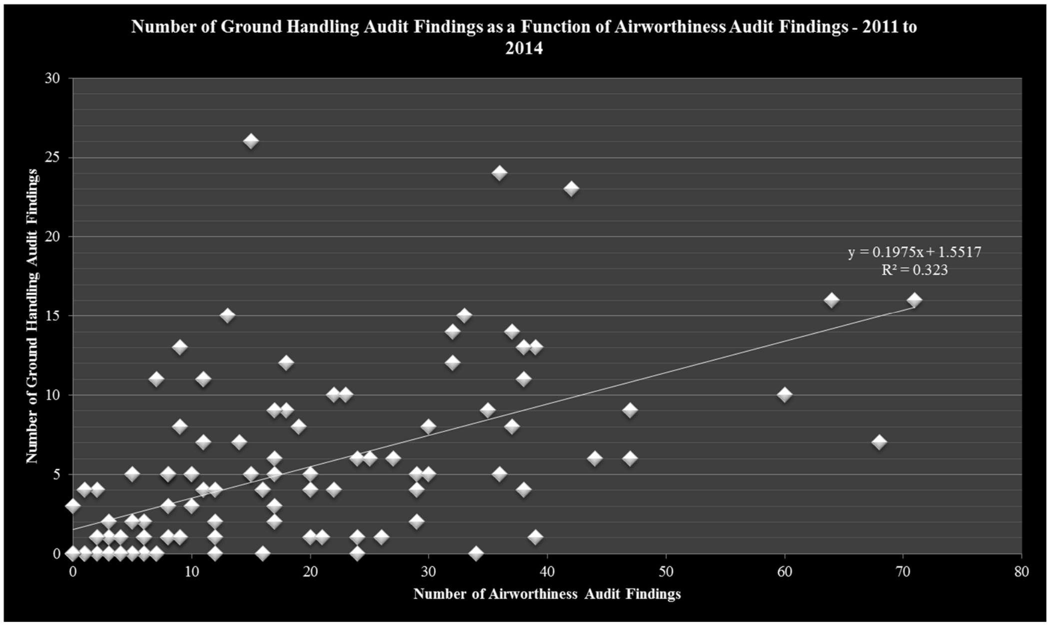

Figure 6.16: Scatter Plot: Number of Ground Handling Audit Findings as a Function of Number of Airworthiness Audit Findings

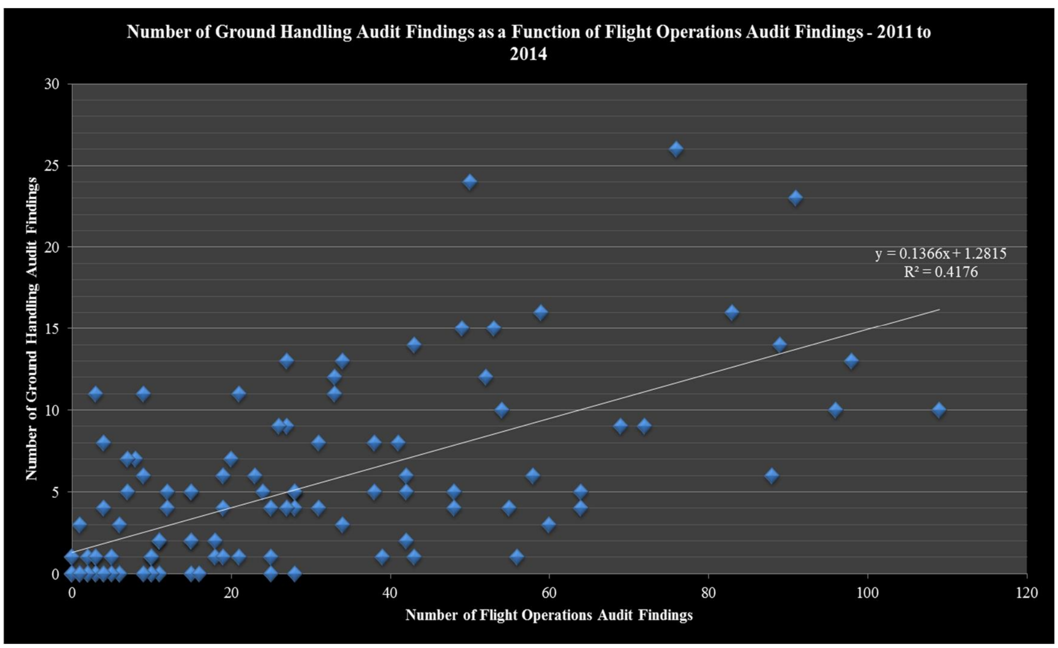

Figure 6.17: Scatter Plot: Number of Ground Handling Audit Findings as a Function of Number of Flight Operations Audit Findings

Table 6.7 contains data which show the number of audits conducted for 2011ï 2014 and the corresponding number of accidents for the sample population. Figure 6.18 shows a linear positive trend line for the number of audits conducted versus the number of accidents. The correlation coefficient (*r*) of 0.26 indicates a very weak relationship between the number of audits and the number of accidents. Essentially, these two variables have little to no effect on each other.

Table 6.7: Number of Audits versus Number of Accidents

Number of Accidents versus Audits		
Year	No of Audits	Number of Accidents
2011	67	25
2012	65	37
2013	71	27
2014	25	26
Total	**228**	**115**
Correlation Coefficient (*r*)		**0.26**

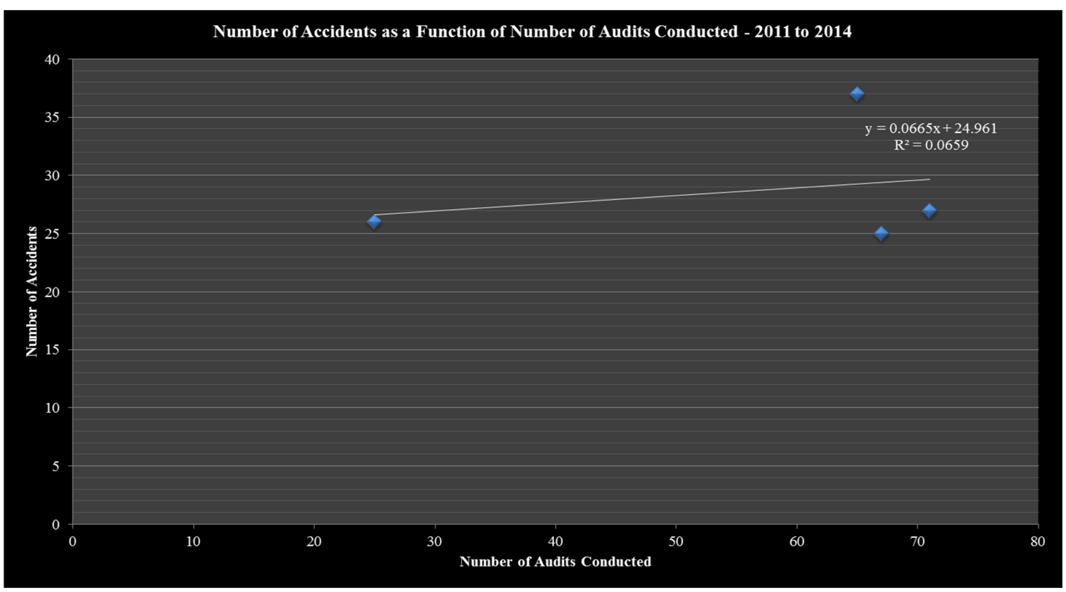

Figure 6.18: Scatter Plot: Number of Accidents as a Function of Number of Audits Conducted (2011–2014)

Table 6.8: Number of Audits versus Number of Audit Findings

Year	2011	2012	2013	2014
No of Audits Conducted	67	65	71	25
Number of Audit Findings	3378	2034	1647	556

Correlation Coefficient (*r*) **0.737**

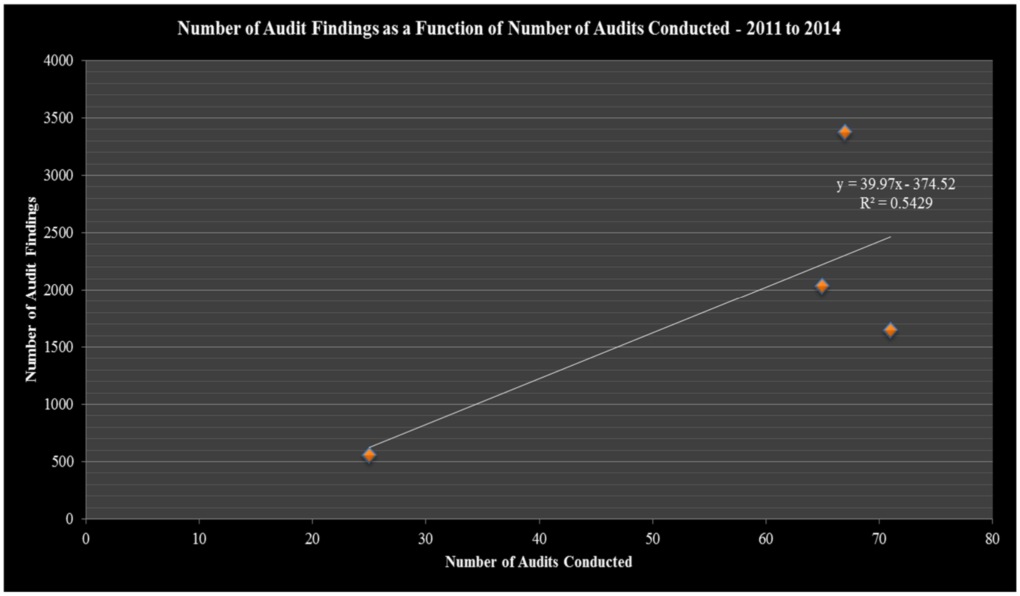

Figure 6.19: Scatter Plot: Number of Audit Findings as a Function of Number of Audits Conducted (2011–2014)

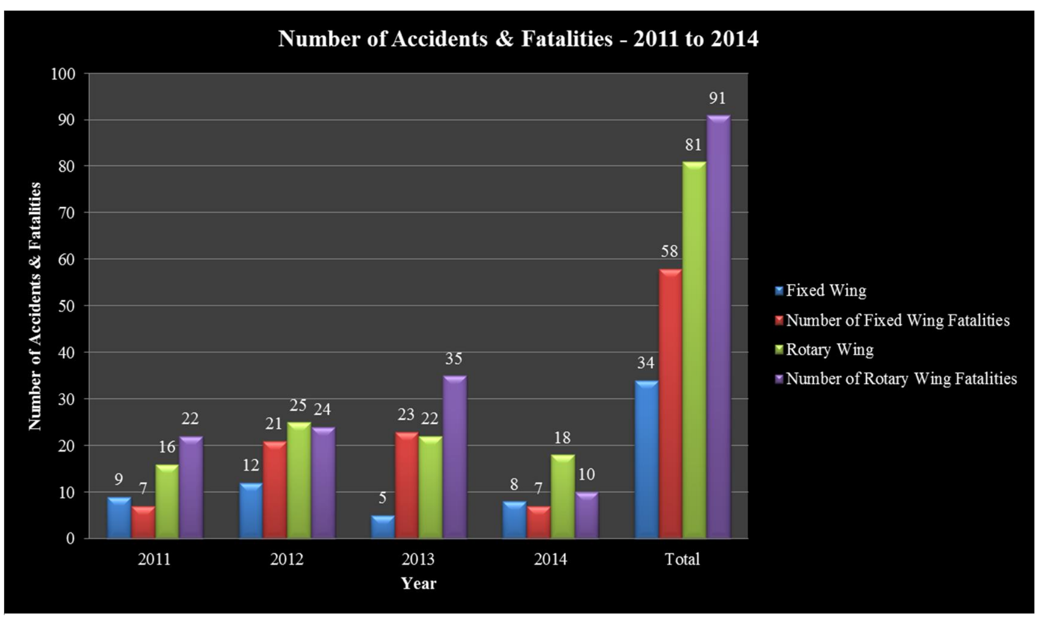

Figure 6.20: Number of Accidents and Fatalities (2011–2014)

Table 6.8 shows the data for the number of audits conducted against the number of audit findings made for the period from 2011ï 2014. It also shows a steady decrease year on year in the findings on the number of audits. The correlation coefficient (*r*) of 0.737 for the number of audits conducted and number of audit findings indicates a strong relationship between the two variables: this can also be seen in Figure 6.19. In other words, it is highly likely that with an increase in the number of audits conducted, there will be a corresponding increase in the number of audit findings made and vice versa.

Figure 6.20 is a graphical representation to provide an overview of the number of accidents that occurred during the sampling period and the nature of the accidents, that is, with or without fatalities. It also segregates the number of accidents by the type of aircraft operations, namely fixed wing, rotary wing or both for the sample population.

Table 6.9 shows the spread and nature of the reported accidents for the sample population by countries. The USA has 26 reported fatalities associated with the accidents reported and tops the list in the category for accidents with fatalities. Canada has a total of 31 accidents reported and tops the list in this category. When considering and comparing the countries in the sample population, it is very interesting to note the results of the findings with operators in the USA and Canada leading in the accident statistics, especially when both these countries are considered as leaders in aviation and aviation safety. Further research outside the scope of this thesis may be necessary to investigate this finding.

Table 6.9[10]: Accidents by Country and Type of Aircraft Operations (2011–2014)

		TOTAL ACCIDENT WITH FATALITIES	TOTAL ACCIDENTS - 2011 to 2014			
	Country	2011 to 2014	2011	2012	2013	2014
Fixed Wing	Australia		1	1		1
Rotary Wing						1
Fixed Wing	Brazil	11		2	1	
Rotary Wing		2			1	
Fixed Wing	Canada	8	3	2		1
Rotary Wing		5	8	9	5	3
Fixed Wing	Chile	2				
Rotary Wing						1
Fixed Wing	China	3	2			
Rotary Wing						
Fixed Wing	Colombia		1			
Rotary Wing		7	2	2	1	
Fixed Wing	Egypt					
Rotary Wing		1			1	
Fixed Wing	France	6				1
Rotary Wing		4		1		
Fixed Wing	Germany					
Rotary Wing		2		1		1
Fixed Wing	Guyana	2				1
Rotary Wing		0				
Fixed Wing	Indonesia	6		2		
Rotary Wing		15	2	2		
Fixed Wing	Italy					
Rotary Wing					1	
Fixed Wing	Kazakhstan					
Rotary Wing		8		1		
Fixed Wing	Mauritania	7		1		
Rotary Wing						
Fixed Wing	Moldova					
Rotary Wing				1		
Fixed Wing	Nigeria		1		1	
Rotary Wing						
Fixed Wing	Papua New Guinea	3		1		
Rotary Wing		4	2	1	1	
Fixed Wing	Peru	9			1	
Rotary Wing		16	1	1	1	1
Fixed Wing	Portugal					
Rotary Wing		1			1	
Fixed Wing	Russian Federation	1		1		
Rotary Wing		7	1	3	2	3
Fixed Wing	South Africa		1	1		
Rotary Wing						
Fixed Wing	Sweden					
Rotary Wing						1
Fixed Wing	Taiwan					
Rotary Wing						1
Fixed Wing	USA	7		1	1	2
Rotary Wing		19		3	8	6
Fixed Wing	Venezuela	0				1
Rotary Wing						
Fixed Wing	Yemen	0				1
Rotary Wing						

[10] Source: Flight Safety Foundation ï World Wide Resource Sector Accident Summary Register

6.2 Case Study 2 Results

The results of the analysis for Case Study 2 are presented in Table 6.10, Figures 6.21 to 6.25, and Appendices 7 and 8.

Table 6.10 shows the number of SMS, airworthiness and flight operations audit findings for the sample population and the number of mandatory safety reports made to the ATSB for the sampling period from 2009ï 2013.

The scatter plot in Figure 6.22 shows that there is positive linear relationship between the number of SMS audit findings and the number of ATSB safety reports. The calculated correlation coefficient (*r*) of 0.24 in Table 6.10 indicates this to be a very weak relationship.

Figure 6.23 shows a positive linear relationship between the number of SMS audit findings and the number of airworthiness audit findings. With reference to Table 6.10, the correlation coefficient (*r*) of 0.36 indicates this to be a weak relationship.

Figure 6.24 shows a positive linear relationship between the number of SMS audit findings and the number of flight operations audit findings. The correlation coefficient (*r*) of 0.58 in Table 6.10 indicates this to be a moderate relationship.

Figure 6.25 shows a positive linear relationship between the number of flight operations audit findings and the number of airworthiness audit findings. The correlation coefficient (*r*) of 0.62 in Table 6.10 indicates this to be a moderate to strong relationship.

Table 6.10: Correlation Coefficients of SMS, Flight Operations and Airworthiness Audit Findings

	Correlation Coefficient (*r*)	Number of Audit Findings/ATSB Safety Reports (2009–2013)
SMS	0.24	596
ATSB Safety Reports		175
SMS	0.36	596
Airworthiness		590
SMS	0.58	596
Flight Operations		1271
Airworthiness	0.62	590
Flight Operations		1271

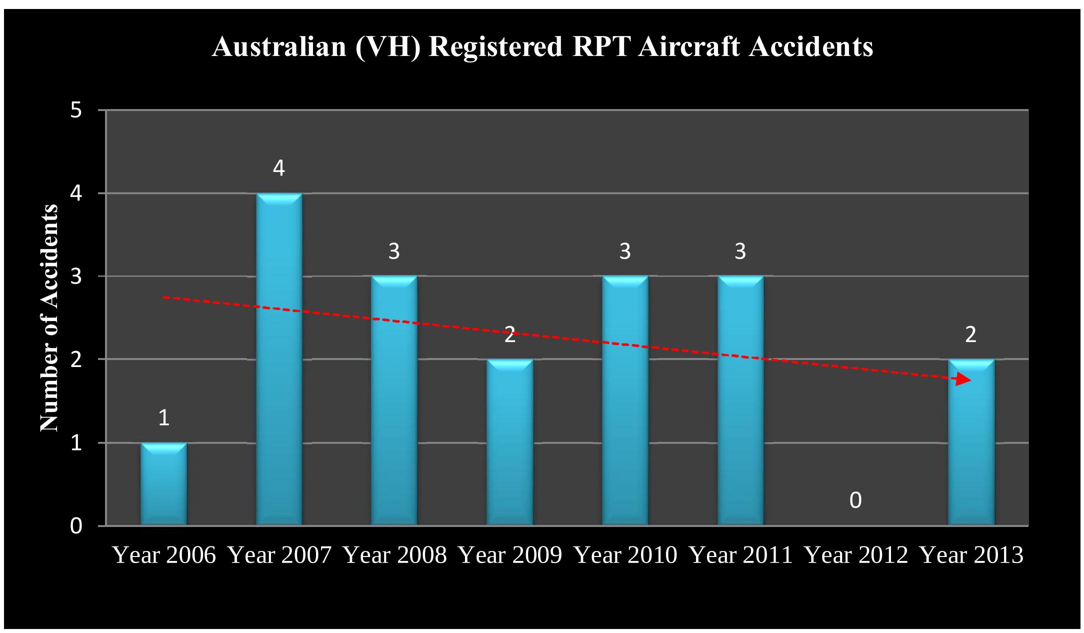

Figure 6.21: Total Number of RPT Accidents in Australia (2006–2013)
(Derived from summation of data in SPI-3 & SPI-5 as shown in Table 5.3)

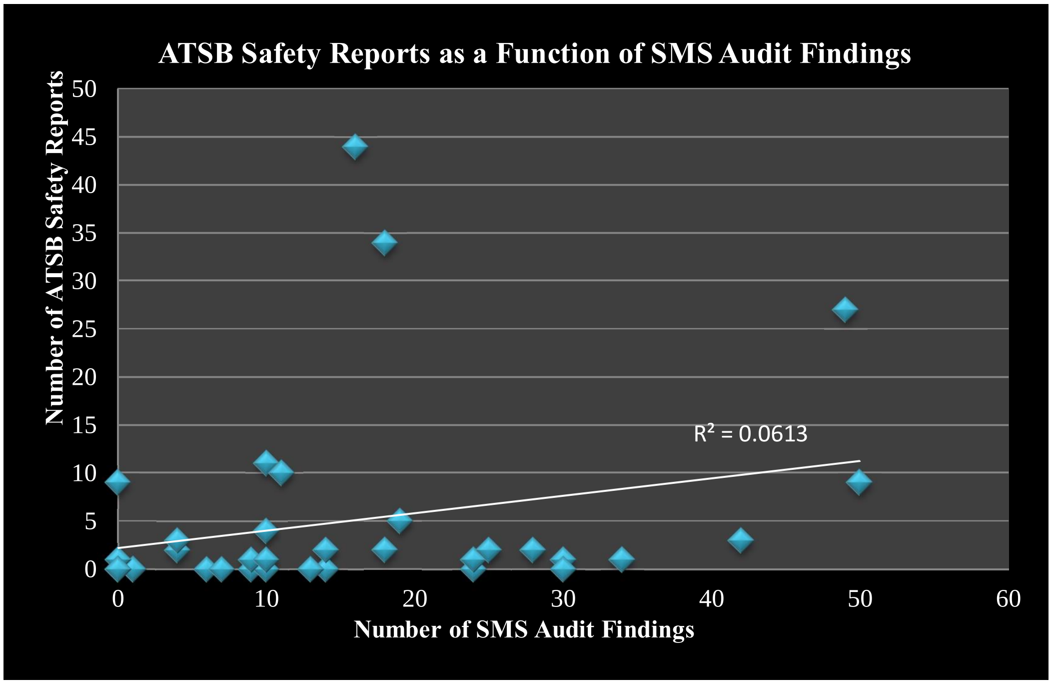

Figure 6.22: Scatter Plot: Number of ATSB Safety Reports as a Function of SMS Audit Findings (2009–2013)

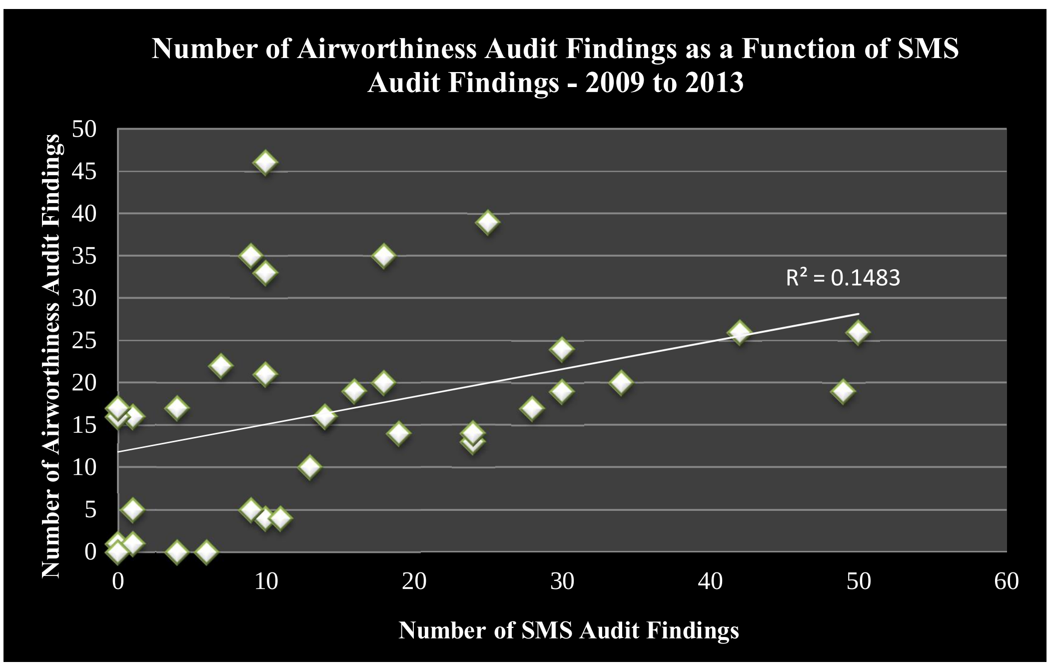

Figure 6.23: Scatter Plot: Number of Airworthiness Audit Findings as a Function of SMS Audit Findings (2009–2013)

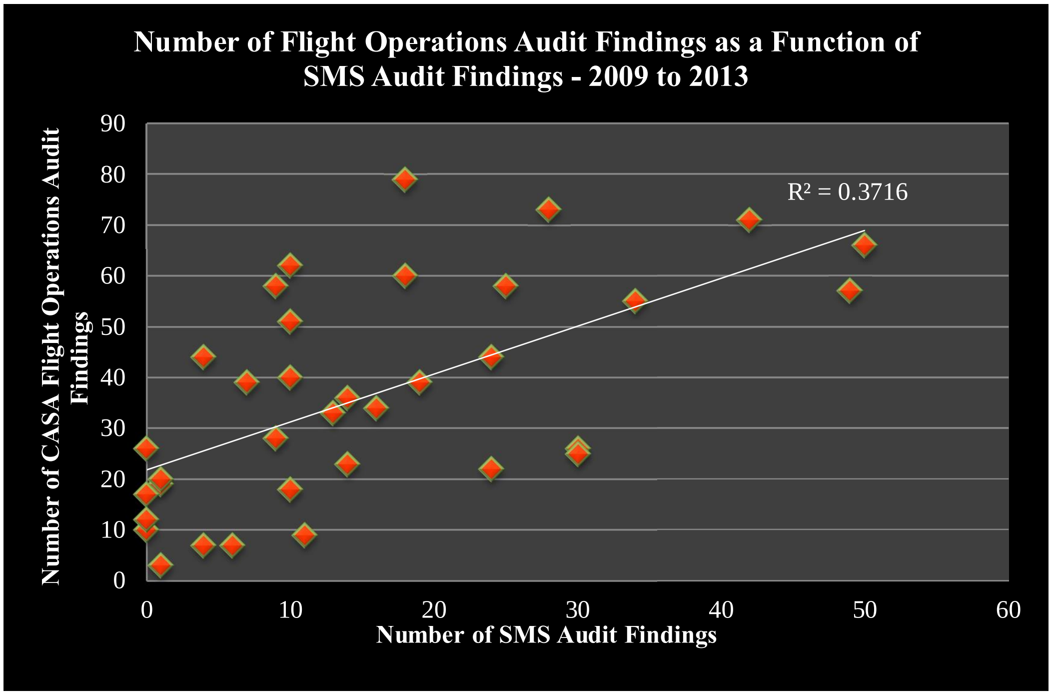

Figure 6.24: Scatter Plot: Number of Flight Operations Audit Findings as a Function of SMS Audit Findings (2009–2013)

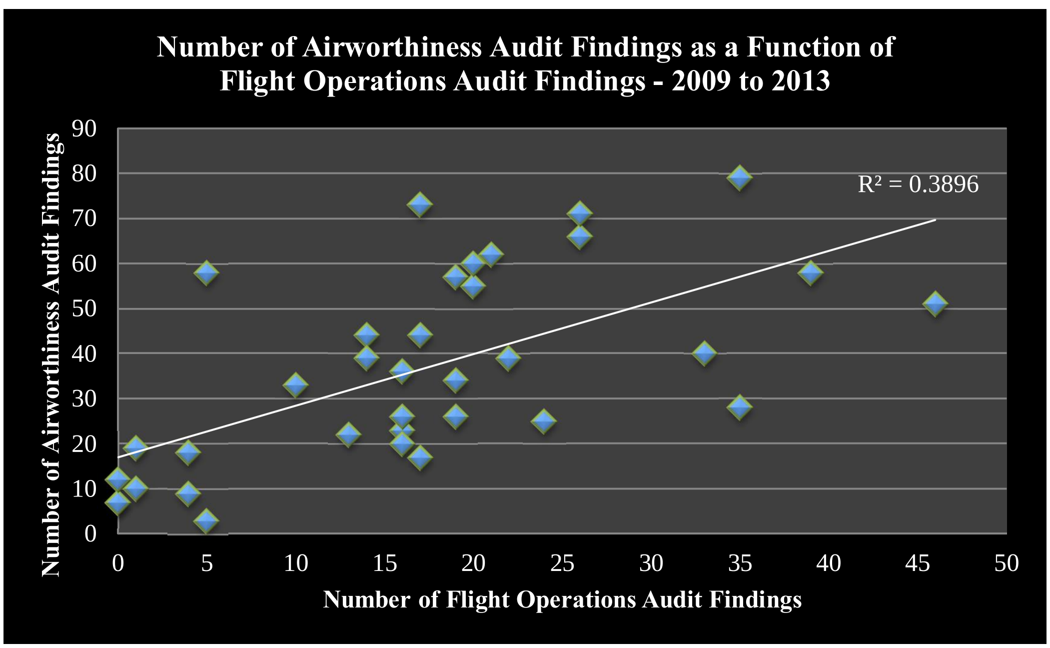

Figure 6.25: Scatter Plot: Number of Airworthiness Audit Findings as a Function of Flight Operations Audit Findings (2009–2013)

Chapter 7 Discussion

7.1 Limitations regarding Case Study 1 Data

Due to the unavailability of the flight departures data for the sample population, it was not possible to assess the safety performance using the accident rate metric. Therefore, an indirect means was required to assess the impact of SMSs on safety performance.

7.2 Interpretation of Case Study 1 Results

The correlation coefficient (r) of 0.737 in Table 6.8 for the number of audits and number of audit findings indicates a strong positive linear relationship. This means that with more audits conducted, there will be a corresponding increase in the number of audit findings.

The BARS program included the progressive auditing of SMSs for the sample population around the year 2011 time frame. This was when many of the operators in the sampled population were beginning to adopt and implement the ICAO SMS model for their organisation.

Table 6.4 shows that the number of SMS audit findings was on a progressive downward trend. Comparing year on year, 2012 registered a 43% decrease from 2011. In 2013, there was a 25% decrease in the number of SMS audit findings from the previous year and, in 2014, there was a 66% decrease in the number of SMS audit findings over the previous year. The number of airworthiness audits was also trekking progressively on a downward trend. The audit findings in 2012 saw a 28% decrease from 2011 followed by a 25% decrease in 2013 from 2012. For 2014, there was a 66% decrease in the number of audit findings over the previous year.

Similarly, the number of flight operations audit findings also decreased progressively. For 2012, there was a 46% decrease from 2011. For 2013, there was a 6% decrease from 2012. For 2014, it was a 66% decrease in the number of audit findings over the previous year. The trend was identical for ground handling audit findings. For 2012, there was a 43% decrease from 2011 for the number of audit findings. For 2013, it was a 25% decrease from the previous year and in 2014, it was a 66% decrease from 2013 for the number of audit findings.

It is observed that in 2013, the 25% reduction of SMS findings occurred in the same year that most audits were carried out for the entire sampling period. Reaffirming what has been stated previously, the correlation coefficient (*r*) of 0.737 in Table 6.8 for the number of audits conducted and the number of audit findings indicates that this is a strong relationship. Therefore, the expected outcome should be an increase rather than a decrease in the number of SMS audit findings in 2013. Potentially, this outcome is due to the development and maturity of the implemented SMSs for the sample population. The empirical data in Table 6.4 show a decreasing trend in the number of audit findings for all the technical disciplines and support the hypothesis that SMSs improve the safety performance of commercial aviation operations.

The correlation coefficient (*r*) value of minus 0.03 for the number of SMS findings against the number of accidents indicates a weak negative linear relationship between these two variables (see Table 6.4). Statistically, the number of SMS findings has little or no effect on the number of accidents. The negative correlation coefficient value simply means that as one variable increases in its value, the other variable decreases in its value.

In Table 6.4, the correlation coefficient (*r*) value of 0.67 for the SMS findings versus the airworthiness findings indicates a moderate linear relationship between these two variables, suggesting that the two variables have a moderate effect on each other. The correlation coefficient (*r*) value of 0.75 for the SMS findings versus the flight operations findings indicates a strong linear relationship between these two variables and this suggests that the two variables have a strong effect on each other. The correlation coefficient (*r*) value of 0.68 for the SMS findings versus the ground handling findings indicates a moderate linear relationship and a moderate effect between these two variables.

Similarly, the correlation coefficient (*r*) value of 0.65 for the flight operations findings versus the airworthiness findings also indicates a moderate linear relationship and suggests a moderate effect between these two variables. The correlation coefficient (*r*) value of 0.66 for the flight operations findings versus ground handling findings indicates a moderate linear relationship and moderate effect between these two variables. The correlation coefficient *(r*) value of 0.59 for the airworthiness findings versus the ground handling findings indicates a moderate linear relationship and a moderate effect between them.

In Table 6.7, the correlation coefficient (*r*) value of 0.26 for the number of audits conducted versus the number of accidents indicates a weak linear relationship between these two variables. The two variables have a weak effect on each other. This suggests that the number of audits conducted has little effect on the number of accidents.

7.3 Interpretation of Case Study 2 Results

Figure 6.21 shows a decreasing trend for the total number of accidents in Australia, averaging two accidents annually. By comparison with the global average number of 103 accidents a year for scheduled commercial flights over the period 2009ï 2013 (ICAO, 2014b, p. 5), it can be argued that the aviation industry for the RPT sector in Australia is very safe in comparison with the rest of the world.

According to IATA, in 2009, SMS provisions were added to IATAôs Operational Safety Audit (IOSA) program which, thereafter, also required SMSs in the IOSA certification for their member airlines which are in excess of over 388 airlines worldwide (International Air Transport Association [IATA], 2013). For the period between the years 2009ï 2014, IATA reported a total of 432 accidents for its members. In 2013, the IOSA registered operators had an accident rate 2.5 times better than non-IOSA carriers (IATA, 2013).

In Case Study 2, a comparison of the CASA safety indicators for the sampled population before and after the implementation of SMSs was conducted. The empirical evidence from the results obtained supports the hypothesis that SMSs improve the safety performance of commercial aviation operations. For this study, the period between 2009 and 2010 was not considered as it was considered to be the SMS implementation phase for the RPT operators. The period from 2006ï 2008 was the pre-SMS period and the time from 2011ï 2013 was the post-SMS period. Summing the values of SPI-1 to SPI-6 in Table 5.3, the following results are obtained.

Table 7.1: Results from Summation of Values of SPI-1 to SPI-6

		2006 to 2008	2011 to 2013
SPI-1	The number of HCRPT fatal accidents	0	0
SPI-1	The number of LCRPT fatal accidents	0	0
SPI-2	The rate of HCRPT fatal accidents (per 100,000 hours flown)	0	0
SPI-2	The rate of LCRPT fatal accidents (per 100,000 hours flown)	0	0
SPI-3	The number of high capacity regular public transport accidents (VH-registered)	7	5
SPI-4	The rate of high capacity regular public transport accidents (per 100,000 hours flown)	0.7	0.3
SPI-5	The number of low capacity regular public transport accidents (VH-registered)	1	0
SPI-6	The rate of low capacity regular public transport accidents (per 100,000 hours flown)	0.6	0.0

No fatal accidents were recorded for either the pre- or post-SMS implementation periods (SPI-1 & SPI-2). For the HCRPT operators, the number of accidents decreased from seven to five (SPI-3) whilst the LCRPT operators recorded a decrease from one to zero accidents (SPI-5) after their SMS was implemented. The rate of HCRPT accidents decreased from 0.7 to 0.3 (SPI-4) and the LCRPT operators rate of accidents fell from 0.6 to zero (SPI-6). In Table 6.10 and Figure 6.22, the correlation coefficient (r) value is shown to be 0.24 for the SMS findings versus the ATSB safety reports. Statistically, this indicates a weak linear relationship between these two variables. The two variables have a weak effect on each other and are considered insignificant. With reference to Table 6.10 and Figure 6.23, the correlation coefficient (r) value of 0.36 for the SMS findings versus the airworthiness findings indicates a weak linear relationship. In practical terms, they have a weak effect on each other and this effect can be considered to be insignificant. In reference to Table 6.10 and Figure 6.24, the correlation coefficient (r) value of 0.58 for the SMS findings versus the flight operations findings indicates a moderate linear relationship between these two variables. This means that there is a likely chance that any change to one variable will have a moderate effect on the other variable in the same direction.

With reference to Table 6.10 and Figure 6.25, the correlation coefficient (r) value of 0.62 for the airworthiness findings versus the flight operations findings indicates a moderate linear relationship and a moderate effect on each other.

Another way of analysing the data is the use of the z-score to measure the statistical significance and relationship to the mean in the group of scores as applied to the number of SMS findings for the sample population (see Appendix 10). A z-score of zero means the score is the same as the mean. A z-score can also be positive or negative, indicating whether it is above or below the mean and by how many standard deviations. The use of z-scores allows the conversion of scores from different data sets into scores that can be accurately compared to each other. Appendix 10-37 shows the analysis of the z-score for each of the 35 RPT operators. Taking HCRPT Operator 1 as an example, the z-score is statistically significant, and there is more than a chance that an audit will find more SMS findings for this operator than will be indicated by the mean of the 23 audit findings.

7.4 Conclusions

The hypothesis in this research study sought to determine whether the introduction and implementation of SMSs improve the safety performance of commercial aviation operations. In order to determine the efficacy of SMSs in improving safety performance, a review of the safety data and indicators was conducted prior to and after the implementation of SMSs for the sampled population of corporate and general aviation operators in Case Study 1 as well as for the airline operators in Case Study 2.

In general, the results obtained from this research support the hypothesis that SMSs improve the safety performance of commercial aviation operations.

In addition, the case studies further highlight the following points (see Appendix 7):

a) There is a moderate to strong positive relationship between the number of SMS and flight operations audit findings.
b) This is not the case for the number of SMS and airworthiness audit findings. The results of the two case studies suggest that this is a weak to moderate positive relationship.

c) The relationship between the number of SMS findings and ground handling findings is a moderate positive one.
d) There is a strong positive relationship with regards to the number of audits conducted and the number of audit findings made.
e) There is a consistent moderate positive relationship between the number of airworthiness and flight operations audit findings.

Chapter 8 Mapping Relationships and Identifying Key Components of SMS Framework Using DEMATEL Method

8.1 Introduction

To address the human factors (HF) issue, the approach to aviation safety management has changed from reactive to become proactive using safety management systems (SMSs) (Liou et al., 2008). It has been suggested that behind every accident is a failed organisation and a need for their SMS to address air safety in a comprehensive way (McDonald et al., 2000). The root causes of accidents are usually composed of many complex and interrelated factors within an organisation. The latent factors of these organisational and management factors have become increasingly important but little emphasis has been given to defining what constitutes an effective SMS and the relationships among the factors in an SMS (Santos-Reyes & Beard, 2002).

To address these issues, a combination of fuzzy logic and the Decision-Making Trial and Evaluation Laboratory (DEMATEL) was employed in mapping out the complex relationships of the SMS components and identifying the key factors in an effective safety management system (SMS). In this study, the CASA SMS model is used as the framework for building the DEMATEL tool. The DEMATEL method uses the knowledge of experts to lay out the structural model of a system. The advantages of the DEMATEL method is that it provides a visualisation of causal relationships among subsystems through the impact relations map (IRM) and it also indicates the degree of influence among factors. In May 1999, CASA initiated the safety intelligence system (SIS) strategy which is aimed at providing an infrastructure to assist in monitoring safety trends, tools to identify emerging safety issues and potential safety hazards, risk assessment methodologies, and criteria and safety performance indicators (ANAO, 1999, p. 127). While the ANAO recognises the benefits of the proposed strategy, it also noted that, in the past, achievements in implementing similar systems have been limited as is the experience of other nations in developing a satisfactory system (ANAO, 1999, p. 127).

The agreement between CASA and the RPT operators on the key performance indicators (KPIs) and expected level of performance to be achieved for their SMS is typically encapsulated within the safety objectives in each operatorǿs SMS manual. A framework is currently being refined by CASA for individual service provider agreements with regard to the safety performance of SMSs (Department of Infrastructure and Transport, 2011, p. 29). Therefore, in the absence to date of any standardised SMS performance measuring tool/indicators promulgated by CASA, the customised DEMATEL tool is recommended for potential adoption.

8.2 DEMATEL Model

In a complex system, all systemic factors are directly or indirectly related (Liou et al., 2008). Consequently, it is difficult for a decision maker to measure a single effect from a single factor while avoiding interference from the rest of the system. To quantify precise values within complex evaluation systems can be a very hard task. Dividing a complex evaluation environment into subsystems facilitates and enables an easier judgement of differences and easier measurement of scores. The DEMATEL method was developed to study the structural relationships in complex systems (Liou et al., 2007). The successful application of the DEMATEL model has been seen in many situations, such as marketing strategies, e-learning evaluation, control systems and safety problems (Chiu, Chen, Shyu & Tzeng, 2006; Hori & Shimizu, 1999). The methodology can confirm interdependence among variables/criteria and restrict the relationships that reflect characteristics within an essential systemic and developmental trend. The final outcome of the DEMATEL process is a visual representation by which the respondent can organise his/her action in the world (Tzeng et al., 2007).

8.3 DEMATEL Method

The DEMATEL method was developed by the Science and Human Affairs program of the Battelle Memorial Institute of Geneva between 1972 and 1976. It was used to research and solve complicated and intertwined problem groups (Fontela & Gabus, 1974, 1976, cited in Li & Tzeng, 2009, p. 9891). This method is based on graph theory and it provides the means for planning and solving problems visually. Furthermore, the relevant factors can be divided into groups of causes and effects as appropriate (Li & Tzeng, 2009, p. 9891).

The DEMATEL method was developed in the belief that the appropriate use of scientific research methods could improve understanding of the specific problem. It was applied to solve problems concerning decisions in order to clarify the essential features of the problems and to help create countermeasures. The fundamentals of the DEMATEL method are that it transforms the attributes of the application and evaluation into a non-independent multi-criteria evaluation of problems (Chen, 2012, p. 26). It then determines the interdependent and constraining relationships based on the specific features of the subjects. In this way, it reflects the essential features and the evolving trend of the system.

Past successful applications of the DEMATEL method range from the analysis of problematic world decision making to industrial planning (Chiu et al., 2006; Hori & Shimizu, 1999; Huang, Shyu, & Tzeng, 2007; Tzeng et al., 2007). The DEMATEL method has been successfully applied in many situations, including marketing strategies, e-learning evaluation, control systems and safety problems (Chiu et al., 2006; Hori & Shimizu, 1999). The methodology can confirm interdependence among variables/criteria and restrict the relationships that reflect characteristics within an essential systemic and developmental trend. The end-product of the DEMATEL process is a visual representation by which the respondent organises his or her action in the world (Tzeng et al., 2007).

A flow chart of the DEMATEL method is presented in Figure 8.1.

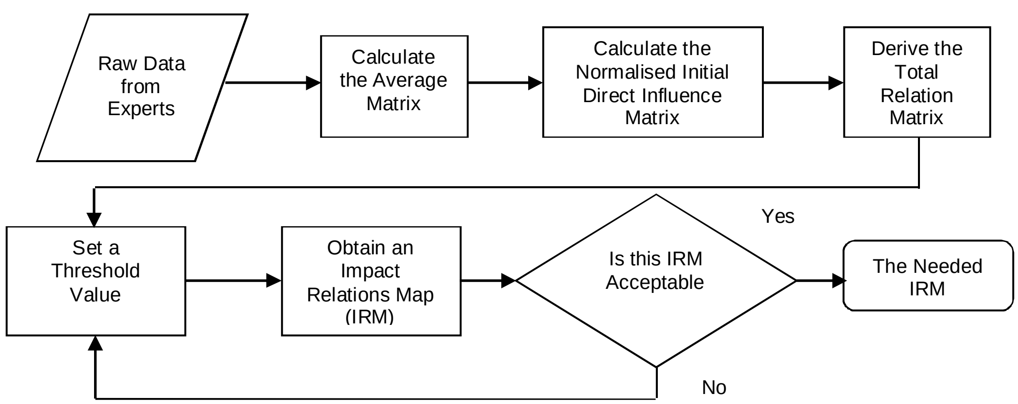

Figure 8.1: Steps of the DEMATEL Process

According to Tzeng et al. (2007), the DEMATEL method can be summarised in the following steps:

1) Respondents are asked to indicate the direct effect they believe each element i exerts on each element j of others, as indicated by a_{ij}, using an integer scale

ranging from 0, 1, 2, 3 and 4, represented from 0 as ‘no influence’ to 4 as ‘very high influence’.

2) The initial direct relation matrix Z is a n x n matrix obtained by pair-wise comparisons in terms of influences and directions between criteria, in which z_{ij} is denoted as the degree to which the criterion i affects the criterion j, that is, $Z = [z_{ij}]_{n \times n}$.

3) The normalised direct relation matrix X, that is, $X = [x_{ij}]_{nxn}$ and $0 \leq x_{ij} \leq 1$ can be obtained through equations (1) and (2), in which all principal diagonal elements are equal to zero:

$$\boldsymbol{X} = s.\boldsymbol{Z} \qquad \text{Equation (1)}$$

$$S = \frac{1}{\max \sum_{j=1}^{n} Z_{ij}}, \qquad i,j = 1, 2, \ldots, n, \qquad \text{Equation (2)}$$

4) The total-relation matrix **T** can be acquired by using equation (3), in which ***I*** is denoted as the identity matrix.

$$\mathbf{T} = \boldsymbol{X}(1\text{-}X)^{-1} \qquad \text{Equation (3)}$$

5) The sum of rows and the sum of columns are separately denoted as D and R within the total-relation matrix T through equations (4)–(6) where D and R denote the sum of rows and the sum of columns respectively:

$$\mathbf{T} = t_{ij},\ i, j = 1, 2, \ldots, n, \qquad \text{Equation (4)}$$

$$\boldsymbol{D} = \sum_{j=1}^{n} t_{ij} \qquad \text{Equation (5)}$$

$$\boldsymbol{R} = \sum_{i=1}^{n} t_{ij} \qquad \text{Equation (6)}$$

6) A causal diagram can be acquired by mapping the data set of ($D + R$, $D - R$), where the horizontal axis ($D + R$) is made by adding $D - R$, and the vertical axis ($D - R$) is made by subtracting D from R.

8.4 Empirical Study to Define the Critical SMS Components

The study into the development of an analytical framework for defining the critical components of an SMS, and the investigation of the structural relationships among the critical SMS components and a means to measure and assess the performance of the SMS is presented in the following sections.

8.5 Finding Relationships of CASA SMS Framework Using DEMATEL

Nine individuals with aviation safety backgrounds were selected as respondents for a questionnaire in which they were asked to rank every SMS component and element of the CASA SMS framework using the scale in Table 8.1. These respondents were asked to indicate the degree of influence they believed each SMS element had on every other element.

Table 8.1: SMS Components and Elements Ranking Score

INTEGER SCALE	INFLUENCE LEVEL
4	Very High
3	High
2	Medium
1	Low
0	No Influence

Using the results obtained, the direct relation/influence matrix **D** for the SMS model dimensions is shown in Figure 8.2.

$$\mathbf{D} = \begin{array}{cc} & \begin{array}{cccc} \mathbf{D_1} & \mathbf{D_2} & \mathbf{D_3} & \mathbf{D_3} \end{array} \\ \begin{array}{c} \mathbf{D_1} \\ \mathbf{D_2} \\ \mathbf{D_3} \\ \mathbf{D_4} \end{array} & \begin{bmatrix} 0 & 3 & 3 & 3 \\ 2 & 0 & 3 & 3 \\ 3 & 3 & 0 & 3 \\ 2 & 3 & 3 & 0 \end{bmatrix} \end{array}$$

Figure 8.2: Direct Relation/Influence Matrix D

Thereafter, the direct/influence matrix **D** was normalised (see Figure 8.3) using equation (7) and the direct relation matrix **T** is then shown on Figure 8.4.

$$\mathbf{D} = \begin{array}{cc} & \begin{array}{cccc} \mathbf{D_1} & \mathbf{D_2} & \mathbf{D_3} & \mathbf{D_3} \end{array} \\ \begin{array}{c} \mathbf{D_1} \\ \mathbf{D_2} \\ \mathbf{D_3} \\ \mathbf{D_4} \end{array} & \begin{bmatrix} 0 & 0.333 & 0.333 & 0.333 \\ 0.222 & 0 & 0.333 & 0.333 \\ 0.223 & 0.333 & 0 & 0.333 \\ 0.222 & 0.333 & 0.333 & 0 \end{bmatrix} \end{array}$$

Figure 8.3: Normalised Direct Relation/Influence Matrix D

$$\mathbf{T} = \begin{array}{cc} & \begin{array}{cccc} \mathbf{D_1} & \mathbf{D_2} & \mathbf{D_3} & \mathbf{D_3} \end{array} \\ \begin{array}{c} \mathbf{D_1} \\ \mathbf{D_2} \\ \mathbf{D_3} \\ \mathbf{D_4} \end{array} & \begin{bmatrix} 3.500 & 4.500 & 4.500 & 4.500 \\ 3.375 & 3.875 & 4.125 & 4.125 \\ 3.750 & 4.500 & 4.250 & 4.500 \\ 3.375 & 4.125 & 4.125 & 3.875 \end{bmatrix} \end{array}$$

Figure 8.4: Direct Relation Matrix T

Using equations (5) and (6), the influences given and received for each component are presented in Table 8.2 with ($R + D$) presenting the effect that is contributed to the system by dimension i, and (D ï R) showing the net effect that dimension i has on the system.

Table 8.2: Total and Net Effects for each SMS Component

Code	Component	*D*	*R*	*(D + R)*	*(D – R)*
D1	Safety Policy, Objectives & Planning	17.000	14.000	31.000	3.000
D2	Safety Risk Management	15.500	17.000	32.500	-1.500
D3	Safety Assurance	17.000	17.000	34.000	0
D4	Safety Training & Promotion	15.500	17.000	32.500	-1.500

The impact direction map (IDM) of the total relationship is plotted and shown in Figure 8.5.

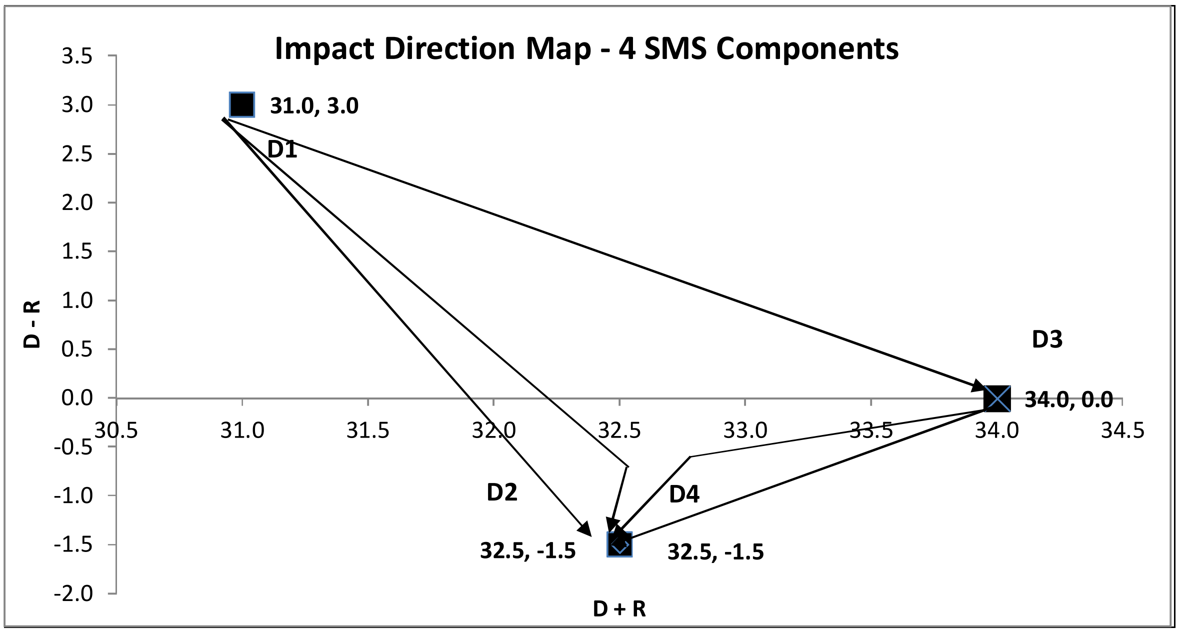

Figure 8.5: Impact Direction Map for CASA SMS Model Components

Based on matrix **T**, the impact relation map (IRM) is then drawn. To simplify the web of causal relationships in **T**, the setting of an appropriate threshold value is needed as a filter for insignificant relationships. A threshold value of 4.468 is chosen as the most appropriate value to acquire a suitable relationship. When the value is above 4.468, the relationship is not obvious and an IRM will be too sparse to draw. If the value is under 4.468, it gains too many factors which result in complex relationships in the whole system. The IRM for the dimensions is shown in Figure 8.6.

Figure 8.6: Impact Relation Map for CASA SMS Model Components

8.6 Finding Relationships of CASA SMS Model Elements

The initial average matrix **A** is a 15 x 15 matrix obtained by pair-wise comparisons of SMS elements in terms of influences and directions between elements. The respondents were asked to indicate and score the influence of each relationship among the elements using the matrix shown on Table 8.1. By calculating the arithmetic average of the respondentsô response as the means of summarising expertsô opinions, the results on Table 8.3 were obtained. By separately calculating the sum of the rows and columns, ***S*** is found to be 55, which is the largest of the sums.

Table 8.3: Initial Average Matrix *A*

Rows	Code	Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
			b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	
			Management Commitment & Responsibility	Safety Accountabilities of Managers	Appointment of Key Safety Personnel	SMS Implementation Plan	Third Party Interfaces	Coordination of the ERP	Documentation	Hazard Identification Processes	Risk Assessment & Mitigation Processes	Safety Performance Monitoring & Measurement	Internal Safety Investigations	The Management of Change	Continuous Improvement of the Safety System	Training & Education	Safety Communication	Total Sum of Row (Influence Given)
1	b	Management Commitment & Responsibility	0	5	5	5	3	3	3	4	4	4	4	4	4	4	4	55
2	c	Safety Accountabilities of Managers	4	0	4	4	4	4	4	4	4	4	4	4	4	4	4	55
3	d	Appointment of Key Safety Personnel	4	4	0	4	3	3	3	4	4	4	4	4	4	4	4	53
4	e	SMS Implementation Plan	3	3	3	0	2	2	3	3	3	3	3	3	3	3	3	39
5	f	Third Party Interfaces	3	3	2	2	0	3	3	3	3	3	3	3	3	3	4	39
6	g	Coordination of the ERP	2	3	3	2	2	0	3	2	2	2	2	2	2	3	3	33
7	h	Documentation	3	3	3	4	3	3	0	4	4	4	3	4	4	4	4	49
8	i	Hazard Identification Processes	3	2	3	3	3	2	3	0	4	4	4	4	4	4	4	48
9	j	Risk Assessment & Mitigation Processes	3	3	3	3	3	3	4	5	0	4	4	4	4	4	4	51
10	k	Safety Performance Monitoring & Measurement	3	4	3	4	3	2	3	3	4	0	4	4	5	4	3	50
11	l	Internal Safety Investigations	3	4	4	2	3	3	4	4	4	4	0	3	4	4	4	48
12	m	The Management of Change	4	4	3	3	3	3	3	3	4	4	3	0	4	4	3	48
13	n	Continuous Improvement of the Safety System	4	4	4	3	3	3	3	4	4	4	3	4	0	4	3	51
14	o	Training & Education	3	4	3	3	3	3	4	4	4	3	4	4	4	0	3	48
15	p	Safety Communication	3	3	2	3	3	3	3	3	3	3	3	4	4	4	0	42
		Total Sum of Column (Influence Received)	44	49	45	44	42	40	45	49	50	50	48	50	52	51	48	

The normalised initial direct relation matrix **D** is obtained by dividing the direct relationship matrix in Table 8.3 by the value of ***S***, as shown in Table 8.4.

Table 8.4: Normalised Initial Direct Relation Matrix *D*

Rows		Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			b	c	d	e	f	g	h	i	j	k	l	m	n	o	p
			Management Commitment & Responsibility	Safety Accountabilities of Managers	Appointment of Key Safety Personnel	SMS Implementation Plan	Third Party Interfaces	Coordination of the ERP	Documentation	Hazard Identification Processes	Risk Assessment & Mitigation Processes	Safety Performance Monitoring & Measurement	Internal Safety Investigations	The Management of Change	Continuous Improvement of the Safety System	Training & Education	Safety Communication
1	b	Management Commitment & Responsibility	0	0.0831	0.0831	0.0857	0.0571	0.0623	0.0545	0.0649	0.0675	0.0727	0.0701	0.0805	0.0753	0.0701	0.0675
2	c	Safety Accountabilities of Managers	0.0675	0	0.0727	0.0727	0.0675	0.0649	0.0675	0.0753	0.0727	0.0805	0.0727	0.0675	0.0701	0.0727	0.0675
3	d	Appointment of Key Safety Personnel	0.0649	0.0727	0	0.0727	0.0571	0.0597	0.0623	0.0675	0.0779	0.0753	0.0753	0.0649	0.0727	0.0675	0.0675
4	e	SMS Implementation Plan	0.0494	0.0545	0.0494	0	0.0364	0.0364	0.0571	0.0519	0.0571	0.0519	0.0519	0.0545	0.0519	0.0519	0.0494
5	f	Third Party Interfaces	0.0468	0.0519	0.0416	0.0364	0	0.0519	0.0545	0.0519	0.0519	0.0571	0.0494	0.0545	0.0519	0.0468	0.0701
6	g	Coordination of the ERP	0.0416	0.0571	0.0519	0.0312	0.0442	0	0.0468	0.0390	0.0390	0.0338	0.0312	0.0416	0.0416	0.0519	0.0468
7	h	Documentation	0.0519	0.0597	0.0571	0.0649	0.0597	0.0571	0	0.0649	0.0675	0.0649	0.0623	0.0727	0.0727	0.0727	0.0675
8	i	Hazard Identification Processes	0.0571	0.0442	0.0571	0.0519	0.0623	0.0442	0.0597	0	0.0753	0.0753	0.0753	0.0649	0.0649	0.0727	0.0649
9	j	Risk Assessment & Mitigation Processes	0.0571	0.0597	0.0571	0.0545	0.0597	0.0494	0.0649	0.0831	0	0.0701	0.0727	0.0779	0.0753	0.0727	0.0649
10	k	Safety Performance Monitoring & Measurement	0.0597	0.0727	0.0623	0.0675	0.0623	0.0390	0.0571	0.0597	0.0701	0	0.0675	0.0701	0.0831	0.0727	0.0571
11	l	Internal Safety Investigations	0.0519	0.0675	0.0649	0.0390	0.0494	0.0494	0.0649	0.0701	0.0753	0.0701	0	0.0519	0.0727	0.0753	0.0675
12	m	The Management of Change	0.0649	0.0727	0.0597	0.0597	0.0519	0.0494	0.0623	0.0623	0.0675	0.0675	0.0468	0	0.0727	0.0675	0.0623
13	n	Continuous Improvement of the Safety System	0.0727	0.0701	0.0649	0.0545	0.0545	0.0494	0.0571	0.0701	0.0753	0.0805	0.0623	0.0727	0	0.0727	0.0623
14	o	Training & Education	0.0597	0.0649	0.0597	0.0571	0.0494	0.0571	0.0649	0.0675	0.0649	0.0571	0.0701	0.0701	0.0675	0	0.0623
15	p	Safety Communication	0.0571	0.0545	0.0442	0.0519	0.0468	0.0494	0.0494	0.0545	0.0545	0.0519	0.0571	0.0701	0.0649	0.0649	0

Dividing the normalised initial direct relation matrix D (Table 8.4) by the formula $T=X(I-X)^{-1}$, the total relation matrix **T** (Table 8.8) is obtained. The values of *D* and *R* (Table 8.9) are obtained by calculating the sum of various rows and columns. A threshold value of 0.49 is chosen: values under 0.49 result in too complex a relationship for the whole system, while the relationship is obscured for values above 0.49. For example, the first row and second column in Table 8.8 is 0.50. This means that *b* will affect *c.*

Table 8.5: Identity Matrix *I*

	Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		b	c	d	e	f	g	h	i	j	k	l	m	n	o	p
		Management Commitment & Responsibility	Safety Accountabilities of Managers	Appointment of Key Safety Personnel	SMS Implementation Plan	Third Party Interfaces	Coordination of the ERP	Documentation	Hazard Identification Processes	Risk Assessment & Mitigation Processes	Safety Performance Monitoring & Measurement	Internal Safety Investigations	The Management of Change	Continuous Improvement of the Safety System	Training & Education	Safety Communication
b	Management Commitment & Responsibility	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	Safety Accountabilities of Managers	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
d	Appointment of Key Safety Personnel	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
e	SMS Implementation Plan	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
f	Third Party Interfaces	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
g	Coordination of the ERP	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
h	Documentation	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
i	Hazard Identification Processes	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
j	Risk Assessment & Mitigation Processes	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
k	Safety Performance Monitoring & Measurement	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
l	Internal Safety Investigations	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
m	The Management of Change	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
n	Continuous Improvement of the Safety System	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
o	Training & Education	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
p	Safety Communication	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 8.6: Matrix of *(I-D)*

1.0000	-0.0831	-0.0831	-0.0857	-0.0571	-0.0623	-0.0545	-0.0649	-0.0675	-0.0727	-0.0701	-0.0805	-0.0753	-0.0701	-0.0675
-0.0675	1.0000	-0.0727	-0.0727	-0.0675	-0.0649	-0.0675	-0.0753	-0.0727	-0.0805	-0.0727	-0.0675	-0.0701	-0.0727	-0.0675
-0.0649	-0.0727	1.0000	-0.0727	-0.0571	-0.0597	-0.0623	-0.0675	-0.0779	-0.0753	-0.0753	-0.0649	-0.0727	-0.0675	-0.0675
-0.0494	-0.0545	-0.0494	1.0000	-0.0364	-0.0364	-0.0571	-0.0519	-0.0571	-0.0519	-0.0519	-0.0545	-0.0519	-0.0519	-0.0494
-0.0468	-0.0519	-0.0416	-0.0364	1.0000	-0.0519	-0.0545	-0.0519	-0.0519	-0.0571	-0.0494	-0.0545	-0.0519	-0.0468	-0.0701
-0.0416	-0.0571	-0.0519	-0.0312	-0.0442	1.0000	-0.0468	-0.0390	-0.0390	-0.0338	-0.0312	-0.0416	-0.0416	-0.0519	-0.0468
-0.0519	-0.0597	-0.0571	-0.0649	-0.0597	-0.0571	1.0000	-0.0649	-0.0675	-0.0649	-0.0623	-0.0727	-0.0727	-0.0727	-0.0675
-0.0571	-0.0442	-0.0571	-0.0519	-0.0623	-0.0442	-0.0597	1.0000	-0.0753	-0.0753	-0.0753	-0.0649	-0.0649	-0.0727	-0.0649
-0.0571	-0.0597	-0.0571	-0.0545	-0.0597	-0.0494	-0.0649	-0.0831	1.0000	-0.0701	-0.0727	-0.0779	-0.0753	-0.0727	-0.0649
-0.0597	-0.0727	-0.0623	-0.0675	-0.0623	-0.0390	-0.0571	-0.0597	-0.0701	1.0000	-0.0675	-0.0701	-0.0831	-0.0727	-0.0571
-0.0519	-0.0675	-0.0649	-0.0390	-0.0494	-0.0494	-0.0649	-0.0701	-0.0753	-0.0701	1.0000	-0.0519	-0.0727	-0.0753	-0.0675
-0.0649	-0.0727	-0.0597	-0.0597	-0.0519	-0.0494	-0.0623	-0.0623	-0.0675	-0.0675	-0.0468	1.0000	-0.0727	-0.0675	-0.0623
-0.0727	-0.0701	-0.0649	-0.0545	-0.0545	-0.0494	-0.0571	-0.0701	-0.0753	-0.0805	-0.0623	-0.0727	1.0000	-0.0727	-0.0623
-0.0597	-0.0649	-0.0597	-0.0571	-0.0494	-0.0571	-0.0649	-0.0675	-0.0649	-0.0571	-0.0701	-0.0701	-0.0675	1.0000	-0.0623
-0.0571	-0.0545	-0.0442	-0.0519	-0.0468	-0.0494	-0.0494	-0.0545	-0.0545	-0.0519	-0.0571	-0.0701	-0.0649	-0.0649	1.0000

Table 8.7: Matrix of $(I\text{-}D)^{-1}$

1.3888	0.5016	0.4749	0.4662	0.4207	0.4060	0.4486	0.4864	0.5038	0.5050	0.4826	0.5134	0.5199	0.5125	0.4836
0.4498	1.4223	0.4636	0.4524	0.4284	0.4065	0.4581	0.4934	0.5061	0.5096	0.4830	0.5000	0.5132	0.5128	0.4818
0.4362	0.4777	1.3842	0.4411	0.4083	0.3916	0.4419	0.4743	0.4978	0.4923	0.4731	0.4849	0.5024	0.4952	0.4694
0.3289	0.3594	0.3356	1.2806	0.3014	0.2871	0.3419	0.3582	0.3736	0.3666	0.3521	0.3703	0.3759	0.3739	0.3521
0.3284	0.3591	0.3303	0.3173	1.2681	0.3032	0.3413	0.3599	0.3707	0.3729	0.3514	0.3724	0.3779	0.3714	0.3730
0.2798	0.3158	0.2947	0.2692	0.2689	1.2150	0.2894	0.3001	0.3092	0.3026	0.2880	0.3109	0.3173	0.3251	0.3043
0.4003	0.4394	0.4129	0.4095	0.3875	0.3675	1.3583	0.4451	0.4608	0.4554	0.4351	0.4642	0.4739	0.4715	0.4430
0.3968	0.4171	0.4048	0.3900	0.3824	0.3486	0.4065	1.3757	0.4589	0.4559	0.4385	0.4485	0.4584	0.4626	0.4323
0.4156	0.4509	0.4239	0.4109	0.3977	0.3699	0.4301	0.4729	1.4100	0.4724	0.4560	0.4808	0.4888	0.4840	0.4523
0.4127	0.4568	0.4232	0.4175	0.3948	0.3559	0.4178	0.4467	0.4694	1.4010	0.4457	0.4679	0.4893	0.4776	0.4395
0.3946	0.4398	0.4140	0.3809	0.3732	0.3555	0.4132	0.4438	0.4614	0.4539	1.3710	0.4396	0.4676	0.4675	0.4368
0.4044	0.4427	0.4078	0.3982	0.3736	0.3539	0.4090	0.4346	0.4522	0.4495	0.4135	1.3881	0.4652	0.4582	0.4300
0.4313	0.4625	0.4331	0.4135	0.3950	0.3717	0.4250	0.4636	0.4821	0.4837	0.4491	0.4786	1.4210	0.4861	0.4519
0.4002	0.4364	0.4084	0.3958	0.3717	0.3614	0.4121	0.4398	0.4508	0.4409	0.4346	0.4539	0.4613	1.3958	0.4308
0.3598	0.3857	0.3554	0.3533	0.3331	0.3203	0.3592	0.3864	0.3981	0.3932	0.3819	0.4109	0.4148	0.4127	1.3308

Table 8.8: Total Relation Matrix *T*

	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	**D**
b	0.39	0.50	0.47	0.47	0.42	0.41	0.45	0.49	0.50	0.51	0.48	0.51	0.52	0.51	0.48	7.11
c	0.45	0.42	0.46	0.45	0.43	0.41	0.46	0.49	0.51	0.51	0.48	0.50	0.51	0.51	0.48	7.08
d	0.44	0.48	0.38	0.44	0.41	0.39	0.44	0.47	0.50	0.49	0.47	0.48	0.50	0.50	0.47	6.87
e	0.33	0.36	0.34	0.28	0.30	0.29	0.34	0.36	0.37	0.37	0.35	0.37	0.38	0.37	0.35	5.16
f	0.33	0.36	0.33	0.32	0.27	0.30	0.34	0.36	0.37	0.37	0.35	0.37	0.38	0.37	0.37	5.20
g	0.28	0.32	0.29	0.27	0.27	0.21	0.29	0.30	0.31	0.30	0.29	0.31	0.32	0.33	0.30	4.39
h	0.40	0.44	0.41	0.41	0.39	0.37	0.36	0.45	0.46	0.46	0.44	0.46	0.47	0.47	0.44	6.42
i	0.40	0.42	0.40	0.39	0.38	0.35	0.41	0.38	0.46	0.46	0.44	0.45	0.46	0.46	0.43	6.28
j	0.42	0.45	0.42	0.41	0.40	0.37	0.43	0.47	0.41	0.47	0.46	0.48	0.49	0.48	0.45	6.62
k	0.41	0.46	0.42	0.42	0.39	0.36	0.42	0.45	0.47	0.40	0.45	0.47	0.49	0.48	0.44	6.52
l	0.39	0.44	0.41	0.38	0.37	0.36	0.41	0.44	0.46	0.45	0.37	0.44	0.47	0.47	0.44	6.31
m	0.40	0.44	0.41	0.40	0.37	0.35	0.41	0.43	0.45	0.45	0.41	0.39	0.47	0.46	0.43	6.28
n	0.43	0.46	0.43	0.41	0.39	0.37	0.43	0.46	0.48	0.48	0.45	0.48	0.42	0.49	0.45	6.65
o	0.40	0.44	0.41	0.40	0.37	0.36	0.41	0.44	0.45	0.44	0.43	0.45	0.46	0.40	0.43	6.29
p	0.36	0.39	0.36	0.35	0.33	0.32	0.36	0.39	0.40	0.39	0.38	0.41	0.41	0.41	0.33	5.60
R	5.83	6.37	5.97	5.80	5.50	5.21	5.95	6.38	6.60	6.55	6.26	6.58	6.75	6.71	6.31	

To find the values of $(D + R)$ and $(D - R)$, the D value and R value are rearranged in the relationship matrix of the total criterion effect (direct/indirect) as in Table 8.4 (sorted in a descending order from the largest to smallest number for $D + R$) according to the order of each element in Table 8.9.

Table 8.9: Sum of Influences Given and Received on Elements of the SMS Model

				Importance	Causal relation	
		D	**R**	**D+R**	**D-R**	**Group**
Safety Accountabilities of Managers	c	7.0811	6.3670	13.4481	0.7141	Cause
Continuous Improvement of the Safety System	n	6.6483	6.7470	13.3953	-0.0987	Effect
Risk Assessment & Mitigation Processes	j	6.6163	6.6050	13.2213	0.0113	Cause
Safety Performance Monitoring & Measurement	k	6.5159	6.5549	13.0708	-0.0390	Effect
Training & Education	o	6.2940	6.7070	13.0010	-0.4130	Effect
Management Commitment & Responsibility	b	7.1143	5.8276	12.9419	1.2867	Cause
The Management of Change	m	6.2808	6.5843	12.8651	-0.3035	Effect
Appointment of Key Safety Personnel	d	6.8703	5.9669	12.8372	0.9034	Cause
Hazard Identification Processes	i	6.2768	6.3809	12.6577	-0.1041	Effect
Internal Safety Investigations	l	6.3126	6.2556	12.5682	0.0570	Cause
Documentation	h	6.4245	5.9523	12.3768	0.4722	Cause
Safety Communication	p	5.5955	6.3117	11.9072	-0.7162	Effect
SMS Implementation Plan	e	5.1577	5.7964	10.9541	-0.6387	Effect
Third Party Interfaces	f	5.1972	5.5048	10.7020	-0.3076	Effect
Coordination of the ERP	g	4.3902	5.2140	9.6042	-0.8238	Effect

The impact direction map (Figure 8.7) is plotted using the coordinate values of each criterion into a scatter plot with the horizontal axis ($D + R$) and the vertical axis ($D – R$). The lines with arrows are used to indicate the direction of the relationship of the criteria that have matrix values higher than the threshold value. Using the results in Table 8.9, the cause and effect of the SMS elements are plotted in Figure 8.8.

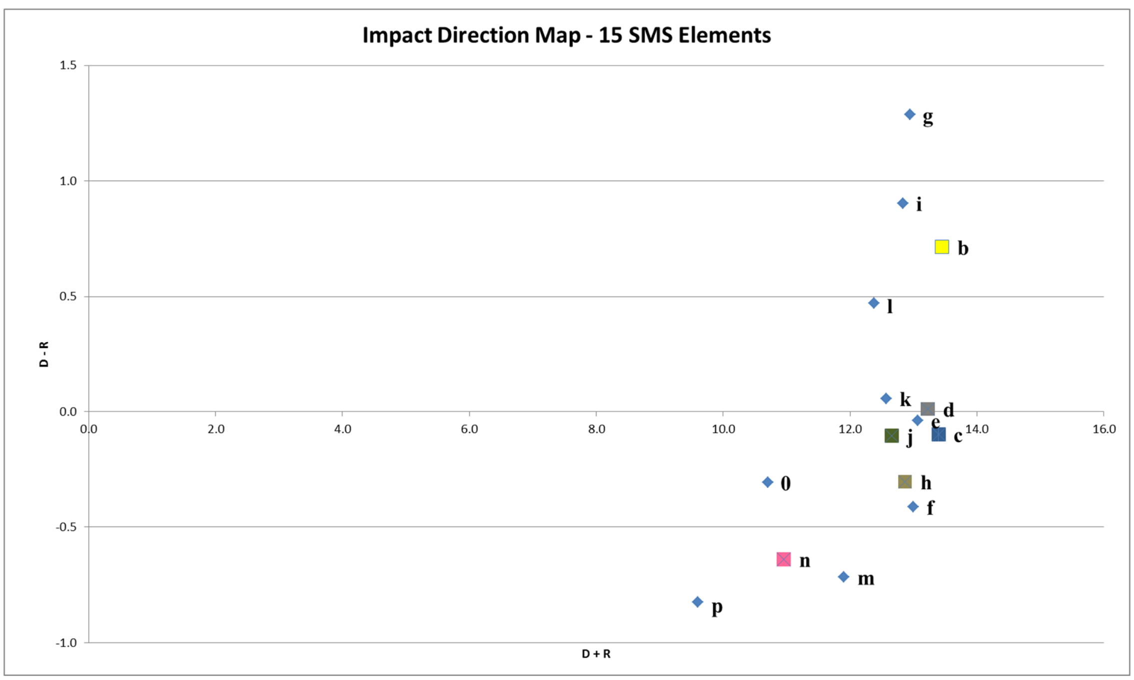

Figure 8.7: Impact Direction Map for SMS Elements

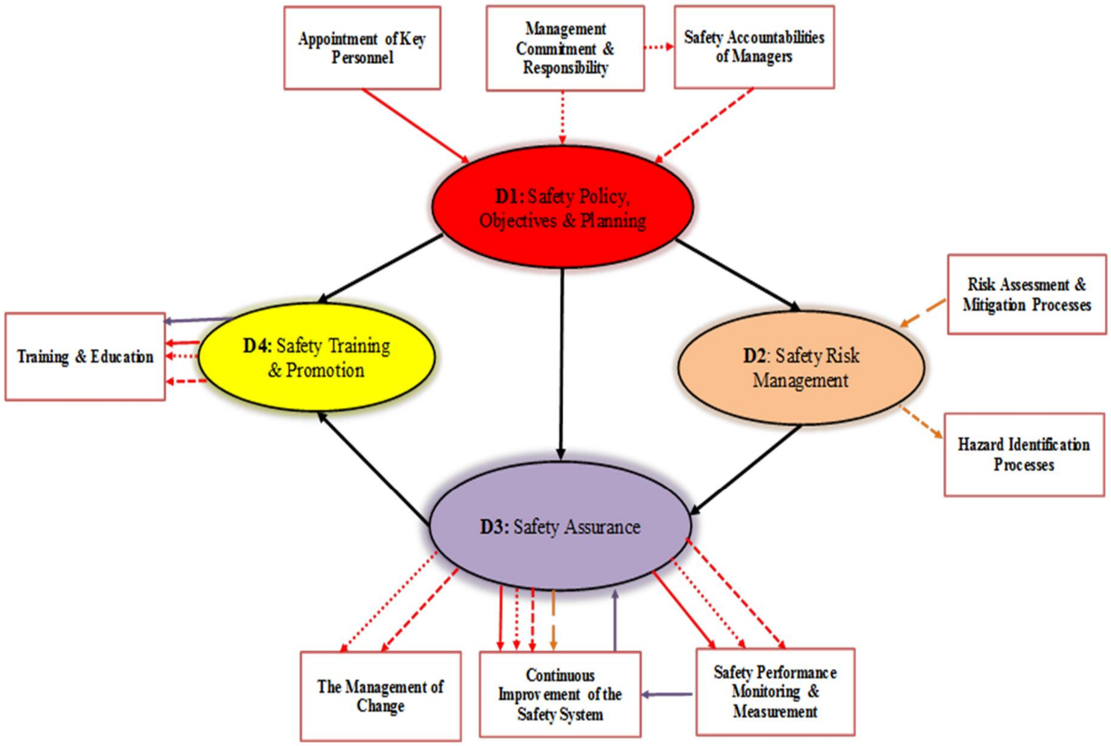

Figure 8.8: Impact Relation Map for CASA SMS Model Elements

The resultant IRM for an effective SMS is illustrated in Figure 8.8, and using equations (5) and (6), the sum of influences given and received for each factor are shown in Table 8.9 with (D + R) representing the effect that is contributed by the factor to the system and (D – R) showing the net effect that the factor has on the system. When the (D + R) value is graphed on the horizontal axis and the (D – R) value on the vertical axis, the impact direction map, shown on Figure 8.7, is created.

The SMS dimension at the top of the IRM is ósafety policy, objectives and planningô and the SMS components are óappointment of key personnelô, ómanagement commitment and responsibilityô and ósafety accountabilities of managersô. The SMS dimension to the left is ósafety training and promotionô with the SMS component ótraining & educationô. To the right is the SMS dimension ósafety risk managementô with the SMS components óhazard identification processesô and órisk assessment & mitigation processesô. At the bottom of the IRM is the SMS dimension ósafety assuranceô with SMS components of ómanagement of changeô, ócontinuous improvement of the safety systemô and ósafety performance monitoring & measurementô.

In addition, the discrete factors within the IRM can be scrutinised using Table 8.9 and the IDM in Figure 8.7. The factors are grouped together in Table 8.10 below to enable easier viewing.

Table 8.10: Group/Factors with their Total Effects and Net Effects

	D+R		***D-R***	
SAFETY POLICY, OBJECTIVES & PLANNING				
Appointment of Key Safety Personnel	12.8372	(8)	0.9034	(2)
Management Commitment & Responsibility	12.9419	(6)	1.2867	(1)
Safety Accountabilities of Managers	13.4481	(1)	0.7141	(3)
SAFETY TRAINING & PROMOTION				
Training & Education	13.001	(5)	-0.413	(9)
SAFETY RISK MANAGEMENT				
Risk Assessment & Mitigation Processes	13.2213	(3)	0.0113	(4)
Hazard Identification Processes	12.6577	(9)	-0.1041	(7)
SAFETY ASSURANCE				
Continuous Improvement of the Safety System	13.3953	(2)	-0.0987	(6)
Safety Performance Monitoring & Measurement	13.0708	(4)	-0.039	(5)
Management of Change	12.8651	(7)	-0.3035	(8)

Firstly, ósafety assuranceô has the highest positive $D + R$ suggesting that it is the largest net generator of effects, has a large effect on the system and plays the most significant role in the safety management system (SMS). Therefore, the SMS components in this dimension should be a priority for improvement. However, the $D - R$ values of this dimension are also strongly negative meaning that it is also affected by the other factors in a big way.

Secondly, the ósafety policy, objectives & planningô group has the second highest $D + R$ value. Unlike the components in the ósafety assuranceô group that can be viewed as the net initiators for higher safety, the SMS components in this SMS dimension are the net multipliers that tie the system together and propagate the improvements from one component to the rest of the system. The implication for the organisation is that they should ensure that the safety accountabilities of managers; management commitment and responsibility; and appointment of key personnel are effective and efficient to tie the various components together within the SMS model.

Thirdly, the components in the ósafety risk managementô group have a moderate $D + R$ value, but their $D - R$ values are negative and close to zero. This means that the components have a moderate effect on the SMS but are also affected by the other factors. They are the net receivers and should be ranked lower in management priority.

Finally, the SMS dimension, ósafety training and promotionô, has the lowest positive $D + R$ value. This suggests it is the lowest generator of effects. The $D - R$ values are negative and close to zero. This means that the components have a low effect on the SMS but are also affected by the other factors. They are the net receivers and should be ranked lowest in management priority.

8.7 Conclusions

The DEMATEL method is shown to be an asset in providing a visualisation of the structural relationships and identifying key components in an SMS framework. In addition, the DEMATEL method can be used to identify the net initiating factors and the net multiplier factors of an SMS to assist management in the prioritisation of its components. The impact direction map (IDM) shows that ósafety assuranceô plays the most important role in an effective SMS and that the components of continuous improvement of the safety system, safety performance monitoring and measurement as well as management of change have the highest net influence over all the other factors.

Chapter 9 Conclusions

One of the key objectives of this study was to determine the impact on safety performance for commercial aviation operations of the implementation of safety management systems (SMSs). The benefits to be gained with the implementation of an effective SMS have been proposed by many civil aviation regulators from ICAO member states such as Australia, Singapore, Canada and the United Kingdom (UK). As reported by Thomas (2012), even though Australiaôs transport industriesô SMS approach is following worldôs best practice, little empirical research evidence has been presented to determine the impact on safety of a structured safety management system (SMS).

Organisations with a certified SMS had significantly lower accident rates but there was a lack of agreement about which components of an SMS individually contributed the most to safety performance (Thomas, 2012). There was also a general lack of consistency across which elements of an SMS affected safety the most (Thomas, 2012). To this end, this study sought to determine the impact of SMSs on safety performance for commercial aviation operations using two case studies. The first case study looked at SMSs within the general aviation/charter operation sector and the second case study reviewed SMSs for the airline sector of the industry.

The study began with a review of the evolution of aviation safety, and of approaches taken to implement, improve and enhance safety in safety-critical industries such as aviation, nuclear, marine, rail and petrochemical. Safety management systems (SMSs) have been identified as a contemporary and effective tool in enhancing safety as opposed to a purely prescriptive regulatory regime.

This study then identified the variations between the ICAO SMS model and the variations as adopted by some of the ICAO member states. The experience of implementing an SMS in Australia was reviewed for regular public transport or airline-type operations together with a review of the independent ANAO post-SMS implementation audit to seek out lessons learnt and recommendations for continuous improvements.

The hypothesis tested with the conduct of two case studies was that SMSs improve the safety performance of commercial aviation operations.

The first case study involved an analysis of de-identified FSF audit findings from their BARS program for their customers operating in the general aviation/charter sector of the industry. A total of 7,625 audit findings were reviewed between the periods from 2011ï 2014 for the sampled population of 117 operators. Although the determination of safety performance was not possible for this sample population using the conventional metric of accident rates owing to the unavailability of flight departures data, one can still infer that safety performance has improved over time when the data show that in 2013, there was a uniform decrease in the number of audit findings for all four disciplines, that is, flight operations, airworthiness, ground operations and safety management system (SMS). This was despite the fact that 2013 saw the most audits conducted for the sample population in a year. A plausible explanation for this phenomenon is the improvement in safety performance for these operators as a consequence of the maturity of the implemented SMS, leading to better compliance with regulations and standards. This can be supported by the result of the correlation analysis conducted as part of this study that indicated a strong positive relationship exists between the number of audits conducted and the number of audit findings made.

For the second case study, a review was conducted of aviation SMSs and the measurement of safety performance for the sampled population of operators involved with airline-type operations in Australia. This case study revealed using a pre- and post-SMS test measure over the period from 2006ï 2013 that safety performance has improved with safety management systems (SMSs).

In addition, various correlation analyses were conducted in both case studies to determine the relationships, significance and effects that SMS, airworthiness, flight operations, ground handling audit findings, the number of accidents and the safety reports to the ATSB have on each other.

The results show a moderate to strong positive relationship between the number of SMS and flight operations audit findings. As for SMS and airworthiness, the results suggest that this is a weak to moderate positive relationship. The relationship between SMS and ground handling is a moderate positive one. A strong positive relationship exists between the number of audits conducted and the number of audit findings made and there is a moderate positive relationship between airworthiness and flight operations audit findings.

In conclusion, the use of the DEMATEL method to test the CASA SMS framework and define its critical dimensions and components has the real advantage of providing a visualisation of the structural relationships and identifying key components in an SMS framework. Moreover, this method has shown that it can identify the net initiating factors and the net multiplier factors of an SMS to assist management in the prioritisation of its components. A key output from the DEMATEL tool is that the impact direction map (IDM) shows that the SMS dimension, safety assurance, plays the most critical role in an effective SMS and its associated sub-components of continuous improvement of the safety system, safety performance monitoring and measurement as well as management of change have the highest net influence over all the other SMS factors.

Chapter 10 Recommendations

To further investigate the impact of SMSs on safety performance for other sectors of the aviation industry for which SMSs are progressively mandated, for example, charter operations, general aviation operations, maintenance organisations and remotely piloted drones, a number of recommendations are made:

- Carry on refining and developing new safety performance indicators that can quantitatively measure safety performance on a real-time and continuous basis.
- Continue to develop and enhance the DEMATEL method for assessing the CASA and other SMS frameworks with the use of the DEMATEL method along with multiple criteria decision-making (MCDM) methods or the analytic network process (ANP) to develop a hybrid model that can also capture the weights of the effects and the influence that the individual components have on each other and on the SMS as a whole.
- Undertake a study to determine the application of the DEMATEL method or a hybrid DEMATEL process for assessment of the framework for the other main aviation technical disciplines, that is, airworthiness, flight operations, ground operations, cabin safety, human factors (HF) and dangerous goods.

It is proposed that each of the above recommendations would add value and significant contributions to the management of safety outcomes for aviation regulators as well as operators. Whilst recognising the limitations of any research studies and proposals, the recommendations if undertaken could potentially point to other areas of opportunities for safety research and increased understanding of safety management systems (SMSs).

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Appendices

Appendix 1: Case Study 1 – Breakdown of Audit Findings for Operators

Operator 1					
1	2011	2012	2013	2014	TOTAL
AW	1	5	2	0	8
FLT	2	6	2	2	12
GH	1	4	0	0	5
SMS	4	8	0	0	12

Operator 2					
2	2011	2012	2013	2014	TOTAL
AW	21	11	4	0	36
FLT	23	11	14	0	48
GH	3	0	2	0	5
SMS	16	11	3	0	30

Operator 3					
3	2011	2012	2013	2014	TOTAL
AW	10	2	10	0	22
FLT	0	7	5	0	12
GH	3	1	0	0	4
SMS	6	5	3	0	14

Operator 4					
4	2011	2012	2013	2014	TOTAL
AW	1	0	2	0	3
FLT	4	0	11	0	15
GH	1	0	1	0	2
SMS	1	4	0	0	5

Operator 5					
5	2011	2012	2013	2014	TOTAL
AW	0	0	2	0	2
FLT	0	0	2	0	2
GH	0	0	0	0	0
SMS	0	0	1	0	1

Operator 6					
6	2011	2012	2013	2014	TOTAL
AW	0	1	0	0	1
FLT	0	1	0	0	1
GH	0	0	0	0	0
SMS	0	0	0	0	0

Operator 7					
7	2011	2012	2013	2014	TOTAL
AW	0	6	0	0	6
FLT	0	0	0	0	0
GH	0	1	0	0	1
SMS	0	2	0	0	2

Operator 8					
8	2011	2012	2013	2014	TOTAL
AW	0	0	0	0	0
FLT	0	0	1	0	1
GH	0	0	3	0	3
SMS	0	0	2	0	2

Operator 9					
9	2011	2012	2013	2014	TOTAL
AW	9	0	0	0	9
FLT	3	2	0	0	5
GH	0	1	0	0	1
SMS	4	0	0	0	4

Operator 10					
10	2011	2012	2013	2014	TOTAL
AW	6	0	0	0	6
FLT	6	0	0	0	6
GH	0	0	0	0	0
SMS	2	0	0	0	2

Operator 11					
11	2011	2012	2013	2014	TOTAL
AW	8	0	0	0	8
FLT	0	0	0	0	0
GH	1	0	0	0	1
SMS	2	0	0	0	2

Operator 12					
12	2011	2012	2013	2014	TOTAL
AW	7	0	3	0	10
FLT	2	0	4	0	6
GH	0	0	3	0	3
SMS	1	0	1	0	2

Operator 13					
13	2011	2012	2013	2014	TOTAL
AW	0	0	1	0	1
FLT	0	0	11	0	11
GH	0	0	0	0	0
SMS	0	0	1	0	1

Operator 14					
14	2011	2012	2013	2014	TOTAL
AW	6	0	0	0	6
FLT	0	1	0	0	1
GH	0	0	0	0	0
SMS	0	0	0	0	0

Operator 15					
15	2011	2012	2013	2014	TOTAL
AW	0	0	0	0	0
FLT	0	2	0	0	2
GH	0	0	0	0	0
SMS	0	4	0	0	4

Operator 16					
16	2011	2012	2013	2014	TOTAL
AW	12	2	2	0	16
FLT	56	6	2	0	64
GH	1	3	0	0	4
SMS	8	4	1	0	13

Operator 17					
17	2011	2012	2013	2014	TOTAL
AW	17	0	0	0	17
FLT	63	1	0	0	64
GH	5	0	0	0	5
SMS	4	0	0	0	4

Operator 18					
18	2011	2012	2013	2014	TOTAL
AW	4	1	0	0	5
FLT	9	1	0	0	10
GH	0	0	0	0	0
SMS	19	2	0	0	21

Operator 19					
19	2011	2012	2013	2014	TOTAL
AW	0	0	1	0	1
FLT	0	0	0	0	0
GH	0	0	0	0	0
SMS	0	0	1	0	1

Operator 20					
20	2011	2012	2013	2014	TOTAL
AW	0	7	0	0	7
FLT	0	3	0	0	3
GH	0	11	0	0	11
SMS	0	3	0	0	3

Operator 21					
21	2011	2012	2013	2014	TOTAL
AW	0	9	0	2	11
FLT	0	0	7	1	8
GH	0	0	6	1	7
SMS	0	0	6	0	6

Operator 22					
22	2011	2012	2013	2014	TOTAL
AW	5	0	0	0	5
FLT	15	0	0	0	15
GH	5	0	0	0	5
SMS	13	0	0	0	13

Operator 23					
23	2011	2012	2013	2014	TOTAL
AW	0	0	1	0	1
FLT	0	3	0	0	3
GH	0	0	0	0	0
SMS	0	0	0	0	0

Operator 24					
24	2011	2012	2013	2014	TOTAL
AW	8	6	0	0	14
FLT	4	2	1	0	7
GH	3	4	0	0	7
SMS	5	6	0	0	11

Operator 25					
25	2011	2012	2013	2014	TOTAL
AW	0	0	12	0	12
FLT	0	0	11	0	11
GH	0	0	2	0	2
SMS	0	0	14	0	14

Operator 26					
26	2011	2012	2013	2014	TOTAL
AW	0	7	5	5	17
FLT	0	16	29	15	60
GH	0	2	1	0	3
SMS	0	7	5	4	16

Operator 27					
27	2011	2012	2013	2014	TOTAL
AW	0	0	3	3	6
FLT	0	0	7	4	11
GH	0	0	2	0	2
SMS	0	0	9	0	9

Operator 28					
28	2011	2012	2013	2014	TOTAL
AW	0	2	0	0	2
FLT	0	18	0	0	18
GH	0	1	0	0	1
SMS	0	10	0	0	10

Operator 29					
29	2011	2012	2013	2014	TOTAL
AW	0	1	0	0	1
FLT	0	0	0	0	0
GH	0	0	0	0	0
SMS	0	0	0	0	0

Operator 30					
30	2011	2012	2013	2014	TOTAL
AW	11	0	0	0	11
FLT	4	5	0	0	9
GH	11	0	0	0	11
SMS	4	1	0	0	5

Operator 31					
31	2011	2012	2013	2014	TOTAL
AW	0	3	0	0	3
FLT	0	3	0	0	3
GH	0	1	0	0	1
SMS	0	0	0	0	0

Operator 32					
32	2011	2012	2013	2014	TOTAL
AW	0	16	6	2	24
FLT	0	9	4	6	19
GH	0	3	1	2	6
SMS	0	7	4	0	11

Operator 33					
33	2011	2012	2013	2014	TOTAL
AW	0	0	3	0	3
FLT	0	0	6	0	6
GH	0	0	0	0	0
SMS	0	0	6	0	6

Operator 34					
34	2011	2012	2013	2014	TOTAL
AW	0	10	0	0	10
FLT	21	7	0	0	28
GH	4	1	0	0	5
SMS	16	12	0	0	28

Operator 35					
35	2011	2012	2013	2014	TOTAL
AW	0	10	0	0	10
FLT	21	7	0	0	28
GH	4	1	0	0	5
SMS	16	12	0	0	28

Operator 36					
36	2011	2012	2013	2014	TOTAL
AW	13	0	0	0	13
FLT	53	0	0	0	53
GH	15	0	0	0	15
SMS	60	0	0	0	60

Operator 37					
37	2011	2012	2013	2014	TOTAL
AW	0	0	20	9	29
FLT	0	0	10	5	15
GH	0	0	1	1	2
SMS	0	0	14	10	24

Operator 38					
38	2011	2012	2013	2014	TOTAL
AW	0	0	0	0	0
FLT	0	3	3	0	6
GH	0	0	0	0	0
SMS	0	1	0	0	1

Operator 39					
39	2011	2012	2013	2014	TOTAL
AW	1	0	0	0	1
FLT	0	0	0	0	0
GH	0	0	0	0	0
SMS	0	0	0	0	0

Operator 40					
40	2011	2012	2013	2014	TOTAL
AW	16	3	6	14	39
FLT	7	10	27	12	56
GH	0	1	0	0	1
SMS	1	0	0	0	1

Operator 41					
41	2011	2012	2013	2014	TOTAL
AW	14	3	9	0	26
FLT	34	4	1	0	39
GH	1	0	0	0	1
SMS	20	0	0	0	20

Operator 42					
42	2011	2012	2013	2014	TOTAL
AW	0	0	5	0	5
FLT	0	0	10	0	10
GH	0	0	0	0	0
SMS	0	0	6	0	6

Operator 43					
43	2011	2012	2013	2014	TOTAL
AW	15	0	0	0	15
FLT	42	0	0	0	42
GH	5	0	0	0	5
SMS	18	0	0	0	18

Operator 44					
44	2011	2012	2013	2014	TOTAL
AW	0	0	7	1	8
FLT	0	9	4	6	19
GH	0	1	0	0	1
SMS	0	9	2	4	15

Operator 45					
45	2011	2012	2013	2014	TOTAL
AW	3	0	0	0	3
FLT	43	0	0	0	43
GH	1	0	0	0	1
SMS	3	0	0	0	3

Operator 46					
46	2011	2012	2013	2014	TOTAL
AW	0	4	0	0	4
FLT	0	1	0	0	1
GH	0	0	0	0	0
SMS	0	6	0	0	6

Operator 47					
47	2011	2012	2013	2014	TOTAL
AW	1	2	5	0	8
FLT	1	13	20	0	34
GH	0	1	2	0	3
SMS	2	1	2	0	5

Operator 48					
48	2011	2012	2013	2014	TOTAL
AW	11	16	0	0	27
FLT	6	17	0	0	23
GH	1	5	0	0	6
SMS	6	15	0	0	21

Operator 49					
49	2011	2012	2013	2014	TOTAL
AW	11	3	2	0	16
FLT	6	28	14	0	48
GH	0	2	2	0	4
SMS	0	5	4	0	9

Operator 50					
50	2011	2012	2013	2014	TOTAL
AW	0	0	1	0	1
FLT	0	0	1	0	1
GH	0	0	0	0	0
SMS	0	0	4	0	4

Operator 51					
51	2011	2012	2013	2014	TOTAL
AW	14	23	0	0	37
FLT	25	15	1	0	41
GH	4	4	0	0	8
SMS	16	18	0	0	34

Operator 52					
52	2011	2012	2013	2014	TOTAL
AW	0	1	0	5	6
FLT	0	7	0	3	10
GH	0	0	0	1	1
SMS	0	1	0	0	1

Operator 53					
53	2011	2012	2013	2014	TOTAL
AW	23	18	3	0	44
FLT	46	34	8	0	88
GH	3	3	0	0	6
SMS	11	7	1	0	19

Operator 54					
54	2011	2012	2013	2014	TOTAL
AW	0	29	0	0	29
FLT	0	55	0	0	55
GH	0	4	0	0	4
SMS	0	16	0	0	16

Operator 55					
55	2011	2012	2013	2014	TOTAL
AW	21	0	7	4	32
FLT	26	0	18	8	52
GH	10	0	2	0	12
SMS	27	0	9	5	41

Operator 56					
56	2011	2012	2013	2014	TOTAL
AW	0	53	18	0	71
FLT	0	40	19	0	59
GH	0	11	5	0	16
SMS	0	29	18	0	47

Operator 57					
57	2011	2012	2013	2014	TOTAL
AW	12	2	3	0	17
FLT	14	19	25	0	58
GH	5	1	0	0	6
SMS	4	3	0	0	7

Operator 58					
58	2011	2012	2013	2014	TOTAL
AW	0	0	2	0	2
FLT	0	0	2	0	2
GH	0	0	1	0	1
SMS	0	0	0	0	0

Operator 59					
59	2011	2012	2013	2014	TOTAL
AW	0	0	8	0	8
FLT	3	0	21	0	24
GH	4	0	1	0	5
SMS	9	0	1	0	10

Operator 60					
60	2011	2012	2013	2014	TOTAL
AW	0	8	0	0	8
FLT	0	4	3	0	7
GH	0	5	0	0	5
SMS	0	22	5	0	27

Operator 61					
61	2011	2012	2013	2014	TOTAL
AW	13	17	1	1	32
FLT	74	6	6	3	89
GH	5	2	5	2	14
SMS	25	9	3	0	37

Operator 62					
62	2011	2012	2013	2014	TOTAL
AW	11	0	0	0	11
FLT	25	0	0	0	25
GH	4	0	0	0	4
SMS	9	0	0	0	9

Operator 63					
63	2011	2012	2013	2014	TOTAL
AW	30	4	0	0	34
FLT	3	0	0	0	3
GH	0	0	0	0	0
SMS	15	0	0	0	15

Operator 64					
64	2011	2012	2013	2014	TOTAL
AW	24	4	1	0	29
FLT	15	3	10	0	28
GH	1	2	2	0	5
SMS	13	7	4	0	24

Operator 65					
65	2011	2012	2013	2014	TOTAL
AW	0	0	0	0	0
FLT	0	0	4	0	4
GH	0	0	0	0	0
SMS	0	0	4	0	4

Operator 66					
66	2011	2012	2013	2014	TOTAL
AW	15	8	1	0	24
FLT	0	1	2	0	3
GH	1	0	0	0	1
SMS	3	1	1	0	5

Operator 67					
67	2011	2012	2013	2014	TOTAL
AW	0	0	0	0	0
FLT	0	0	0	0	0
GH	0	0	0	0	0
SMS	0	0	0	10	10

Operator 68					
68	2011	2012	2013	2014	TOTAL
AW	0	2	0	0	2
FLT	0	3	1	0	4
GH	0	4	0	0	4
SMS	0	4	1	0	5

Operator 69					
69	2011	2012	2013	2014	TOTAL
AW	0	4	0	0	4
FLT	0	0	3	0	3
GH	0	0	1	0	1
SMS	0	0	0	0	0

Operator 70					
70	2011	2012	2013	2014	TOTAL
AW	7	0	2	0	9
FLT	9	0	1	0	10
GH	1	0	0	0	1
SMS	1	5	5	0	11

Operator 71					
71	2011	2012	2013	2014	TOTAL
AW	9	0	0	0	9
FLT	4	0	0	0	4
GH	8	0	0	0	8
SMS	2	0	0	0	2

Operator 72					
72	2011	2012	2013	2014	TOTAL
AW	17	0	0	0	17
FLT	11	0	0	0	11
GH	2	0	0	0	2
SMS	37	0	0	0	37

Operator 73					
73	2011	2012	2013	2014	TOTAL
AW	11	2	6	0	19
FLT	25	4	2	0	31
GH	5	3	0	0	8
SMS	36	7	7	0	50

Operator 74					
74	2011	2012	2013	2014	TOTAL
AW	0	0	0	0	0
FLT	2	0	0	0	2
GH	0	0	0	0	0
SMS	0	0	0	0	0

Operator 75					
75	2011	2012	2013	2014	TOTAL
AW	10	5	0	0	15
FLT	23	5	0	0	28
GH	5	0	0	0	5
SMS	14	3	0	0	17

Operator 76					
76	2011	2012	2013	2014	TOTAL
AW	13	10	14	0	37
FLT	21	12	10	0	43
GH	5	5	4	0	14
SMS	42	11	10	0	63

Operator 77					
77	2011	2012	2013	2014	TOTAL
AW	0	0	12	3	15
FLT	0	0	34	42	76
GH	0	0	8	18	26
SMS	0	0	14	20	34

Operator 78					
78	2011	2012	2013	2014	TOTAL
AW	12	13	7	7	39
FLT	52	37	1	8	98
GH	5	3	0	5	13
SMS	35	21	5	7	68

Operator 79					
79	2011	2012	2013	2014	TOTAL
AW	4	5	0	0	9
FLT	21	11	2	0	34
GH	0	13	0	0	13
SMS	28	6	1	0	35

Operator 80					
80	2011	2012	2013	2014	TOTAL
AW	0	7	11	0	18
FLT	0	20	7	0	27
GH	0	4	5	0	9
SMS	0	24	18	0	42

Operator 81					
81	2011	2012	2013	2014	TOTAL
AW	0	13	21	13	47
FLT	0	50	13	6	69
GH	0	9	0	0	9
SMS	0	34	9	6	49

Operator 82					
82	2011	2012	2013	2014	TOTAL
AW	12	0	0	0	12
FLT	28	0	0	0	28
GH	0	0	0	0	0
SMS	6	0	0	0	6

Operator 83					
83	2011	2012	2013	2014	TOTAL
AW	13	10	13	0	36
FLT	20	12	18	0	50
GH	13	5	6	0	24
SMS	11	10	10	0	31

Operator 84					
84	2011	2012	2013	2014	TOTAL
AW	1	5	0	0	6
FLT	16	26	0	0	42
GH	1	1	0	0	2
SMS	11	8	0	0	19

Operator 85					
85	2011	2012	2013	2014	TOTAL
AW	9	17	4	0	30
FLT	20	9	9	0	38
GH	6	2	0	0	8
SMS	17	4	3	0	24

Operator 86					
86	2011	2012	2013	2014	TOTAL
AW	0	0	5	0	5
FLT	0	0	18	0	18
GH	0	0	2	0	2
SMS	0	0	8	0	8

Operator 87					
87	2011	2012	2013	2014	TOTAL
AW	20	0	0	0	20
FLT	21	0	0	0	21
GH	1	0	0	0	1
SMS	3	0	0	0	3

Operator 88					
88	2011	2012	2013	2014	TOTAL
AW	16	0	0	0	16
FLT	9	0	0	0	9
GH	0	0	0	0	0
SMS	16	0	0	0	16

Operator 89					
89	2011	2012	2013	2014	TOTAL
AW	0	0	7	0	7
FLT	0	0	15	0	15
GH	0	0	0	0	0
SMS	0	0	8	0	8

Operator 90					
90	2011	2012	2013	2014	TOTAL
AW	0	10	7	0	17
FLT	0	25	1	0	26
GH	0	7	2	0	9
SMS	0	21	7	0	28

Operator 91					
91	2011	2012	2013	2014	TOTAL
AW	41	23	0	0	64
FLT	75	8	0	0	83
GH	12	4	0	0	16
SMS	20	12	0	0	32

Operator 92					
92	2011	2012	2013	2014	TOTAL
AW	23	13	2	0	38
FLT	10	17	0	0	27
GH	9	3	1	0	13
SMS	4	10	1	0	15

Operator 93					
93	2011	2012	2013	2014	TOTAL
AW	22	7	4	0	33
FLT	26	12	11	0	49
GH	12	2	1	0	15
SMS	33	13	0	0	46

Operator 94					
94	2011	2012	2013	2014	TOTAL
AW	14	23	5	0	42
FLT	48	27	16	0	91
GH	17	4	2	0	23
SMS	25	13	3	0	41

Operator 95					
95	2011	2012	2013	2014	TOTAL
AW	32	0	19	9	60
FLT	66	0	24	19	109
GH	7	0	3	0	10
SMS	27	0	15	6	48

Operator 96					
96	2011	2012	2013	2014	TOTAL
AW	0	18	0	0	18
FLT	0	33	0	0	33
GH	0	12	0	0	12
SMS	0	15	0	0	15

Operator 97					
97	2011	2012	2013	2014	TOTAL
AW	0	0	0	0	0
FLT	5	0	0	0	5
GH	0	0	0	0	0
SMS	2	0	0	0	2

Operator 98					
98	2011	2012	2013	2014	TOTAL
AW	0	12	0	0	12
FLT	0	28	0	0	28
GH	0	4	0	0	4
SMS	0	15	0	0	15

Operator 99					
99	2011	2012	2013	2014	TOTAL
AW	0	0	22	0	22
FLT	0	0	54	0	54
GH	0	0	10	0	10
SMS	0	0	14	0	14

Operator 100					
100	2011	2012	2013	2014	TOTAL
AW	0	0	12	0	12
FLT	0	0	25	0	25
GH	0	0	1	0	1
SMS	0	0	9	0	9

Operator 101					
101	2011	2012	2013	2014	TOTAL
AW	0	49	6	13	68
FLT	0	9	0	11	20
GH	0	3	1	3	7
SMS	0	11	0	9	20

Operator 102					
102	2011	2012	2013	2014	TOTAL
AW	7	0	0	0	7
FLT	4	0	0	0	4
GH	0	0	0	0	0
SMS	8	0	0	0	8

Operator 103					
103	2011	2012	2013	2014	TOTAL
AW	5	28	2	3	38
FLT	17	4	6	0	27
GH	1	3	0	0	4
SMS	7	10	1	1	19

Operator 104					
104	2011	2012	2013	2014	TOTAL
AW	33	0	14	0	47
FLT	25	0	15	2	42
GH	2	1	3	0	6
SMS	25	0	26	4	55

Operator 105					
105	2011	2012	2013	2014	TOTAL
AW	0	0	0	25	25
FLT	0	0	0	9	9
GH	0	0	0	6	6
SMS	0	0	0	12	12

Operator 106					
106	2011	2012	2013	2014	TOTAL
AW	23	0	0	0	23
FLT	96	0	0	0	96
GH	10	0	0	0	10
SMS	69	0	0	0	69

Operator 107					
107	2011	2012	2013	2014	TOTAL
AW	0	0	0	4	4
FLT	0	0	0	16	16
GH	0	0	0	0	0
SMS	0	0	0	5	5

Operator 108					
108	2011	2012	2013	2014	TOTAL
AW	0	0	7	0	7
FLT	0	0	1	0	1
GH	0	0	0	0	0
SMS	0	0	9	0	9

Operator 109					
109	2011	2012	2013	2014	TOTAL
AW	0	2	25	3	30
FLT	0	4	3	8	15
GH	0	1	3	1	5
SMS	0	0	16	11	27

Operator 110					
110	2011	2012	2013	2014	TOTAL
AW	0	7	14	0	21
FLT	0	8	2	0	10
GH	0	1	0	0	1
SMS	0	17	2	0	19

Operator 111					
111	2011	2012	2013	2014	TOTAL
AW	0	1	0	0	1
FLT	0	9	8	2	19
GH	0	3	1	0	4
SMS	0	3	1	1	5

Operator 112					
112	2011	2012	2013	2014	TOTAL
AW	38	0	0	0	38
FLT	33	0	0	0	33
GH	11	0	0	0	11
SMS	39	0	0	0	39

Operator 113					
113	2011	2012	2013	2014	TOTAL
AW	0	0	11	9	20
FLT	0	0	25	6	31
GH	0	0	3	1	4
SMS	0	0	26	4	30

Operator 114					
114	2011	2012	2013	2014	TOTAL
AW	21	0	3	0	24
FLT	15	0	10	0	25
GH	0	0	0	0	0
SMS	18	0	7	0	25

Operator 115					
115	2011	2012	2013	2014	TOTAL
AW	15	0	5	0	20
FLT	15	0	23	0	38
GH	3	0	2	0	5
SMS	15	0	10	0	25

Operator 116					
116	2011	2012	2013	2014	TOTAL
AW	11	0	0	0	11
FLT	21	0	0	0	21
GH	11	0	0	0	11
SMS	8	0	0	0	8

Operator 117					
117	2011	2012	2013	2014	TOTAL
AW	0	0	22	13	35
FLT	0	0	25	47	72
GH	0	0	5	4	9
SMS	0	0	13	13	26

Legend:
AW ï Airworthiness (Maintenance)
FLT ï Flight Operations
GH ï Ground Handling
SMS ï Safety Management System

Appendix 2: Case Study 1 – Breakdown of SMS Audit Findings by Operation Type

Type of Operation (Fixed Wing / Rotary Wing / Both)	Size of Operation	Year	Safety Policy, Objectives and Planning: Management Commitment & Responsibility	Safety Accountabilities of Managers	Appointment of Key Safety Personnel	SMS Implementation Plan	Third-Party Interface	Coordination of the Emergency Response Plan	Documentation	Safety Risk Management: Hazard Identification Process	Risk Assessment & Mitigation Process	Safety Assurance: Safety Performance Monitoring & Measurement	Internal Safety Investigation	The Management of Change	Continuous Improvement of the Safety System	Safety Promotion: Training & Education	Safety Communication
Both	MEDIUM	2011	10	0	2	0	0	2	1	0	0	0	0	10	1	0	1
Both	MEDIUM	2012	8	0	3	0	1	14	8	2	0	5	1	17	0	4	1
Both	MEDIUM	2013	4	2	1	0	2	5	4	2	1	4	0	7	0	7	0
Both	MEDIUM	2014	1	1	0	0	0	2	0	0	0	0	0	0	0	1	0
	TOTAL		23	3	6	0	3	23	13	4	1	9	1	34	1	12	2

Type of Operation (Fixed Wing / Rotary W Both)	Size of Operation	Year	Safety Policy, Objectives and Planning: Management Commitment & Responsibility	Safety Accountabilities of Managers	Appointment of Key Safety Personnel	SMS Implementation Plan	Third-Party Interface	Coordination of the Emergency Response Plan	Documentation	Safety Risk Management: Hazard Identification Process	Risk Assessment & Mitigation Process	Safety Assurance: Safety Performance Monitoring & Measurement	Internal Safety Investigation	The Management of Change	Continuous Improvement of the Safety System	Safety Promotion: Training & Education	Safety Communication
FW	MEDIUM	2011	71	13	10	0	3	27	31	0	0	10	7	85	5	0	18
FW	MEDIUM	2012	20	5	7	0	5	27	11	8	5	22	2	23	0	11	0
FW	MEDIUM	2013	8	2	3	0	4	20	14	6	2	13	2	9	0	9	0
FW	MEDIUM	2014	7	1	0	0	3	10	3	3	2	5	0	3	0	6	0
	TOTAL		106	21	20	0	15	84	59	17	9	50	11	120	5	26	18

			Safety Policy, Objectives and Planning							Safety Risk Management		Safety Assurance				Safety Promotion	
Type of Operation (Fixed Wing / Rotary W Both)	Size of Operation	Year	Management Commitment & Responsibility	Safety Accountabilities of Managers	Appointment of Key Safety Personnel	SMS Implementation Plan	Third-Party Interface	Coordination of the Emergency Response Plan	Documentation	Hazard Identification Process	Risk Assessment & Mitigation Process	Safety Performance Monitoring & Measurement	Internal Safety Investigation	The Management of Change	Continuous Improvement of the Safety System	Training & Education	Safety Communication
FW	SMALL	2011	41	3	2	0	0	21	10	0	1	11	7	42	3	0	7
FW	SMALL	2012	5	1	0	0	0	8	4	4	2	11	0	7	0	5	0
FW	SMALL	2013	7	1	4	0	4	17	6	6	2	13	3	12	0	6	0
FW	SMALL	2014	2	1	1	0	2	7	7	5	0	11	2	6	0	3	0
	TOTAL		55	6	7	0	6	53	27	15	5	46	12	67	3	14	7

			Safety Policy, Objectives and Planning							Safety Risk Management		Safety Assurance				Safety Promotion	
Type of Operation (Fixed Wing / Rotary Wi Both)	Size of Operation	Year	Management Commitment & Responsibility	Safety Accountabilities of Managers	Appointment of Key Safety Personnel	SMS Implementation Plan	Third-Party Interface	Coordination of the Emergency Response Plan	Documentation	Hazard Identification Process	Risk Assessment & Mitigation Process	Safety Performance Monitoring & Measurement	Internal Safety Investigation	The Management of Change	Continuous Improvement of the Safety System	Training & Education	Safety Communication
Both	Large	2011	3	0	0	0	0	4	0	0	1	3	0	11	0	0	4
Both	Large	2012	3	1	1	0	2	10	0	2	0	1	0	3	0	1	0
Both	Large	2013	1	0	0	0	0	5	0	0	0	0	0	0	0	0	0
Both	Large	2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL		7	1	1	0	2	19	0	2	1	4	0	14	0	1	4

			Safety Policy, Objectives and Planning							Safety Risk Management		Safety Assurance				Safety Promotion	
Type of Operation (Fixed Wing / Rotary Wi Both)	Size of Operation	Year	Management Commitment & Responsibility	Safety Accountabilities of Managers	Appointment of Key Safety Personnel	SMS Implementation Plan	Third-Party Interface	Coordination of the Emergency Response Plan	Documentation	Hazard Identification Process	Risk Assessment & Mitigation Process	Safety Performance Monitoring & Measurement	Internal Safety Investigation	The Management of Change	Continuous Improvement of the Safety System	Training & Education	Safety Communication
FW	Large	2011	38	3	5	0	3	21	17	0	0	8	3	49	5	0	18
FW	Large	2012	8	3	6	0	6	17	4	4	1	3	1	12	0	3	0
FW	Large	2013	8	3	2	0	1	7	4	4	3	10	2	10	0	12	0
FW	Large	2014	2	0	0	0	0	2	0	5	2	2	0	1	0	0	0
	TOTAL		56	9	13	0	10	47	25	13	6	23	6	72	5	15	18

			Safety Policy, Objectives and Planning							Safety Risk Management		Safety Assurance				Safety Promotion	
Type of Operation (Fixed Wing / Rotary Wi Both)	Size of Operation	Year	Management Commitment & Responsibility	Safety Accountabilities of Managers	Appointment of Key Safety Personnel	SMS Implementation Plan	Third-Party Interface	Coordination of the Emergency Response Plan	Documentation	Hazard Identification Process	Risk Assessment & Mitigation Process	Safety Performance Monitoring & Measurement	Internal Safety Investigation	The Management of Change	Continuous Improvement of the Safety System	Training & Education	Safety Communication
RW	Large	2011	21	2	0	0	0	17	6	0	0	0	0	24	2	0	5
RW	Large	2012	8	1	4	0	0	28	4	9	4	6	0	9	0	5	0
RW	Large	2013	2	0	0	0	0	9	1	0	0	0	0	4	0	3	0
RW	Large	2014	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0
	TOTAL		31	3	4	0	0	57	11	9	4	6	0	37	2	9	5

			Safety Policy, Objectives and Planning							Safety Risk Management		Safety Assurance				Safety Promotion	
Type of Operation (Fixed Wing / Rotary Win Both)	Size of Operation	Year	Management Commitment & Responsibility	Safety Accountabilities of Managers	Appointment of Key Safety Personnel	SMS Implementation Plan	Third-Party Interface	Coordination of the Emergency Response Pla	Documentation	Hazard Identification Process	Risk Assessment & Mitigation Process	Safety Performance Monitoring & Measurement	Internal Safety Investigation	The Management of Change	Continuous Improvement of the Safety System	Training & Education	Safety Communication
RW	MEDIUM	2011	45	2	1	0	2	26	5	0	0	7	2	39	1	0	9
RW	MEDIUM	2012	14	3	6	0	7	17	10	7	2	17	1	8	0	7	0
RW	MEDIUM	2013	7	1	3	0	2	16	5	3	3	6	2	10	0	7	0
RW	MEDIUM	2014	0	0	0	0	1	2	0	0	1	1	0	0	0	1	0
	TOTAL		66	6	10	0	12	61	20	10	6	31	5	57	1	15	9

			Safety Policy, Objectives and Planning							Safety Risk Management		Safety Assurance				Safety Promotion	
Type of Operation (Fixed Wing / Rotary Win Both)	Size of Operation	Year	Management Commitment & Responsibility	Safety Accountabilities of Managers	Appointment of Key Safety Personnel	SMS Implementation Plan	Third-Party Interface	Coordination of the Emergency Response Pla	Documentation	Hazard Identification Process	Risk Assessment & Mitigation Process	Safety Performance Monitoring & Measurement	Internal Safety Investigation	The Management of Change	Continuous Improvement of the Safety System	Training & Education	Safety Communication
RW	SMALL	2011	10	2	2	0	0	8	4	0	0	0	0	11	0	0	4
RW	SMALL	2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW	SMALL	2013	3	2	2	0	2	10	1	1	1	3	0	3	0	2	0
RW	SMALL	2014	2	0	0	0	0	6	0	0	0	2	0	0	0	2	0
	TOTAL		15	4	4	0	2	24	5	1	1	5	0	14	0	4	4

Notes:

The size of operation is defined by the following criteria:

- Small: 20 or less employees

- Medium: 21 to 100 employees
- Large: More than 100 employees

The profile of the sampled population in terms of its size is:

- 15% are small size aircraft operators
- 43% are medium size aircraft operators
- 42% are large size aircraft operators.

The average number of employees across all aircraft operators is 173.

Appendix 3: Research Information and Participant Consent Form

INFORMATION SHEET

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Title of Research Project:

"The Impact of Safety Management System implementation for Safety Performance – Commercial Aviation Operations"

Researcher Details:

Student Name: Richard Yeun
Academic Program: 6001 Doctor of Philosophy, School of Biomolecular and Physical Sciences, Nathan Campus
Email: richard.yeun@griffithuni.edu.au
Mobile: 0433373308

Why is the research being conducted?

This research is conducted as part of the researcher's thesis as a higher research student with Griffith University to fulfil the requirements for the award of a PhD. Griffith University's involvement with this research is purely from academic perspective and has final oversight and award of the PhD upon successful completion of all the requirements. An expressed aim of this research by the student researcher is that the knowledge and understanding gained from this research will either confirm the benefits of a SMS in improving safety or provide a case to push for a review and amendment to the associated SMS regulations in the Civil Aviation Orders.

What you will be asked to do

Participants in this research may potentially be asked to provide on an anonymous basis their views and comments on the question of aviation safety amongst the regular transport operations in Australia or asked to complete a survey.

The basis by which participants will be selected or screened

Participants are randomly selected to give a non-bias perspective.

The expected benefits of the research

It is not envisaged that there will be any expected benefits for participants in the research other than for the researcher to present an academic thesis paper

Risks to you

It is not envisaged that participation in this research bears any risks to those involved.

Your confidentiality

The research will not actively seek data that potentially could identify the participants. Further, a process to de-identify all data collected will be instituted as part of the research process. Provision of any data to the research is on a voluntary basis and the researcher undertakes to ensure to the best of his ability to maintain confidentiality and privacy of participant's data when provided. The data is used solely for academic research purposes.

Your participation is voluntary

Participation in this research is voluntary and potential participants are assured free to withdraw from the study at any time.

Questions / further information

For any queries or additional information about the project, please contact the student researcher, Richard Yeun.

The ethical conduct of this research

This research is conducted under the auspices of Griffith University and in accordance with the *National Statement on Ethical Conduct in Research Involving Humans*. If potential participants have any concerns or complaints about the ethical conduct of the research project they should contact the Manager, Research Ethics on 3875 5585 or research-ethics@griffith.edu.au.

Feedback to you

Participants in this research will not be given a report or feedback. Pending the publication of the thesis as an academic paper, participants may then review the outcome of the research and its findings.

Privacy Statement

The conduct of this research involves the collection, access and / or use of your identified personal information. The information collected is confidential and will not be disclosed to third parties without your consent, except to meet government, legal or other regulatory authority requirements. A de- identified copy of this data may be used for other research purposes. However, your anonymity will at all times be safeguarded. For further information consult the University's Privacy Plan at www.gu.edu.au/ua/aa/vc/pp or telephone (07) 3875 5585.

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Australia

Title of Research Project:

"The Impact of Safety Management System implementation for Safety Performance - Commercial Aviation Operations"

CONSENT FORM

Research Team

Student Name: Richard Yeun
Academic Program: 6001 Doctor of Philosophy, School of Biomolecular and Physical Sciences, Nathan Campus
Email: richard.yeun@griffithuni.edu.au
Mobile: 0433373308

By signing below, I confirm that I have read and understood the information package and in particular have noted that:

- I understand that my involvement in this research will include participation in surveys and/or interviews with the researcher.
- I have had any questions answered to my satisfaction;
- I understand the risks involved;
- I understand that there will be no direct benefit to me from my participation in this research;
- I understand that my participation in this research is voluntary;
- I understand that if I have any additional questions I can contact the research team;
- I understand that I am free to withdraw at any time, without comment or penalty;
- I understand that I can contact the Manager, Research Ethics, at Griffith University Human Research Ethics Committee on 3875 5585 (or research- ethics@griffith.edu.au) if I have any concerns about the ethical conduct of the project; and
- I agree to participate in the project.

Expressing consent
By signing below, it indicates that the person named and signed is deemed to have consented to their participation in the research. Please print this sheet and retain it for your later reference.

Name	
Signature	
Date	

Appendix 4: CASA SMS Model Scoring Template (DEMATEL)

SMS SUB ELEMENT	CODE	Direct Effect Rating Score ["0" - No Influence to "4" - Very High Influence]													
Management Commitment & Responsibility	b	Management Commitment & Responsibility													
		a_{bc}	a_{bd}	a_{be}	a_{bf}	a_{bg}	a_{bh}	a_{bi}	a_{bj}	a_{bk}	a_{bl}	a_{bm}	a_{bn}	a_{bo}	a_{bp}
Safety Accountabilities of Managers	c	Safety Accountabilities of Managers													
		a_{cb}	a_{cd}	a_{ce}	a_{cf}	a_{cg}	a_{ch}	a_{ci}	a_{cj}	a_{ck}	a_{cl}	a_{cm}	a_{cn}	a_{co}	a_{cp}
Appointment of Key Safety Personnel	d	Appointment of Key Safety Personnel													
		a_{db}	a_{dc}	a_{de}	a_{df}	a_{dg}	a_{dh}	a_{di}	a_{dj}	a_{dk}	a_{dl}	a_{dm}	a_{dn}	a_{do}	a_{dp}
SMS Implementation Plan	e	SMS Implementation Plan													
		a_{eb}	a_{ec}	a_{ed}	a_{ef}	a_{eg}	a_{eh}	a_{ei}	a_{ej}	a_{ek}	a_{el}	a_{em}	a_{en}	a_{eo}	a_{ep}
Third Party Interfaces	f	Third Party Interfaces													
		a_{fb}	a_{fc}	a_{fd}	a_{fe}	a_{fg}	a_{fh}	a_{fi}	a_{fj}	a_{fk}	a_{fl}	a_{fm}	a_{fn}	a_{fo}	a_{fp}
Coordination of the ERP	g	Coordination of the ERP													
		a_{gb}	a_{gc}	a_{gd}	a_{ge}	a_{gf}	a_{gh}	a_{gi}	a_{gj}	a_{gk}	a_{gl}	a_{gm}	a_{gn}	a_{go}	a_{gp}
Documentation	h	Documentation													
		a_{hb}	a_{hc}	a_{hd}	a_{he}	a_{hf}	a_{hg}	a_{hi}	a_{hj}	a_{hk}	a_{hl}	a_{hm}	a_{hn}	a_{ho}	a_{hp}
Hazard Identification Processes	i	Hazard Identification Processes													
		a_{ib}	a_{ic}	a_{id}	a_{ie}	a_{if}	a_{ig}	a_{ih}	a_{ij}	a_{ik}	a_{il}	a_{im}	a_{in}	a_{io}	a_{io}
Risk Assessment & Mitigation Processes	j	Risk Assessment & Mitigation Processes													
		a_{jb}	a_{jc}	a_{jd}	a_{je}	a_{jf}	a_{jg}	a_{jh}	a_{ji}	a_{jk}	a_{jl}	a_{jm}	a_{jn}	a_{jo}	a_{jp}
Safety Performance Monitoring & Measurement	k	Safety Performance Monitoring & Measurement													
		a_{kb}	a_{kc}	a_{kd}	a_{ke}	a_{kf}	a_{kg}	a_{kh}	a_{ki}	a_{kj}	a_{kl}	a_{km}	a_{kn}	a_{ko}	a_{kp}
Internal Safety Investigations	l	Internal Safety Investigations													
		a_{lb}	a_{lc}	a_{ld}	a_{le}	a_{lf}	a_{lg}	a_{lh}	a_{li}	a_{lj}	a_{lk}	a_{lm}	a_{ln}	a_{lo}	a_{lp}
The Management of Change	m	The Management of Change													
		a_{mb}	a_{mc}	a_{md}	a_{me}	a_{mf}	a_{mg}	a_{mh}	a_{mi}	a_{mj}	a_{mk}	a_{ml}	a_{mn}	a_{mo}	a_{mp}
Continuous Improvement of the Safety System	n	Continuous Improvement of the Safety System													
		a_{nb}	a_{nc}	a_{nd}	a_{ne}	a_{nf}	a_{ng}	a_{nh}	a_{ni}	a_{nj}	a_{nk}	a_{nl}	a_{nm}	a_{no}	a_{np}
Training & Education	o	Training & Education													
		a_{ob}	a_{oc}	a_{od}	a_{oe}	a_{of}	a_{og}	a_{oh}	a_{oi}	a_{oj}	a_{ok}	a_{ol}	a_{om}	a_{on}	a_{op}
Safety Communication	p	Safety Communication													
		a_{pb}	a_{pc}	a_{pd}	a_{pe}	a_{pf}	a_{pg}	a_{ph}	a_{pi}	a_{pj}	a_{pk}	a_{pl}	a_{pm}	a_{pn}	a_{po}

Appendix 5: BARS SMS Questions to CASA SMS Model Conversion Table

BARS Question Checklist Reference Number	CASA SMS MODEL FRAMEWORK SUB-ELELMENT
ORG 1.01.01	Documentation
ORG 1.01.02	The Management of Change
ORG 1.02.01	Documentation
ORG 1.02.02	Third Party Interfaces
ORG 2.01.01	Management Commitment & Responsibility
ORG 2.01.02	Safety Accountabilities of Managers
ORG 2.01.03	Appointment of Key Safety Personnel
ORG 2.03.01	Documentation
ORG 2.03.02	Documentation
ORG 2.03.03	Documentation
ORG 3.01.01	Documentation
ORG 3.01.03	Management Commitment & Responsibility
ORG 3.01.04	Management Commitment & Responsibility
ORG 3.01.05	Appointment of Key Safety Personnel
ORG 3.01.06	Appointment of Key Safety Personnel
ORG 3.02.01	Management Commitment & Responsibility
ORG 3.02.02	Management Commitment & Responsibility
ORG 3.02.03	Management Commitment & Responsibility
ORG 3.02.04	Safety Performance Monitoring & Measurement
ORG 3.02.05	Safety Performance Monitoring & Measurement
ORG 3.03.02	Safety Accountabilities of Managers
ORG 3.03.03	Documentation
ORG 3.04.01	Hazard Identification Processes
ORG 3.04.02	Risk Assessment & Mitigation Processes
ORG 3.04.03	Risk Assessment & Mitigation Processes
ORG 3.04.04	Risk Assessment & Mitigation Processes
ORG 3.04.05	Risk Assessment & Mitigation Processes
ORG 3.05.01	Safety Performance Monitoring & Measurement
ORG 3.05.02	Safety Performance Monitoring & Measurement
ORG 3.06.01	Internal Safety Investigations
ORG 3.06.03	Third Party Interfaces
ORG 3.07.01	Safety Performance Monitoring & Measurement
ORG 3.07.02	Safety Performance Monitoring & Measurement
ORG 3.07.03	Safety Performance Monitoring & Measurement
ORG 3.08.01	Third Party Interfaces
ORG 3.08.02	Training & Education
ORG 3.08.03	Training & Education
ORG 3.08.04	Training & Education
ORG 3.09.01	Safety Performance Monitoring & Measurement
ORG 3.09.02	The Management of Change
ORG 3.09.03	The Management of Change
ORG 3.09.04	The Management of Change
ORG 3.10.01	Safety Performance Monitoring & Measurement
ORG 3.10.02	Safety Performance Monitoring & Measurement
ORG 3.11.01	Coordination of the ERP
ORG 3.11.02	Coordination of the ERP
ORG 3.11.03	Coordination of the ERP
ORG 3.11.04	Coordination of the ERP
ORG 3.11.05	Coordination of the ERP
ORG 3.11.06	Coordination of the ERP
ORG 3.11.07	Coordination of the ERP
ORG 3.11.08	Coordination of the ERP
ORG 3.11.09	Coordination of the ERP
ORG 3.11.10	Coordination of the ERP
ORG 3.11.11	Coordination of the ERP
ORG 3.11.13	Coordination of the ERP
ORG 3.11.14	Coordination of the ERP

Appendix 6: *CASA Audit Findings and ATSB Safety Reports (2009–2013)

RPT Operator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	TOTAL
SMS Audit Findings	34	23	0	1	57	24	10	14	16	38	24	39	4	10	1	60	18	43	13	1	30	4	11	25	11	6	9	11	0	28	0	0	7	10	14	596
Airworthiness Audit Findings	20	20	1	1	19	13	4	16	19	19	14	14	0	21	5	26	35	26	10	16	24	17	35	39	46	0	5	4	16	17	17	0	22	33	16	590
Flight Operations Audit Findings	55	60	10	19	57	22	18	23	34	26	44	39	7	62	3	66	79	71	33	20	25	44	28	58	51	7	58	9	26	73	17	12	39	40	36	1271
Total CASA Audit Findings	109	98	11	21	125	59	32	53	69	75	82	72	11	93	9	142	132	139	56	37	79	65	72	122	107	13	72	24	42	118	34	12	68	83	66	2402
ATSB Safety Reports	1	2	9	0	27	0	11	0	44	1	1	5	2	4	0	9	34	3	0	0	0	3	0	2	0	0	1	10	1	2	0	0	0	1	2	175

***Appendix 8:** Yeun et al. (2014)

Appendix 7: Comparison of Correlation of Variables Examined in Case Studies

	Case Study 1 – Corporate & General Aviation Operators	**Case Study 2 –** RPT/Airlines Operations
Number of audits conducted and number of accidents	**Weak** positive linear relationship	
Number of audits conducted and number of audit findings	**Strong** positive linear relationship	
Number of SMS findings and ATSB safety reports		**Weak** positive linear relationship
Number of SMS findings and airworthiness findings	**Moderate** positive linear relationship	**Weak** positive linear relationship
Number of SMS findings and flight operations findings	**Strong** positive linear relationship	**Moderate** positive linear relationship
Number of SMS findings and ground handling findings	**Moderate** positive linear relationship	
Number of airworthiness findings and flight operations findings	**Moderate** positive linear relationship	**Moderate** positive linear relationship
Number of airworthiness findings and ground handling findings	**Moderate** positive linear relationship	
Number of flight operations findings and ground handling findings	**Moderate** positive linear relationship	

Appendix 8: Journal Article

Yeun, R., Bates, P. & Murray, P., Aviation Safety Management Systems. *World Review of Intermodal Transportation Research, Vol. 5,* No. 2 (2014), pp. 168–196.

Abstract

The importance of a safety management system (SMS) is reinforced by the International Civil Aviation Organisation (ICAO)'s 2009 mandate requiring its introduction. The post SMS implementation findings of an ICAO Council Member State highlighted the need for a timely and verifiable project management structure when instituting such change. The appropriateness of using accident rates, number of accidents or audit results to measure of SMS effectiveness is discussed along with a comparison of some ICAO Council Member States' SMS frameworks.

Keywords: Safety Management System (SMS); Aviation; International Civil Aviation Organisation (ICAO); Civil Aviation Safety Authority (CASA); Civil Aviation Authority of Singapore (CAAS); Civil Aviation Authority (CAA), United Kingdom; Transport Canada (TC).

1. Introduction

ICAO states that aviation is arguably the safest mode of mass transportation (International Civil Aviation Organisation, 2009, p. 3-5). The transformation of the industry from a fledging business with a fragile safety record to the first ultra-safe system is attributed to the continuous investment in safety efforts made by the aviation community (International Civil Aviation Organisation, 2009, p. 3-5). As a consequence of the significant reductions in the frequency of safety breakdowns between 1970 and through mid-1990s, the search for safety lessons shifted from the individual or accident investigations to incident investigations (International Civil Aviation Organisation, 2009, p. 3-5). Accompanying this was a mass introduction of technology and an ensuing multiple-fold increase in safety regulations (International Civil Aviation Organisation, 2009, p. 3-5). From the 1990s to the present day, aviation entered a safety reliability era characterised by an ultra-safe system (International Civil Aviation Organisation, 2009, p. 3-5). This is defined as one that experiences less than one catastrophic safety breakdown per one million production cycles (International Civil Aviation Organisation, 2009, p. 3-5). Globally, and notwithstanding regional spikes, accidents became infrequent to the extent of becoming exceptional events. Serious incidents also became fewer and further apart (International Civil Aviation Organisation, 2009, p. 3-5). Coupled to this, the global accident rate from 2005 to 2010 of 4.2, 3.9, 4.0, 4.6, 2.9 and 4.0 accidents per million departures respectively indicates a decreasing trend (International Civil Aviation Organisation, 2011, p.12). For the global accident commercial scheduled flights, "The number of accidents experienced annually was generally stable from 2006 to 2011, varying between 110 and 120 per year, resulting in an equivalently stable accident rate of approximately four accidents per million departures until 2011. There was a significant decrease in these figures in 2012" (International Civil Aviation Organisation, 2013a, p. 39).

1.1 Research Methodology

This review seeks to study the aviation safety management systems within the literature to understand commonalities, differences, challenges with its implementation and measurement of safety performance. A systematic review methodology has been selected from the range of literature review methodologies as it provides the most scientific rigor and is specifically oriented towards providing an unbiased, highly structured and complete review of evidence. The emphasis of a traditional narrative literature review is on a topic of interest and augments to the review a varied range of theoretical positions to generate fresh understandings in the form of a synthesis of findings from previous literature. In comparison, a systematic review focuses on the analysis of the results from interventional studies in a contracted topic area in order to answer a pre-determined research question about the effectiveness of the intervention of interest.

1.2 Research Objectives

This paper is designed to add to the pool of knowledge about aviation SMS, by meeting the following objectives:

- To conduct a comparative analysis of some key ICAO council member Statesô SMS frameworks.
- To investigate the problems with measuring the effectiveness of SMS.
- To examine the issues and challenges faced by an aviation authority with the implementation of SMS for airline operations using CASAøs example as a case study.
- To verify the use of SMS audit findings in creating a safety profile.

In keeping with the aims of this research, the paper is divided into eleven sections. Section 2 is the literature review. The purpose of this section is to discover the existing body of work for aviation SMS. The result serves to explore what has been done in aviation safety management, to identify the problem generated from the current system, and to verify what is needed for the continual improvement of SMS. Section 3 states the reasons for SMS implementation in aviation. Section 4 discusses the problems associated with measuring the effectiveness of a SMS. Section 5 presents the limitations of existing safety indicators. Section 6 serves to discuss what a SMS is. Section 7 summarises and compares various SMS framework model of key ICAO council member States against the generic ICAO framework model. Section 8 is a case study of Australiaøs experience and lessons learnt with implementing SMS for its Regular Public Transport (RPT) operators. Section 9 presents two commonly used safety performance indicators. Section 10 presents a quantitative case study to investigate the correlation between the number of SMS audit findings and the number of safety reports as well as the use of SMS audit data for safety performance profiling. Section 11 summarises the knowledge gained from this research as a whole with respect to SMS.

2. Literature Review

In a comprehensive search of literature comprising 2,009 articles, it was found that only 37 are directly relevant to the objectives of their investigation into the effectiveness of SMS (Thomas, 2012). Very few of these studies were undertaken in transport domains, and many studies only measured subjective perceptions of safety rather than objective measures (Thomas, 2012). Consequently, the use of SMS literature from civil aviation regulatory agencies is considered to be the next best alternative given the very limited scientific literature currently available.

In examining safety climate within the commercial and military aviation sectors, it was found that the safety climate factors identified in the aviation safety climate questionnaires were consistent with the literature examining safety climate in non-aviation high reliability organisations (OøConnor, OøDea, Kennedy, & Buttrey, 2011, p. 128). Therefore, it was concluded that the aviation safety climate tools had some construct validity (OøConnor et al., 2011, p. 128). Rather than constructing more aviation safety climate questionnaires, it was recommended that researchers should focus on establishing the construct and discriminant validity of existing measures by correlating safety climate with other metrics of safety performance as the accident rate is recognised in commercial aviation as too low to provide a sufficiently sensitive measure of safety performance (OøConnor et al., 2011, p. 128). The use of other measures of safety performance, collected as part of a companyøs aviation safety action program or flight operational Quality Assurance could be used to assess the discriminant validity of an aviation safety climate tool (OøConnor et al., 2011, p. 128).

To assess the discriminant validity of a safety climate questionnaire in commercial aviation, it will be necessary to obtain safety performance information and questionnaire responses from a number of companies. This level of access and co-operation will undoubtedly be challenging (OøConnor et al., 2011, p. 136). Nevertheless, collaboration between rival companies with the goal of improving safety climate has been achieved in other domains, such as the offshore oil and gas industry (Mearns, Whitaker, Flin, Gordon, & OøConnor, 2003). Pooling safety climate data across companies provides a larger sample size for analysis, and allows the discriminant validity to be evaluated (OøConnor et al., 2011, p. 136).

Safety as perceived by the flying public focuses heavily on accidents without consideration to contributing elements affecting safety such as management, operations, maintenance, environment, aircraft design, and air traffic control. Any measurement of aviation safety simply cannot just assume that any one contributing factor is independent of others (Liou, Tzeng, & Chang, 2007, p. 243). The commonly used measurement in safety performance is accident rate (Bureau of Transport and Communications Economics, 1992). A deficiency with the use of this measurement indicator is that over 90% of latent events are not reflected (Liou et al., 2007, p.243). Liou et al. (2007) proposes a new safety measurement model based on the DEMATEL method to detect complex relationships and build relation structure among criteria for airline safety measurement. Coupled to this, an analytic network process (ANP) is used to overcome the problem of dependence and feedback among criteria or alternatives. Using the new safety measurement model to method to measure airline safety levels, 13 of Taiwanês Civil Aviation Authority (CAA) safety inspectors conducted safety assessments and participated in the annual safety evaluation program for the 6 major airlines in Taiwan. For each of these airlines, the inspectors were asked to evaluate each criterion, excluding accident rates and ratios of certified technicians. These were directly obtained from the Taiwan CAA annual statistics report. The normalised performance score for the airlines is obtained. Using the performance data of each airline and the weight of each criterion, the safety index of each airline was calculated. The results show that when using traditional accident rate as a safety index, the safety levels of four airlines were found to be identical. This reason being there were very few air accidents overall. Such a result may potentially cause some airlines to cut back on safety expenditures in an effort to reduce their costs (Liou et al., 2007, p. 248). If an airline uses accident rate as a safety measurement when applying for new routes, flight quotas, or safety rankings, it may not be easily differentiated from other companies. In contrast, with the use of the new safety measurement model that combines accident rate with three other dimensions, individual airline safety indexes may be more easily distinguished as evidenced from an empirical testing of the approach using the Taiwanese case study to illustrate its usefulness (Liou et al., 2007, p. 249).

Understanding safety performance in aviation at the level of forming a theoretical framework suitable for its measurement has opened various discussions about the goals of a SMS. The measurement of safety performance is notoriously problematic as measures such as accident rates and compensation costs tend to be reactive and relatively infrequent (Cooper & Phillips, 2004). The emphasis on safety results (Cohen, 2002) usually translates to mean that the success of safety is measured by lower levels of system failure. In many modern approaches (Strickoff, 2000), the use of proactive measures like safety climate, hazard identification and/or observed percent safe behaviour is advocated with the focus on current safety activities to ascertain system success rather than system failure. Used in combination, both approaches can assist organisations to ascertain the effects of their safety programs. A derivative from behavioural safety, the observed percent safe score is thought to be one of the most useful indicators of current safety performance (Reber, Wallin, & Duhon, 1989). Reviews of behavioural safety studies have demonstrated dramatic improvements in safety performance (Grindle, Dickinson, & Boettcher, 2000; McAfee & Winn, 1989; Sulzer-Azaroff, Harris, & Blake-McCann, 1994) in terms of reduction in the number of accidents, workers compensation costs, and insurance premiums.

3. *Reasons for implementation of SMS in Aviation*

Each ICAO Member State requires their operators to implement a SMS to comply with ICAO Standards (Australian National Audit Office, 2010, p.25). An effective SMS may result in the following (Civil Aviation Safety Authority, 2008, p. 16):

- a reduction of incidents and accidents
- reducing direct and indirect costs
- reducing insurance premiums
- an improvement of staff productivity
- safety recognition by the travelling public
- proof of diligence in the event of legal or regulatory safety investigations

The Civil Aviation Safety Authority (CASA) of Australia also states that SMS can overcome limitations associated with the exclusive use of technical and operational standards in a rapidly expanding industry with global interconnectedness The Civil Aviation Authority of Singapore (CAAS) noted that safety cannot be achieved by simply introducing rules or directives concerning the procedures to be followed by operational employees (Civil Aviation Authority Singapore, 2010, p. 2). They perceive SMS to be in common with modern quality assurance practices but emphasise proactive hazard identification and risk analysis across all aspects of an organisation (Civil Aviation Authority Singapore, 2006, p. 29).

The Civil Aviation Authority (CAA) of the United Kingdom indicates that the adoption of SMS by airlines and others allows them to make safety checks and decisions as part of the everyday operation as opposed to the regulator to raising an issue on an audit or visit (Civil Aviation Authority, n.d.a). Transport Canada (TC) states that SMS is an effective risk mitigation strategy to combat the potential increase in the number of accidents accompanying any growth in the aviation industry (Transport Canada, 2012).

4. *Problems with measuring effectiveness of Safety Management Systems*

With the introduction of SMS, the management of aviation safety changed from an industry best practice to a regulatory requirement (Roelen & Klompstra, 2012). Consequently, the aviation authorities must find new ways to define safety management activities of the industry and industry must find the means to demonstrate compliance with the regulations (Roelen & Klompstra, 2012). Many countries departed from the traditional forms of safety oversight by large numbers of product inspections to one that is focused on monitoring of the SMS using safety performance indicators (Roelen & Klompstra, 2012).

In the late 1970s, the shift in safety management from an approach that focused on adherence to prescriptive legislation to one that focused on an organisation taking responsibility for its own management of its unique risk profile heralded the era of outcome based legislation and self-regulation (Feyer & Williamson, 1998). Self-regulation is defined as the requirement for an organisation to ensure that they took all reasonably practical steps to ensure the health and safety of their workforce (Feyer & Williamson, 1998). The impetus for this swing in regulatory orientation was the result of a spate of catastrophic events in a diverse set of industry domains like the Seveso disaster of 1976 in Italy. A dense dioxin vapour cloud was accidentally released from a chemical plant and resulted in a widespread dispersal of a lethal substance to man even in small doses (European Commission, 2014). Some ten square miles of land and vegetation were contaminated and more than 600 people had to be evacuated from their homes. About 2000 people were treated for dioxin poisoning. The consequences of this accident included mandatory systematic management systems across facilities in Europe that handled dangerous substances (Anvari, Zulkifli, & Yusuff, 2011).

In this environment, SMS emerged as a conglomerate of safety-related activities that empowered an organisation to discharge their responsibilities under the guise of self-regulation (Thomas, 2012, p. 2). ñInstead of completely walking away from regulation, the role of the regulator has in turn evolved to one that attempts to support and evaluate the strengths and weaknesses of a safety management systemò (Thomas, 2012, p. 2). This change not only presented challenges to an organisation that now must effectively self-regulate, but also to the regulator who must now evaluate the effectiveness of a system, rather than compliance with a prescriptive regulation (Thomas, 2012, p. 2).

5. Limitations of existing Safety Indicators

The use of accident data to assess the level of safety and endeavouring to understand the safety problem using only these data is meaningless, if not impossible due to the infrequency of fatal accidents in the aviation sector (European Transport Safety Council, 2001, p. 47). This necessitates the development of other mechanisms to analyse safety. A study conducted by Roelen and van der Nat (1998) highlighted that the aviation sector needs a comprehensive set of safety performance indicators for the entire system. The conclusion of this study was that components of the aviation sector regularly use performance indicators, but no comprehensive system is yet available (European Transport Safety Council, 2001, p.47).

Safety oversight in the aviation sector has a long history and strong tradition of regulation and inspection to assess compliance with regulation (European Transport Safety Council, 2001, p. 47). Inspection reports by government agencies could be considered as the backbone of safety in the aviation sector. In the past, these reports relied heavily on accident and incident rates, measures of efficiency such as reliability, delay rates and inspector activities (European Transport Safety Council, 2001, p. 47).

However, these could not be used to compare the safety performance of the different parties and they do not readily improve the understanding of the causes of poor safety performance (European Transport Safety Council, 2001, p. 47). In another approach to understand poor safety performance, underlying influences were identified as potential explanations for unsatisfactory safety performances. Not only obvious indicators like pilot competence and maintenance quality were used, but also factors such as the maturity of the carrier, the financial conditions of a company, the fleet size etc. Again, this failed to establish any reliable indicator based on a sound causal relationship with observed accident rates (European Transport Safety Council, 2001, p. 47).

Having a good understanding of why accidents occur and how they can be prevented is the first of two elements needed for the development of aviation safety performance indicators. The second is a holistic approach to understanding the necessary intervention in the chain of events leading to an accident by considering all the parties in the aviation sector (European Transport Safety Council, 2001, p. 47). Further work is needed to define the necessary safety performance indicators and the means for monitoring them (European Transport Safety Council, 2001, p. 48). It is recommended that a set of performance indicators should be established which combines both technical failures and human errors (European Transport Safety Council, 2001, p. 48).

For decades, the concept of utilising indicators for the continuous monitoring and analysis of processes has been standard practice in industrial quality management. The aviation safety community should exploit this simple and robust concept (European Transport Safety Council, 2001, p. 50).

6. What is a SMS?

SMS builds upon the dogma of System Safety and expands the field of perspective to include Human Factors (HF) and human performance as key safety considerations during system design and operation (International Civil Aviation Organisation, 2009, p. 4-1). A major difference between SMS and System Safety is that SMS takes a proactive approach to safety management and it goes beyond prescriptive audits and checklist-based inspections to develop procedures and indicators that anticipate safety risks (Bayuk, n.d.). While acceptance and compliance oversight is prescriptive based, oversight of safety performance indicators and targets is performance-based (International Civil Aviation Organisation, 2009, p. 6-15). The responsibility for a safe operation is spread throughout the different levels of the entire organisation structure in SMS. This approach increases the likelihood of more people watching out for safety issues and reporting it so that the chance of a hazard going undetected is reduced. This follows James Reasonôs concept of accident causation chain.

According to the CAA, there is no recognised standard for defining a typical SMS and therefore, it has been necessary to adapt best practice from other industries in order to provide guidelines for those parts of the aviation industry that are required to implement a formal SMS (Civil Aviation Authority, n.d.b). The CAA originally defined SMS as ñan explicit element of the corporate management responsibility which sets out a companyôs safety policy and defines how it intends to manage safety as an integral part of its overall businessò (Civil Aviation Authority, 2002, p. 2). It has since updated this definition and now describes it as a proactive and integrated approach to safety as well as the management system of an organisation (Civil Aviation Authority, 2010, p. 3). CASAôs definition is ñA systematic approach to managing safety, including the necessary organisational structures, accountabilities, policies and proceduresò (Civil Aviation Safety Authority, 2009, p. 8). The CAAS terms it as ña systematic, explicit and proactive process for managing safety that integrates operations and technical systems with financial and human resource management to achieve safe operations with as low as reasonably practicable riskò (Civil Aviation Authority Singapore, 2010, p. 2). TC defines SMS as ña businesslike approach to safety. It is a systematic, explicit and comprehensive process for managing safety risks. As with all management systems, a safety management system provides for goal setting, planning, and measuring performanceò (Transport Canada, 2001, p. 1).

7. SMS frameworks

The ICAO SMS framework (Table 1) is recommended as a generic model for its Member States. However, it is interesting to note that the frameworks of some ICAO council Member States that introduced SMS before 2009 such as Australia (Table 2), Singapore (Table 3), United Kingdom (Table 4) and Canada (Table 5) differ innocuously with ICAO and also each other. A table highlighting the commonalities and differences of these frameworks is shown in Table 6.

ICAO SAFETY MANAGEMENT SYSTEM MODEL			
4 MAJOR ELEMENTS			
Safety Policy and Objectives	Safety Risk Management	Safety Assurance	Safety Promotion
12 SUB-ELEMENTS			
Management Commitment & Responsibility	Hazard Identification	Safety Performance Monitoring & Measurement	Training and Education
Safety Accountabilities	Safety Risk Assessment & Mitigation	Management of Change	Safety Communication
Appointment of Key Personnel		Continuous Improvement of the SMS	
Coordination of the Emergency Response Plan			
SMS Documentation			

Table 1 ï ICAO SMS Model –
(Constructed from International Civil Aviation Organisation, 2013b, pp. 5-2, 5-3).

CASA SAFETY MANAGEMENT SYSTEM MODEL			
4 MAJOR ELEMENTS			
Safety Policy, Objectives and Planning	Safety Risk Management	Safety Assurance	Safety Promotion
15 SUB-ELEMENTS			
Management Commitment & Responsibility	Hazard Identification Process	Safety Performance Monitoring & Measurement	Training & Promotion
Safety Accountabilities of Managers	Safety Assessment and Mitigation Process	Internal Safety Investigation	Safety Communication
Appointment of Key Safety Personnel		Management of Change	
SMS Implementation Plan		Continuous Improvement of the SMS	
Third Party Interface			
Coordination of the Emergency Response Plan			
Documentation			

Table 2 ï Australiaǿs CASA SMS Model ï (Constructed from Civil Aviation Safety Authority, 2009, p. 12).

CAA SINGAPORE SAFETY MANAGEMENT SYSTEM MODEL			
4 MAJOR ELEMENTS			
Safety Policy and Objectives	Safety Risk Management	Safety Assurance	Safety Promotion
12 SUB-ELEMENTS			
Management Commitment & Responsibility	Hazard Identification and Process	Safety Performance Monitoring & Measurement	Training & Education
Safety Accountabilities of Managers	Safety Assessment and Mitigation Process	Management of Change	Safety Communication
Appointment of Key Safety Personnel		Continuous Improvement and Audit	
Emergency Response Planning			
Documentation & Control			

Table 3 – CAA Singapore SMS Model ï
(Constructed from Civil Aviation Authority Singapore, 2010, p. 4)

UNITED KINGDOM CAA SAFETY MANAGEMENT SYSTEM MODEL			
4 MAJOR ELEMENTS			
Safety Policy and Objectives	Safety Risk Management	Safety Assurance	Safety Promotion
13 SUB-ELEMENTS			
Management Commitment & Responsibility	Hazard Identification Process	Safety Performance Monitoring & Review	Training & Education
Safety Accountabilities	Safety Assessment and Mitigation Process	Management of Change	Safety Communication
Appointment of Key Safety Personnel	Internal Safety Investigation	Continuous Improvement of Safety System	
Coordination of the Emergency Response Plan			
SMS Documentation			

Table 4 – United Kingdom CAA SMS Model ï
(Constructed from Civil Aviation Authority, 2010, p. 2).

TRANSPORT CANADA SAFETY MANAGEMENT SYSTEM MODEL					
6 MAJOR ELEMENTS					
Safety Management	Documentation	Safety Oversight	Training	QA Program	Emergency Response Plan
17 SUB-ELEMENTS					
Safety Policy	Identification & maintenance of Applicable Regulations	Reactive Process	Training Awareness & Competence	Operational Quality Assurance	Emergency Preparedness & Response
Non Punitive Safety Reporting Policy	SMS Documentation	Proactive Process			
Roles, Responsibilities & Employee Involvement	Records Management	Investigation & Analysis			
Communication		Risk Management			
Safety Planning, Objectives & Goals					
Performance Measurement					
Management Review					

Table 5 – Transport Canada SMS Model ï
(Constructed from Transport Canada, 2008, p.6).

	ICAO	CASA	CAAS	CAA	TC
Number of Major Elements in SMS Framework	**4**	**4**	**4**	**4**	**6**
Safety Policy and Objectives	Generic Model	ã	ã	ã	X
Safety Risk Management	Generic Model	ã	ã	ã	X
Safety Assurance	Generic Model	ã	ã	ã	X
Safety Promotion	Generic Model	ã	ã	ã	X
Safety Management	X	X	X	X	ã
Documentation	X	X	X	X	ã
Safety Oversight	X	X	X	X	ã
Training	X	X	X	X	ã
QA Program	X	X	X	X	ã
Emergency Response Plan	X	X	X	X	ã
Number of Sub-Elements in SMS Framework	**12**	**15**	**12**	**13**	**17**
Management Commitment and Responsibility	Generic Model	ã	ã	ã	X
Safety Accountabilities	Generic Model	ã	ã	ã	X
Appointment of Key Safety Personnel	Generic Model	ã	ã	ã	X
Coordination of the Emergency Response Plan	Generic Model	ã	ã	ã	ã
SMS Documentation	Generic Model	ã	ã	ã	ã
Hazard Identification	Generic Model	ã	ã	ã	X
Safety Risk Assessment and Mitigation	Generic Model	ã	ã	ã	ã
Safety Performance Monitoring and Measurement	Generic Model	ã	ã	ã	ã
Management of Change	Generic Model	ã	ã	ã	X
Continuous Improvement of the SMS	Generic Model	ã	ã	ã	X
Audit	X	X		X	X
Training and Education	Generic Model	ã	ã	ã	ã
Safety Communication	Generic Model	ã	ã	ã	ã
SMS Implementation Plan	X	ã	X	X	X
Third Party Interfaces	X	ã	X	X	X
Internal Safety Investigation	X	ã	X	ã	X
Safety Policy	X	X	X	X	ã
Non Punitive Safety Reporting Policy	X	X	X	X	ã
Roles, Responsibilities and Employee Involvement	X	X	X	X	ã
Safety Objectives, Planning & Goals	X	X	X	X	ã
Management Review	X	X	X	X	ã
Identification & Maintenance of Applicable Regulations	X	X	X	X	ã
Records Management	X	X	X	X	ã
Reactive Processes	X	X	X	X	ã
Proactive Processes	X	X	X	X	ã
Investigation and Analysis	X	X	X	X	ã
Operational QA	X	X	X	X	ã

LEGEND:

Element or Sub-Element in SMS Framework ã Element or Sub-Element not in SMS Framework X

Table 6 – Table comparing the SMS Frameworks

According to Bayuk (n.d.), there are 4 key features of any SMS. The first is top management commitment to safety. This is an important attribute as the attitudes and actions of management can significantly influence the culture of the entire workforce. Therefore, it is critical that these leaders commit to the success of an SMS implementation. Second, a proactive hazard identification process and reporting structure which is characterised by the continuing prompt identification as well as reporting of hazards. This potentially can save significant amount of time and resources at a later stage. Third, there must be timely and appropriate actions taken to manage risks to a level that is As Low as Reasonably Practice (ALARP). A system must be in place to control logical approaches to respond to known risks and mitigate the risks to a level for continued safe operation. Last but not least is a robust change management program to evaluate changes and safety actions. The continuing appraisal of the impacts of risk management actions is necessary to ensure a closed loop process for determining if further remedial activities are required.

8. Australia's experience with SMS and lessons learnt with SMS implementation for Regular Public Transport operators

Australia is chosen as a case review because it is an ICAO council member State and mandated the implementation of SMS for its Regular Public Transport (RPT) operators in 2009. An initial attempt to introduce a proactive method for improving airline safety performance was consequent to a small number of highly publicised fatal aircraft accidents within the Australian regional airline industry in the 1990s. This method was the Identifying Needed Defences in the Civil Aviation Transport Environment (INDICATE) safety program (Edkins, 1998, p. 275). Besides the public inquiries, the high social and economic costs of aviation accidents force the industry to consider proactive safety management programs as a means of improving aviation safety hazard identification and management (Edkins, 1998, p. 277). Subsequent to the development of the INDICATE program, there are few formal safety management programs designed to proactively prevent airline accidents within the Australian community (Edkins, 1998, p. 277).

Partly, this is due to a number of misperceptions that proactive safety programs are only applicable to high capacity aircraft operators, costly to implement and maintain, and require system safety expertise for effective management (Edkins, 1997; Edkins and Brown, 1996).

Edkins noted that whilst the Reason model of accident causation has been used successfully in the retrospective accident contributing factors (International Civil Aviation Organisation, 1992), there is a need for a system where latent failures such as inadequate training, poor management communication and inadequate maintenance can be monitored proactively. Consequently, this has led to number of proactive indicators with the methodology based on the ñReason modelò being developed (Edkins, 1998, p. 278). These indicators periodically monitor those organisational latent failures that have appeared in catastrophic accidents (Edkins, 1998, p. 278). Examples include the Tripod-DELTA (Hudson, Reason, Wagenaar, Bentley, Primrose, & Visser, 1994) used by Shell International in their drilling and exploration operations and REVIEW (Reason, 1993) that focuses on predicting or making latent failures more visible so that remedies can be implemented to improve safety at British Rail (Edkins, 1998, p. 278).

The results of this study provided some strong evidence that the INDICATE program has had a positive influence on safety management within the participating airline (Edkins, 1998, p. 291). The findings suggest that measuring the safety culture can provide a useful method to monitor changes in company safety performance and may assist in identifying elements of a safety management program that require improvement (Edkins, 1998, p. 293).

The measurement of an individualôs subjective estimation of risk may provide management with feedback regarding employeeôs appraisal of the safety of their operation and there may be a point where a lower perception of risk could be potentially unhealthy for an organisation (Edkins, 1998, p. 293). The greatest source of variance in airline safety is not necessarily aircraft equipment or the category of operation but the real cost comes from the safety culture of organisations within the aviation system (Edkins, 1998, p. 293).

Edkins (1998) states that the results of the INDICATE trial suggest that measuring safety culture provides a useful method for monitoring changes in company safety performance and may assist in identifying elements of a safety management programme that require improvement, such as a hazard reporting system. The benefits from implementing such initiatives will ultimately help to improve operational safety and, in some cases, reduce operating costs. Over 20 passenger carrying operators of varying size in both Australia and overseas have implemented the INDICATE program (Edkins, 1999, p. 8).

In all likelihood, this potentially would have been superseded by the changes resulting with the formal legislative requirement for SMS in 2009. Table 7 is a tabular comparative review of similarities between the current CASA SMS framework and the INDICATE safety management model. Arguably, the CASAôs SMS framework is more comprehensive and granular in its coverage of the safety factors that the

INDICATE model. Therefore, it can be expected that the CASAôs SMS framework will potentially yield an even more positive impact on safety management than the INDICATE model.

CASA SMS MODEL	INDICATE SAFETY MODEL
Similarities and Differences	
SAFETY POLICY, OBJECTIVES AND PLANNING	
Management Commitment and Responsibilities	
Safety Accountabilities of Managers	
Appointment of Key Personnel	Appointing an operational safety manager or officer who is available to staff as a confidante for safety related issues
SMS Implementation Plan	
Coordination of the Emergency Response Plan	
Documentation	
SAFETY RISK MANAGEMENT	
Hazard Identification Process	1) Conducting a regular series of staff focus groups to identify safety hazards within the organisation 2) Establishing a confidential safety hazard reporting system
Risk Assessment and Mitigation Process	
SAFETY ASSURANCE	
Safety Performance Monitoring and Measurement	1) Conducting regular safety meetings with management 2) Maintaining a safety information database
Internal Safety Investigations	
Management of Change	
Continuous Improvement of the Safety System	
SAFETY TRAINING AND PROMOTION	
Training and Education	
Safety Communication	Ensuring that safety information is regularly distributed to all staff

Table 7 – Comparison of CASA SMS Model with INDICATE Safety Model

The Australian National Audit Office (ANAO) was tasked in 2008 to audit CASAôs implementation and administration of the regulation of aircraft operatorsô SMS (Australian National Audit Office, 2010, p. 13). In their report, the ANAO noted that the first step taken by CASA to meet its international obligations with the regulation of operator SMS was to change the relevant regulations to require RPT operators to have and use a CASA approved SMS (Australian National Audit Office, 2010, p. 14). These regulatory changes came into effect in January 2009, but operators were allowed to adopt a phased approach to implementing an SMS similar to the method suggested by ICAO (Australian National Audit Office, 2010, p. 14). However, the approach used by CASA differs from the ICAO recommendation as the implementation phases are structured around three management strategies namely, reactive, proactive and predictive strategies (Australian National Audit Office, 2010, pp. 43-44).

The reactive processes involve responding to events that have already occurred, such as accidents and incidents. (International Civil Aviation Organisation, 2009, 3-11). The proactive processes aim to identify safety risks through the analysis of organisational activities (International Civil Aviation Organisation, 2009, 3-11). The predictive processes rely on the collection of routine operational data and attempt to identify safety incidents that have not yet occurred (International Civil Aviation Organisation, 2009, 3-11). As it eventuated, 7 of the 18 High Capacity Regular Public Transport[1] (HCRPT) operators opted not to use a phased approach to implementing their respective SMS. The remaining 11 HCRPT operators and all 17 Low Capacity Regular Public Transport[2] (LCRPT) operators elected to adopt a phased implementation approach (Australian National Audit Office, 2010, pp. 47-48).

CASA had to extended the time frame for HCRPT operators to obtain the endorsement of their SMS from 1 July 2009 to 2 November 2009 because there was confusion amongst the RPT operators regarding the date that safety manuals were required to be submitted to CASA, with many operators assuming that the

[1] Operators using high capacity aircraft, defined as aircraft that are certified as having a maximum seating capacity exceeding 38 seats or a maximum payload exceeding 4200 kg.

[2] Operators using aircraft other than high capacity aircraft, being aircraft with a seating capacity of 38 seats or less or a maximum payload of 4200 kg or less.

1 July 2009 due date was the date that safety manuals were required to be submitted to CASA for its consideration, as opposed to being the date by which the SMS needed to be approved and in place.

The SMS authorisation from CASA reflected the phased transition to full SMS implementation for each RPT operator (Australian National Audit Office, 2010, p. 49). The first part of CASAôs review process is the document evaluation phase which determines if the associated SMS documentation submitted by an operator contained the elements required under the regulations and suitable for the operator (Australian National Audit Office, 2010, p. 57). Part two or the capability assessment phase is for checking whether the elements in the submitted SMS have been implemented as approved and are operating effectively (Australian National Audit Office, 2010, p. 57). An associated Senior Management Instruction (SMI)[3] from CASA further clarifies that the SMS documentation evaluation was intended to assist in determining whether an operatorôs SMS complied with the relevant legislative requirements (Australian National Audit Office, 2010, pp. 57-58). Additionally, SMS approval could be provided in advance of suitable documentation being in place as long as CASA was satisfied with the timeline proposed by the operator to appropriately document its proposed SMS (Australian National Audit Office, 2010, p. 58).

Accordingly, in deciding whether to approve an operatorôs proposed SMS, CASA did not consider the results of the capability assessment for any of the SMS implementation phases, or the results of the documentation evaluation for the remaining two phases where operators chose to adopt a phased documentation approach.

In this way, the approvals were granted by CASA without knowledge as to whether the safety procedures and SMS elements contained within the SMS material submitted to CASA by the operator were operating as intended or effective albeit that this was recognised by CASA in its transition plan (Australian National Audit Office, 2010, p. 59). A desktop review of an operatorôs proposed SMS manual against the criteria set out in the assessment checklist was the predominant compliance approach used by CASA to satisfy itself that an operator had a suitable SMS Implementation Plan and/or SMS in place (Australian National Audit Office, 2010, p. 73).

The ANAO review found that instances where CASAôs assessment of the SMS proposed by a number of operators failed to report results against Civil Aviation Order (CAO) level components or elements, and/or compiled results at the component level that were inconsistent with the Instructions.

Similarly, there were also other examples of mixed results recorded in the assessment checklist for Civil Aviation Advisory Publication (CAAP) level sub-elements that resulted in an overall positive result for the higher level element, often with no explanatory comment provided to reconcile the apparent inconsistency (Australian National Audit Office, 2010, p. 75).

The ANAO identified a number of instances in which CASAôs documentation evaluation had determined an operatorôs SMS satisfied a line item in relation to both the óPresentô and óSuitableô criteria, even though the item was unable to be effectively measured through a desktop review (Australian National Audit Office, 2010, p. 76). When the SMS approvals were issued, it appeared that CASA did not have clearly documented procedures in place for how or when it would assess the capability of the operators in relation to their respective approved SMS to assure itself that the conditions of the approval were being met (Australian National Audit Office, 2010, p. 98). Further, the SMI issued by CASA in October 2009 identified that the assessment of the operating effectiveness of an operatorôs SMS would be subject to CASA surveillance activities post-certification. In February 2010, the ANAO was informed that CASA had trialled a SMS capability assessment on one RPT operator during that month (Australian National Audit Office, 2010, p. 103). At that time, CASA had not completed any formal procedures for conducting an SMS capability assessment, but development of a document outlining the approach CASA would take to carrying out the assessments was underway. The procedures outlined in that document were used to develop findings that were incorporated into the scheduled annual audit report for that operator undertaken as part of CASAôs existing compliance approach (Australian National Audit Office, 2010, p. 103).

In total, the audit identified 19 findings that required remedial and corrective action. Significantly, more than half of these findings issued were related to deficiencies identified in all 4 components of the operatorôs approved SMS, including 10 of the 14 key Civil Aviation Order based elements. The earlier desktop review of the operatorôs proposed SMS undertaken in October 2009 had determined that all of the 10 key SMS elements identified in the findings were both present in the SMS documentation submitted and suitable for the operator, and therefore satisfied the legislative requirements (Australian National Audit Office, 2010, p. 103). This example highlights ñthe risks involved with granting an approval based solely on a desktop documentation evaluationò (Australian National Audit Office, 2010, p. 104).

9. Safety Performance Indicators

[3] CASA Senior Management Instruction, Approving an SMS Implementation Plan and SMS for CAO 82.3 and CAO 82.5 RPT Operations, Oct 09, Issue 1, p. 12.

The two common types of safety measures in industry are accountability measures and performance indicators (Strickoff, 2000, p. 36). Accountability measures are a means of motivating people (Strickoff, 2000, p. 36). They relate to specific performance expectations and specific people (Strickoff, 2000, p. 36). Accountability measures must not be equated with indicator or outcome measures (Strickoff, 2000, p. 36). Activities are rarely direct predictors of results (Strickoff, 2000, p. 36). For example, people who consistently and diligently perform an incomplete or incorrect set of tasks may nonetheless receive high marks for accountability, even though they have not produced the desired outcomes (Strickoff, 2000, p. 36). Performance indicators are measures for indicating how successfully programs are achieving their ultimate objective (Strickoff, 2000, p. 36). In the case of safety, it means fewer injuries (Strickoff, 2000, p. 36). In order to determine whether performance is improving, it will require a measurement system (Strickoff, 2000, p. 36). An indicator may be characterised in terms of its timeliness and its validity, visa-vis, the outcome for which it is an indicator. ñTimeliness refers to when the indicator is measured (and to when it is measurable) in relation to the endpoint targetò (Strickoff, 2000, p.36). In safety, an indicator can be either prospective (measured before the incident) or retrospective (measured after the incident). Validity refers to how accurately the measure predicts the endpoint event. A less-valid measure may provide a loose approximation of this event, while a highly valid measure reflects an actual count. Prospective measures are generally more useful yet have less validity than retrospective measures. Thus, the goal is to identify prospective measures that have the best possible validity (Strickoff, 2000, pp. 36-37).

10. Methods/Results

In aviation safety, the severity of the harm is described by ICAOôs definition of an accident as an occurrence resulting in fatalities, serious injuries or severe damage to the aircraft (International Civil Aviation Organisation, 2001). Therefore, aviation safety performance indicators should provide a clue of the probability of an accident (Roelen & Klompstra, 2012). This is somewhat opposed to the earlier view of the European Transport Safety Council about the appropriateness of using accident data for assessing the level of safety and understanding the safety problems in the aviation sector rates (European Transport Safety Council, 2001, p. 5). Nonetheless, CASA uses 6 dedicated safety indicators to monitor the RPT operations (Table 8). The values of these 6 safety indicators are presented in Table 9 over the period from 2006 to 2013.

Number	Safety Indicator For RPT Operations	Data Requirements	Data Source
SPI-1	The number of fatal accidents	Accident Data	ATSB
SPI-2	The rate of fatal accidents (per 100,000 hours flown)	Accident Data	ATSB
		Activity Data	BITRE
SPI-3	The number of High Capacity Regular Public Transport Accidents	Accident Data	ATSB
SPI-4	The rate of High Capacity Regular Public Transport Accidents (per 100,000 hours flown)	Accident Data	ATSB
		Activity Data	BITRE
SPI-5	The number of Low Capacity Regular Public Transport Accidents	Accident Data	ATSB
SPI-6	The rate of Low Capacity Regular Public Transport Accidents (per 100,000 hours flown)	Accident Data	ATSB
		Activity Data	BITRE

Table 8[4] - CASA Safety Indicators for RPT Operations

Figure 1 shows a decreasing trend in the total number of RPT accidents in Australia averaging at 2 accidents annually. In comparison with the global average number of 103 accidents a year for scheduled commercial flights for the period 2009 to 2013 (International Civil Aviation Organisation, 2014, p. 5), it shows that the aviation industry in Australia is operating very safely. However, these 6 safety indicators may not be suitable to measure or yield the necessary information to quantify the impact or contribution made by the SMS on the operating environment.

[4] Source: CASA Regulatory Safety Management Program Manual version 1.0 (Not to be reproduced without written permission from CASA)

Number	Safety Indicator For RPT Operations	2006	2007	2008	2009	2010	2011	2012	2013
SPI-1	The number of HCRPT fatal accidents	0	0	0	0	0	0	0	0
SPI-1	The number of LCRPT fatal accidents	0	0	0	0	1	0	0	0
SPI-2	The rate of HCRPT fatal accidents (per 100,000 hours flown)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SPI-2	The rate of LCRPT fatal accidents (per 100,000 hours flown)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SPI-3	The number of High Capacity Regular Public Transport Accidents (VH Registered)	1	3	3	1	2	3	0	2
SPI-4	The rate of High Capacity Regular Public Transport Accidents (per 100,000 hours flown)	0.1	0.3	0.3	0.1	0.2	0.2	0.0	0.1
SPI-5	The number of Low Capacity Regular Public Transport Accidents (VH Registered)	0	1	0	1	1	0	0	0
SPI-6	The rate of Low Capacity Regular Public Transport Accidents (per 100,000 hours flown)	0.0	0.6	0.0	0.9	0.9	0.0	0.0	0.0

Table 9[5] – CASAôs RPT Operations Safety Indicators ï 2006 to 2013

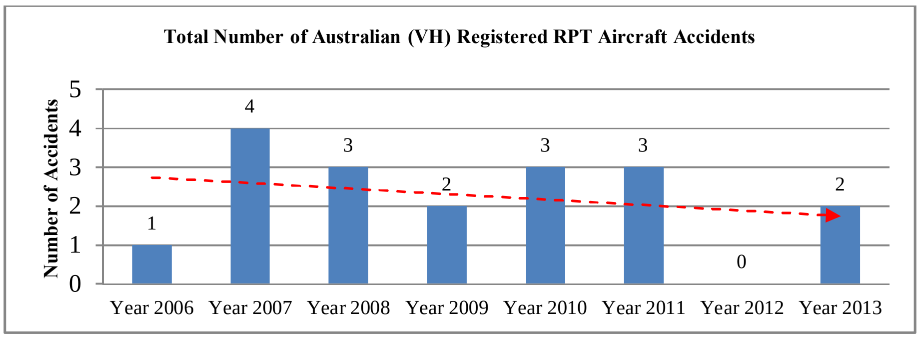

Figure 1[6] – Graph Showing the Total Number RPT Accidents In Australia ï 2006 to 2013 (Derived from summation of data in SPI-3 & SPI-5 as shown in Table 9)

As part of this review, an attempt was made to investigate the correlation between the number of SMS audit findings and the number of mandatory safety reports from the RPT operators to the Australian Safety Transport Bureau (ATSB). The aim was to find out whether the numbers of SMS audit findings have any relationship to the numbers of ATSB safety reports. The first batch of 35 RPT operators that implemented a SMS is chosen as the sample population. In total, 124 audit reports were sampled reviewed. 596 SMS audit findings[7] were found raised against 175 ATSB safety reports[7] during the period 2009 to 2013. The scatter plot (Figure 2) and the calculated correlation coefficient (r) of +0.25 indicates a weak positive linear relationship between the two variables. This means that the numbers of SMS audit findings have no effect on the numbers of ATSB safety reports, vice versa.

[5] Unpublished data from CASA (not to be reproduced without written permission from CASA)
[6] Data extracted from CASA audit reports of sampled population
[7] Data compiled & extracted from ATSB aviation safety and investigation reports of the sampled population

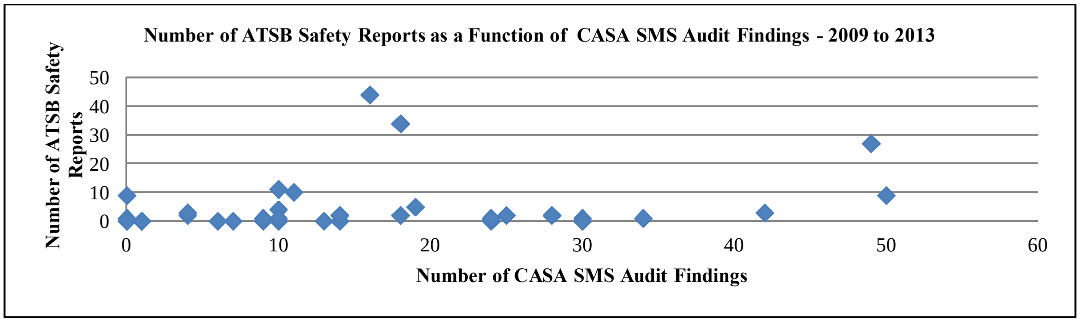

Figure 2 – Scatter Plot - Number of ATSB Safety Reports as a function of CASA SMS Audit Findings (2009 to 2013)

ñSurveillance is the mechanism by which CASA monitors the ongoing safety health and maturity of authorisation holders. Surveillance comprises audits and operational checks involving the examination and testing of systems, sampling of products, and gathering evidence, data, information and intelligenceò (Civil Aviation Safety Authority, 2014, p. 2-2). Non-compliance to the regulations are raised as audit findings by CASA and it was thought by the authors that perhaps a simple classification of each SMS audit finding against the SMS framework sub-elements may yield an opportunity for assessing the SMS safety performance.

Using the SMS findings from the 124 audit reports for the sampled population of 35 RPT operators, each finding is then classified accordingly into CASA SMS framework sub-elements. The Pareto Chart in Figure 3 shows in a descending order the number of audit findings against each SMS sub-element for the sampled population over a 5 year period, post SMS implementation.

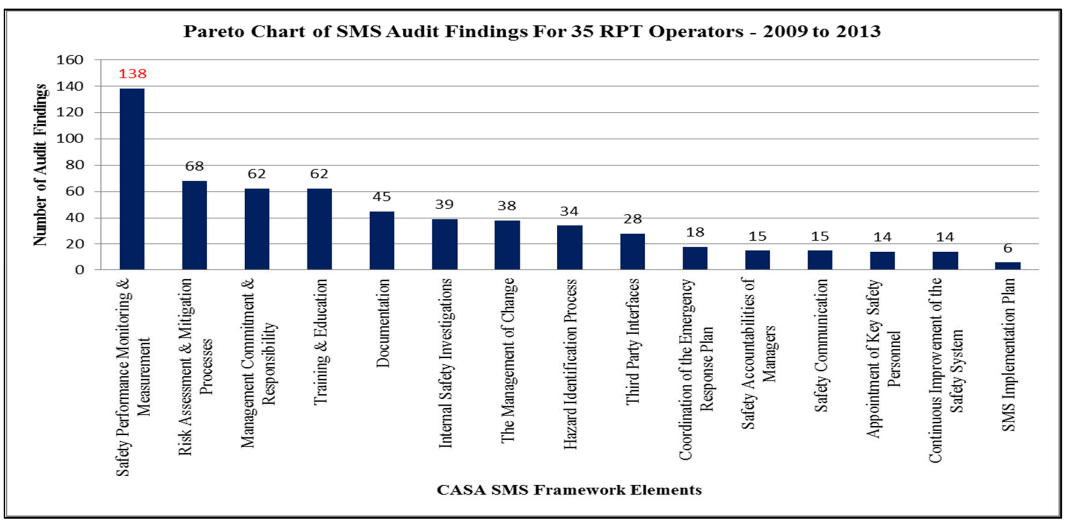

Figure 3 – Pareto Chart of SMS Audit Findings By Elements For 35 RPT Operators ï 2009 to 2013

The value of using this method of assessing a SMS is that it is simple and the results enable a targeted assessment on a priority basis for each SMS framework sub-elements. Each individual SMS sub-element and trends are also shown in Figures 4 to 18.

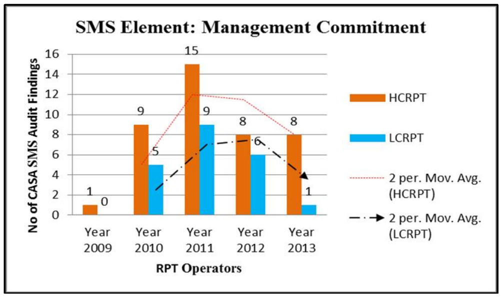

Figure 4- SMS Element: Management Commitment - Audit Findings **-** 2009 to 2013

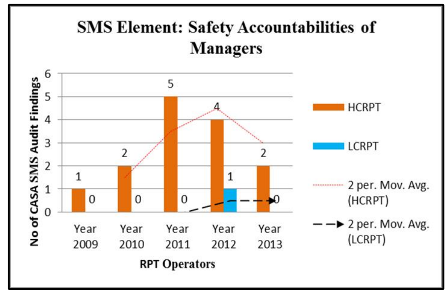

Figure 5 - SMS Element: Safety Accountabilities of Managers - Audit Findings **-** 2009 to 2013

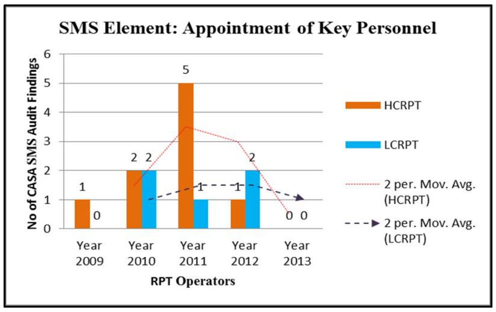

Figure 6 - SMS Element: Appointment of Key Personnel - Audit Findings **-** 2009 to 2013

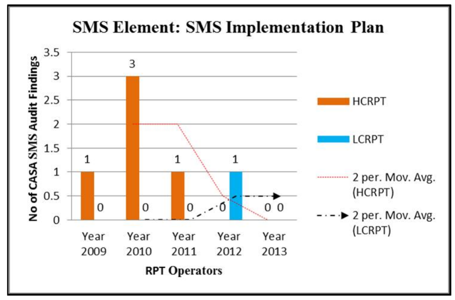

Figure 7 - SMS Element: SMS Implementation Plan - Audit Findings **-** 2009 to 2013

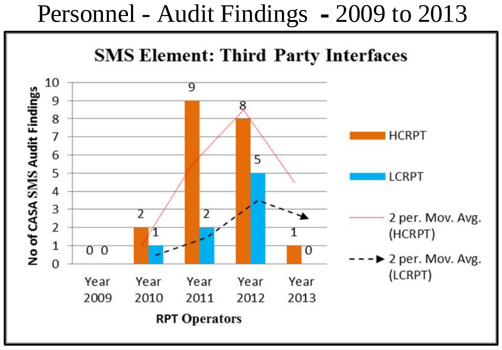

Figure 8 - SMS Element: Third Party Interfaces - Audit Findings **-** 2009 to 2013

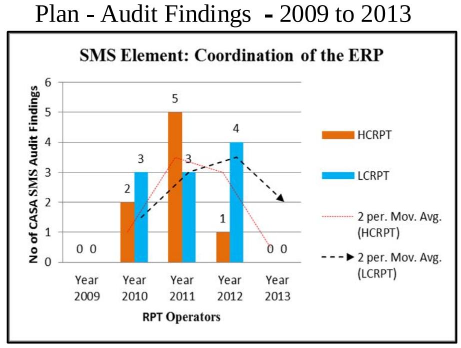

Figure 9 - SMS Element: Coordination of the Emergency Response Plan (ERP) - Audit Findings **-** 2009 to 2013

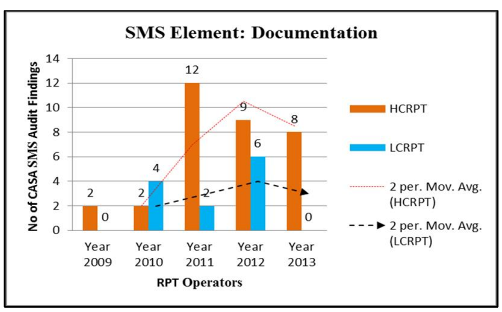

Figure 10 - SMS Element: Documentation - Audit Findings **-** 2009 to 2013

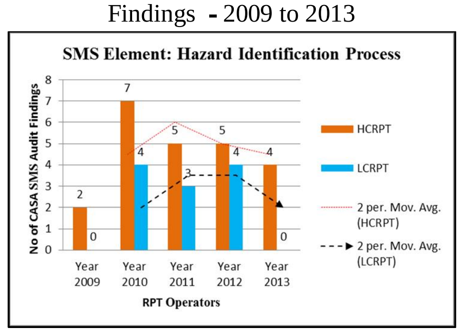

Figure 11 - SMS Element: Hazard Identification Process - Audit Findings **-** 2009 to 2013

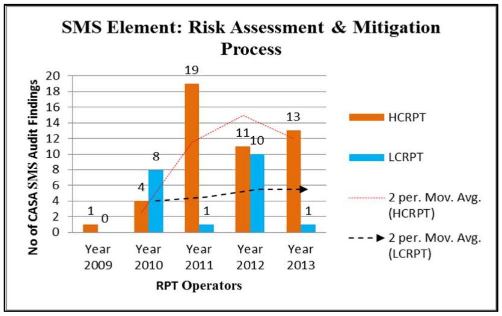

Figure 12 - SMS Element: Risk Assessment & Mitigation Process - Audit Findings **-** 2009 to 2013

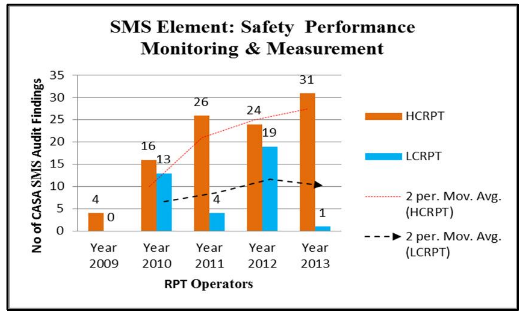

Figure 13 - SMS Element: Safety Performance Monitoring & Measurement - Audit Findings **-** 2009 to 2013

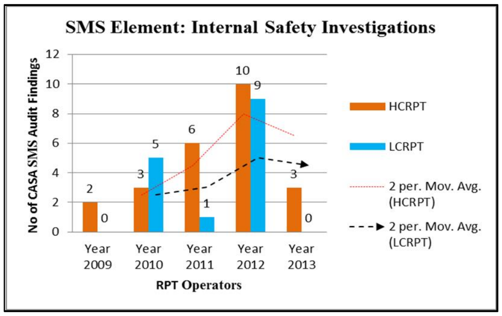

Figure 14 - SMS Element: Internal Safety Investigations - Audit Findings **-** 2009 to 2013

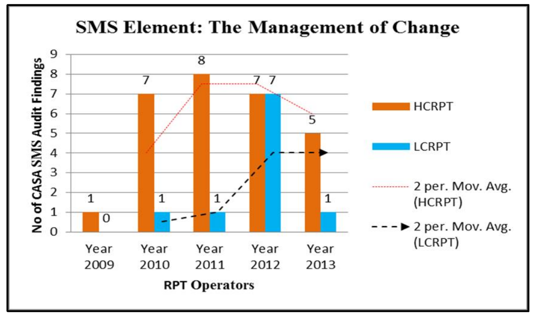

Figure 15 - SMS Element: Management of Change - Audit Findings **-** 2009 to 2013

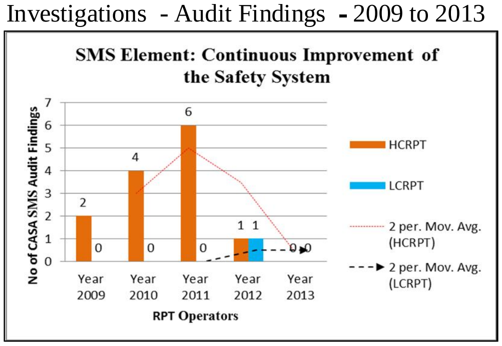

Figure 16 - SMS Element: Continuous Improvement of the Safety System - Audit Findings **-** 2009 to 2013

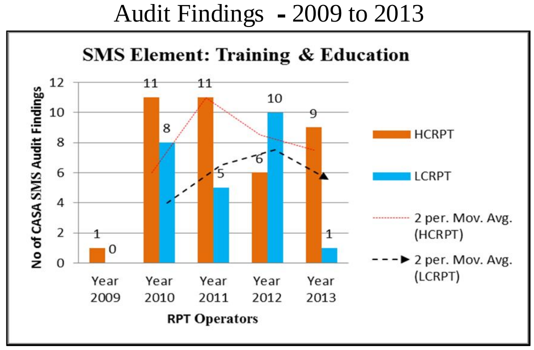

Figure 17 - SMS Element: Training & Education - Audit Findings **-** 2009 to 2013

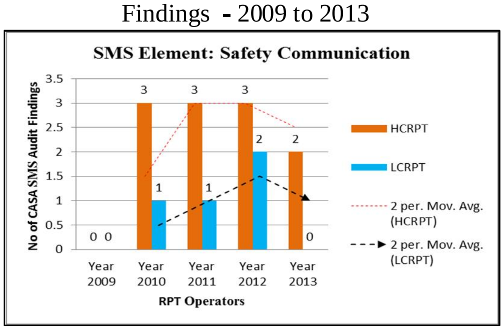

Figure 18 - SMS Element: Safety Communication - Audit Findings **-** 2009 to 2013

In terms of a risk profile, the ñsafety performance monitoring and measurementò sub-element has the highest risk especially coupled with a rising trend line (Figure 13). A key disadvantage of using this approach for assessing the effectiveness of SMS is that it does not account for the detection of complex relationships and building of relationship structures between the SMS sub-elements. The use of a decision-making trial and evaluation laboratory (DEMATEL) method and an analytic network process (ANP) was employed by Saaty (1996) to overcome the problem of dependence and feedback among criteria or alternatives. DEMATEL is based on Graph Theory and it provides the means for planning and solving problems visually. It has been successfully applied in many situations, such as marketing strategies, e-learning evaluation, control systems and safety problems (Chiu, Chen, & Tzeng, 2006; Hori and Shimizu, 1999).

11. Conclusion

This paper has established the need for SMS to be a key part in enhancing safety for a dynamic and safety critical industry like aviation. It also demonstrates the potentially complex and challenging issues faced by any aviation regulator when introducing and implementing a SMS. The traditional method of using audits to assess a SMS may not necessarily be optimal for the purpose. Almost 15 years after the INDICATE model was trialled, there has not been any further research conducted in Australia to find a more robust method for evaluating the efficacy of the contemporary CASA SMS framework (Thomas, 2012, p. iii). Similarly, there is also very limited research globally, save for examples such as the Airline Safety Index (Chang & Yeh, 2004) and the Scale SMS Measurement Method (Chen & Chen, 2012). Therefore, there is an urgent need for each ICAO Member State to develop a tool that can measure and assess the effectiveness of their unique SMS framework.

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Appendix 9: Approval for Academic Research

Australian Government
Civil Aviation Safety Authority

OPERATIONS

File Ref: EF12/4996

MINUTE

DATE: 26 July 2012

TO: Richard Yeun, SSI, Melbourne Region

FROM: Peter Cromarty, A/Executive Manager, Operations Division

SUBJECT: Request for Approval for Academic Research

Summary

With reference to your email of 9 July 2012, I advise that CASA has no objection to your research proposal, subject to all the following conditions being met, in order to mitigate any actual or perceived conflicts of interest to which the research may give rise:

1. In any approach made to CASA-regulated organisations you must make it clear that your research is being conducted by you in your private capacity and not in your capacity as a CASA officer;

2. Each operator must provide to you written permission to use their SMS documentation for the proposed research;

3. Your research paper cannot be published without the prior consent of the Executive Manager, Operations or the Associate Director of Aviation Safety of CASA.

I trust this will allow you to continue with your studies.

Yours sincerely

Peter Cromarty
Acting Executive Manager
Operations Division

GPO Box 2005 Canberra ACT 2601 Telephone: (02) 6217 1330 Facsimile: (02) 6217 1555

Appendix 10: The Sevesco Disaster

Overview

The Seveso Diaster is tied to the experience of a seriously mismanaged toxic chemical release (Conti 1977; Hay 1982; Pocchiari, Silano, and Zapponi 1987 cited in Marchi, B. De., Funtowicz, S. & Ravetz, J. n.d.). For others, it is firmly and positively linked with a set of innovative public policies for managing industrial disasters. These contradictory characterizations make the interpretation of this industrial disaster both paradoxical and ambiguous. The Seveso experience illustrates many different types of uncertainty that are mobilized by industrial disasters and suggests a new interpretive model (Marchi et al., n.d.)

Around midday on Saturday 10 July 1976, an explosion occurred in a TCP (2,4,5-trichlorophenol) reactor of the ICMESA chemical plant on the outskirts of Meda, a small town about 20 kilometres north of Milan, Italy.1 A toxic cloud containing TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin), then widely believed to be one of the most toxic man-made chemicals (Mocarelli et al. 1991 cited in Marchi et al., n.d.), was accidentally released into the atmosphere. The dioxin cloud contaminated a densely populated area about six kilometres long and one kilometre wide, lying downwind from the site. This event became internationally known as the Seveso disaster, after the name of a neighbouring municipality that was most severely affected (Hay 1982; Pocchiari, Silano, and Zapponi 1987 cited in Marchi et al., n.d.).

The Seveso disaster had a particularly traumatic effect on exposed local populations because its seriousness was recognized only gradually. The community was divided by rancorous conflicts. People in other countries also experienced much heightened concern about industrial risks and the need for tighter regulation of hazardous chemical installations. In these respects Seveso resembled Bhopal (1984) and Chernobyl (1986), which have both come to be regarded as international symbols of industrial pathology.

The best-known consequence of the Seveso disaster was the impulse that it gave to the creation of the European Community's Seveso Directive, a new system of industrial regulation. Within the EC, each country previously followed its own rules for managing industrial safety. Urgent discussions about a new EC-wide regulatory framework for ensuring the safety of hazardous installations started after an explosion of cyclohexane in the Nypro Ltd. plant at Flixborough (United Kingdom, 1974). During the next two years, three additional serious chemical accidents occurred within the European Community: these were at Beek (the Netherlands 1975), Manfredonia (Italy 1976), and finally Seveso (Otway and Amendola 1989; Drogaris 1991 cited in Marchi et al., n.d.).

One of the most remarkable features of the Seveso experience was that neither the residents nor the local and regional authorities suspected that the ICMESA plant was a source of risk. They did not even know much about the type of production processes and chemical substances that occurred there. As the Mayor reported (Rocca 1992, personal communication), the factory had been in existence for 30 years and the only occasional complaints from nearby residents concerned some unpleasant smells. Moreover, at Seveso as well as Flixborough, "changes had been made in plant or processes which compromised the safety of the facilities but were not communicated to authorities responsible for public health and safety" (Otway and Amendola 1989: 507 cited in Marchi et al., n.d.).