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HUMAN FACTORS IN AIR ACCIDENT INVESTIGATION:

A TRAINING NEEDS ANALYSIS

By Camille Burban

School of Aerospace, Transport and Manufacturing

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Supervisor: Professor Graham Braithwaite

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Abstract

Human Factors (HF) has long been identified as one of the main causes of incidents and accidents in the transportation industry, and more recently has become increasingly important in air accident investigation and safety improvement. As a result, many National Investigation Agencies (NIAs) are now explicitly acknowledging HF in their final investigation reports. Whereas engineering-and operations-led investigation can highlight *what* happened and *how* it occurred, it is increasingly recognised that the integration of HF into an investigation can help understand *why* a sequence of events led to an incident or accident.

However, there are considerable challenges to more thorough integration of HF into air accident investigations. Most notably, there remains a reluctance amongst some NIAs to fully embrace HF and address potentially important HF issues in detail in their investigations. Consequently, there is a risk that some investigations are consistently overlooking potentially critical HF issues, and as a result fail to fully address *why* an incident or accident occurred. There is a need for research that examines these challenges, including the possible gap that exists between research and industry regarding the development and applicability of accident analysis tools, and that provides practical solutions to enable a better integration of HF in air accident investigations.

The thesis aims to address this gap in knowledge by examining the training needs of air accident investigators in order to develop more thorough human factors integration in accident investigations. Following the methodological process of a Training Needs Analysis (TNA), it provides recommendations on what NIAs could do to ensure more thorough and credible HF investigations. These recommendations focus on the training provision for investigators and managers, the involvement (or not) of HF specialists, and the adoption of an approved approach or methodology. They are based on the findings from four separate studies conducted as part of the Training Needs Analysis; namely, an analysis of accident investigation reports from five major NIAs, an online questionnaire survey of current air accident investigators, a series of qualitative semi-structured interviews with HF specialists involved in air accident investigations and an associated follow-up questionnaire survey.

It was found that the quality of HF integration in accident reports varied between NIAs, with those who systematically involved HF specialists generally producing more detailed and thorough HF investigations. Other key findings include the lack of standardised and adapted HF training for investigators, the lack of HF refresher training, and the need for investigators to understand specialist input. Recommendations from the TNA include the need to involve HF specialists throughout the investigation process in order to provide a thorough and credible HF element to accident investigation report, as well as the necessity to develop adapted and standardised HF training for investigators and managers.

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Abbreviations

AAIB	Air Accidents Investigation Branch
AIID	Accident and Incident Investigation Division
ATSB	Australian Transport Safety Bureau
BEA	Bureau d'Enquêtes et d'Analyses
CAA	Civil Aviation Authority
CRM	Crew Resource Management
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
FDR	Flight Data Recorder
GPS	Global Positioning System
HF	Human Factors (Note: unless stated otherwise 'human factors' refers to the field or discipline and will therefore be employed as singular)
HFACS	Human Factors Analysis and Classification System
HFI	Human Factors Integration
HMI	Human-Machine Interaction
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IIC	Investigator In Charge
ISASI	International Society of Air Safety Investigators
NIA	National Investigation Agency
NTSB	National Transportation Safety Board
STAMP	Systems-Theoretic Accident Model and Processes
TNA	Training Needs Analysis

UK	United Kingdom
US	United States

Chapter I – Introduction

I- 1 Context

I- 1- 1 Aviation Safety and Human Factors

In the past decade, the aviation industry has continued to become ever-safer, illustrated by a slow but nonetheless significant reduction of accident rate from 3.46 accidents per million sectors in 2005 to 1.92 accidents per million sectors in 2014 for both jet and turboprop aircraft (International Air Transport Association (IATA), 2015). Figures are also improving in terms of fatal accidents: between 2005 and 2014 the industry went from a fatal accident rate of 0.82 to 0.32 per million sectors (also for both jet and turboprop aircraft) (IATA, 2015). As a result, aviation and the air transport sector is widely-regarded as one of the safest industries in the world.

Much of this improvement can be attributed to the increasing performance and reliability of aircraft technologies, which has seen a reduction in the number of accidents caused by purely technical failures. As a result, in recent years there has been a renewed focus on the role of human error in air accidents, as it has been widely demonstrated that the majority of accidents involve human error in one way or another (Dismukes, 2010; Shappell and Wiegmann, 2009; Shappell at al, 2007).

Most accidents and serious incidents are investigated by National Investigation Agencies (NIAs), who need to conduct blame-free and independent investigations of the incidents in question. Standard practices and recommendations on how to conduct such investigations are detailed in the International Civil Aviation Organisation (ICAO) Annex 13 to the Chicago Convention on International Civil Aviation "Accident and Incident Investigation" (ICAO, 2010). Commercial organisations such as airlines and manufacturers also conduct their own organisations, particularly when NIAs are not involved (for smaller incidents, for example).

Dismukes (2010), emphasizes that human error, and more particularly errors made by highly-skilled experts (such as pilots or air traffic controllers) are symptoms, rather than causes, of the system in which they work, and that therefore, apportioning blame and punishment would not improve safety. Instead, the entire system should be considered in the investigation.

Given the growing importance of human factors in accidents, it is increasingly being recognised that human error should form the starting point of an investigation, and that in order to thoroughly investigate an error, it is necessary to understand "why the operator did what they did and why it made sense at the time" (Dekker, 2006). For this to happen, it requires investigators to remove any hindsight bias that they may have, and embrace the role of human factors in the accident investigation process (Dekker, 2006). The system that should be investigated includes both the human and his/her physical environment (cockpit, weather), it also involves organisational factors such as procedures, structure or policies as well as training and interactions within this system. Investigating human factors therefore means considering the human within its context, and both investigating human error and organisational factors. This change in approach potentially poses challenges for investigations that have traditionally focussed only on technical aspects of accidents.

I- 1- 2 Preliminary research

In this context where thoroughly investigating human factors is essential to conducting a credible air accident investigation, the researcher undertook a qualitative study regarding the consideration of human factors in a National Investigation Agency (NIA). Unlike some NIAs, the one used in the study did not have an 'in-house' human factors specialist. The research was undertaken as part of the author's MSc research in 2012, and aimed to identify how such an organisation integrate HF into their investigations and reports. While this was conducted separately from the PhD, the findings from the project represented important influences on the focus and design of the current research, and as such are reported here.

The research consisted of conducting 15 semi-structured interviews with investigators with different levels of experience. This organisation's investigation team is formed of inspectors specialised in either Flight Data Recorders (FDRs), Operations (Ops.) or Engineering (Eng.). The operations investigators focus on all the aspects of flying and circumstances of the flight, the engineering inspectors focus on the more technical part of the investigation including but not limited to the maintenance process, the structure of the aircraft, the examination of ground marks and the FDRs inspectors are in charge of the recovery and interpretation of recording devices such as Digital Flight Data Recorders (DFDRs), Cockpit Voice Recorders (CVRs) and Global Positioning System (GPS).

The interviews focused on what the investigators thought of human factors and how they considered it in their task of investigating an accident. Their HF training was also approached. Findings from this study are presented in an adaptation of the original interview coding on Figure 1.

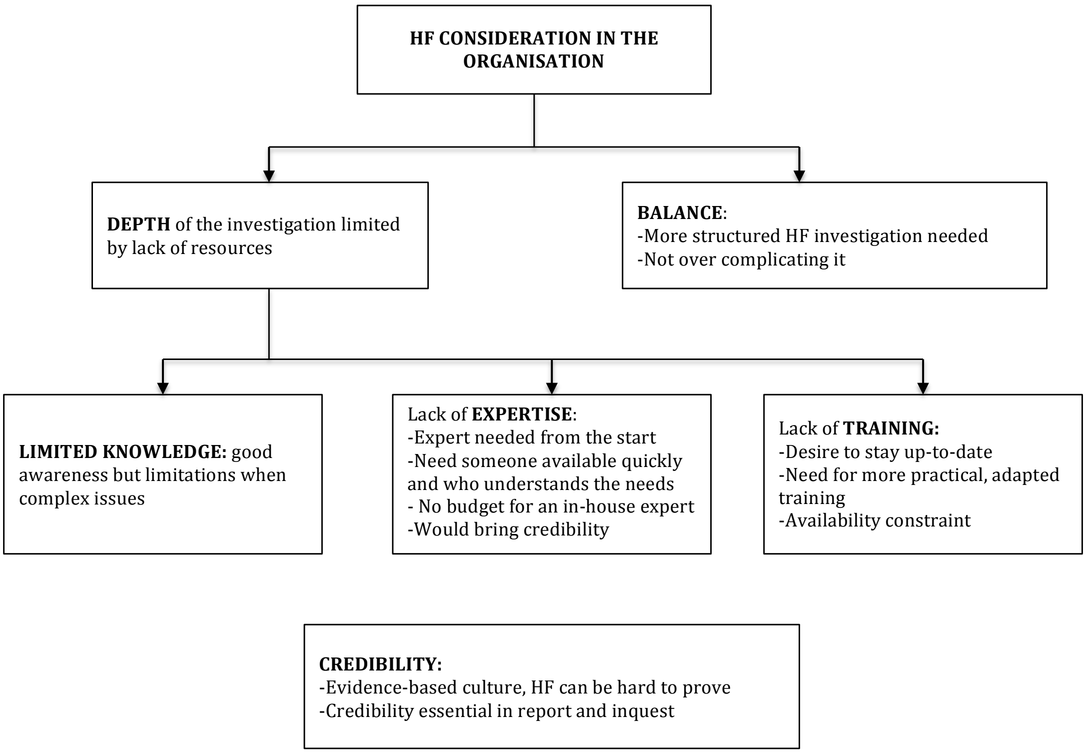

Figure 1: Coding from preliminary research interviews (adapted from Burban, 2012)

After analysing the transcripts of the interviews using grounded theory, key themes arose from the interviews. Those key themes were all related to human factors and were presented as key challenges for the investigators and the organisation. The 'depth' of the HF investigation being limited due to a lack of resources and the search for 'balance' in terms of HF versus technical element within an investigation were two of the main challenges that were emphasized.
The resources limiting the thoroughness of HF investigation were believed to be their 'limited knowledge', the 'lack of HF training' and the 'lack of expertise', or specialist to refer to.

The limitations of the interviewees' knowledge was expressed by the fact that they believed they had a good awareness of the different HF topics but reached their limitations when faced with more complex issues and therefore did not integrate them into the report due to lack of evidence. The lack of training was also one essential factor as to why HF was not always investigated in sufficient depth. It was found that the investigators from that specific organisation were only given a very short introduction to HF and no refresher training. They also specified that more adapted and practical training would be more useful and effective. The investigators found it difficult to apply HF theory to the accident investigation process. The fact they that their schedule is already busy with other training and investigations was also a limitation to receiving more HF training.

This has however evolved. Since 2014-2015, the investigators and managers are now undertaking a course focused on investigating human performance as part of their training. The impact is yet to be observed.

As well as their limited knowledge and the lack of HF training, the other key theme was the lack of HF expertise to involve in investigation. Most of the participants expressed concerns regarding who to contact. Their requirements involved the necessity for someone who understands the needs for the organisation and who would be available quickly, and preferably from the start of the investigation. However, it was believed that the budget did not allow the recruitment of a full time in-house HF specialist, even though it is proven that most of the accidents involve human error (Shappell and Wiegmann, 1997). Some inspectors also strongly believed that the workload (i.e. a rather low amount of investigations that would require the specialist's input) would not justify such an investment.

Finally, the key theme that appeared from the interviews was 'credibility'. Being credible is essential for the accident investigation organisation, particularly when involved in an inquest and considering the high public interest that commercial aircraft accidents create. The majority of the investigators interviewed believed that HF was difficult to prove and therefore the HF elements in the reports were limited due to the importance of remaining 'evidence based'.

It appears therefore that HF training, HF expertise and credibility were the three main challenges identified by this organisation's investigators when considering human factors. With this in mind, it would seem relevant to further examine the role of human factors in accident investigation in order to understand how these challenges could be overcome. The public trust is based on the independence of the organisation and the credibility of its investigations and thus the quality of its investigators (Smart, 2004).

I- 2 Aim and objectives

Considering the importance of investigating human factors in aircraft accident and incidents in today's aviation industry, and the fact that it is not made clear how this should be done, nor to what extent, looking at how human factors could be more integrated within air accident investigation would be a step further in improving aviation safety. Moreover, HF training and expertise have been identified as key challenges for accident investigators.

Thus, the aim of this thesis is:

"To examine the training needs of air accident investigators in order to develop more thorough integration of human factors in accident investigations."

Five objectives were developed in order to reach that aim:

1. To identify the current role of, and key human factors challenges for, air accident investigators.
2. To analyse human factors integration in accident investigation reports.
3. To evaluate the relevance and efficiency of human factors training provision for air accident investigators.
4. To assess the training needs of air accident investigators.
5. To provide recommendations for developing human factors integration in accident investigations.

I- 3 Structure of the thesis

This thesis is formed of seven other chapters. Although reporting distinct studies, they are related to each other.

Chapter II: Literature review

A review of the literature is undertaken to identify the role of human factors in accident investigation and safety as well as the key HF challenges for air accident investigators. This chapter also highlights the gap in the literature that this research fills.

Chapter III: Research design

Chapter III presents the paradigm in which this research is taking place, the research strategy and provides a description of the main methodology employed to build this thesis, Training Needs Analysis (TNA). It also details the objectives guiding this thesis and how each chapter fulfils the relevant objective.

Chapter IV: Accident investigation reports analysis

A content analysis of 15 official accident reports was conducted as the first stage of the TNA. Its purpose was to examine in existing reports what the literature had identified: the lack of thorough HF investigation. The analysis section of each report was therefore analysed looking for how the HF issues were dealt with and integrated.

Chapter V: Accident investigators training

An online questionnaire was sent to air accident investigators in order to find out more about the type of HF training they had received and how useful they thought it was. 89 investigators from different regions, with different roles and working for different types of organisations took the survey. Descriptive statistics were employed to analyse the three parts of the questionnaire. The first one focused on the initial training they received, the second one on specialist training and the final part focused on human factors.

Chapter VI: Human factors experts interviews

Thematic analysis was used to analyse interviews conducted with human factors experts who are involved in accident investigation. The questions were focused on their opinion of the training for accident investigators, their involvement in an investigation, the way HF should be integrated and who the ideal HF investigator should be. This study is the first part of a triangulation methodology aiming at increasing the validity of the findings.

Chapter VII: Human factors experts consensus

As the second part of the triangulation process, a questionnaire was sent to the specialists who were interviewed in the previous study. The questions focused on the content and format of HF training for investigators and the skills and attributes of the ideal HF specialists to be involved in accident investigation. Descriptive statistics were employed to identify the elements that received the majority of responses from the participants.

Chapter VIII: Discussion and conclusion

The final chapter of the thesis discusses the findings from all the different studies and the use of TNA. It provides recommendations regarding the integration of HF within accident investigation. It also discusses the limitations of the research and describes further research that could be carried out based on the conclusions.

I- 4 Ethics considerations

Each individual study presented in this thesis was carefully designed neither to put the participants' career at risk, nor to have an impact on the organisations' reputation. For this reason the interviews participants and the questionnaires respondents will remain anonymous. Each study involving human participants received approval from the Cranfield University Ethics System (CURES).

Chapter II – Literature review

II-1 Introduction

The objective of this chapter is to identify the current role of and key human factors challenges for air accident investigators by providing an analysis of the literature. Peer-reviewed journals, books, and also regulations and standard operating procedures documentation were reviewed in order to identify the gap in research that led to the aim of this study: examining the training needs of air accident investigators in order to develop more through integration of human factors in accident investigations. It is presented in three complementary sections with the objective of providing a relevant and solid context for this research project.

First of all, the role of accident investigation in aviation safety and its main purposes are addressed. Where accident investigation is considered as a reactive process, its proactive character, through safety recommendations, is also highlighted. Then, considering the complex exercise that is an air accident investigation, the most important challenges raised by such an enterprise are determined. The terminology used in causation, the shift in focus that has occurred since the early days of aviation, the type of events that need to be investigated, the importance of being blame-free and independent, the recruitment and training of accident investigators are then also identified. These challenges as well as the purpose of the accident investigation determine and highlight its multi-disciplinary character. Finally, human factors is addressed in greater detail by providing a brief history of its evolution as well as its implications and importance in accident investigation. These three sections provide evidence that the evolution of aviation and aviation human factors occurred in parallel with the shift in focus of accident investigation and that the latter is inseparable from the umbrella discipline that is human factors.

II-2 Accident investigation role

II-2-1 Accident investigation and aviation safety

Accident investigation plays a major role in the improvement of aviation safety (Tench, 1985). For Tench (1985), former head of the Air Accidents Investigation Branch (AAIB) in the United Kingdom (UK), "*Safety is no accident"*. The absence of accident is the meaning and essence of safety. The International Civil Aviation Organisation (ICAO), which sets requirements and recommended practices to the aviation industry defines safety as "*the state in which the possibility of harm to persons or of property damage is reduced to, and maintained at or below, an acceptable level through a continuing process of hazard identification and safety risk management*" (ICAO, 2013, p 2-1). This definition implies the acceptance of a certain level of risk, which is different from the Oxford dictionary definition of Safety: "*the condition of being protected from or unlikely to cause danger, risk or injury*". For everyone who isn't directly involved in the high-risk industry and who is a common user of transportation, safety means being able to go from A to B safely and in a safe manner. In the aviation industry, safety is essential to gain public trust in order to be profitable. Without excellent safety records, commercial aviation would not have developed into the major worldwide industry that it is nowadays. But the ultimate goal remains avoiding incidents and accidents. This is the reason why the definition that is believed to be the most relevant to this research is: Safety is "*to prevent something unwanted from happening or to protect against its consequences*" (Hollnagel, 2008, p221).

The measurement of safety is an important concern for the aviation industry because it is a direct evidence of performance to the public. In 2001, with an aim to define safety, Braithwaite (2001) highlights the importance of linking risk and safety in order to get measurable data on which safety can be judged. "*Safety is not measurable – risks are. Safety may be judged relative to its level of risk versus the acceptable level of risk. To determine safety therefore, involves two quite separate activities; measuring risk and judging safety*" (Braithwaite, 2001, p19). Nevertheless, safety is generally represented statistically, for example the number of accidents during the past decades, and often by specifying the number of fatalities per passenger mile (Allward, 1967; Stolzer et al, 2008, p 15). Yet, Reason (2000) and Hollnagel (2008) highlight the fact that safety is often measured by its absence rather than its presence and "*while high accident rates may reasonably be taken as indicative of a bad safety state, low asymptotic rates do not necessarily signal a good one*" (Reason, 2000, p6).

Another important question for both aviation industry and research is whether the absence of accidents is even possible. As of 2016, Australia still has not had a single passenger fatality in a commercial jet aviation accident or incident. However, a number of recent high-profile accidents (e.g. Malaysian Airlines flights MH370, MH17, and the Germanwings flight 9525) show that safety and therefore accident investigation are still key challenges for aviation.

Whether or not safety can be measured accurately by accident rates, it is widely thought that investigating accidents and incidents is a major tool to safety improvement. Jerry Lederer, first elected president of the Society of Air Safety Investigators (SASI), later the International Society of Air Safety Investigators

(ISASI), noted during its first international seminar in 1970 that "*Much of the progress in the development of safety resulted from lessons learned from accident investigation*" and "*There is no reason to doubt that this will continue and that new techniques will be developed to aid the investigator to determine probable causes with less time and more accuracy than in the past*" (Martinez, 2014, p9). And although there has been much development in the field of safety since the 1970s, this still guides much of the current thinking on accident investigation today. Table 1 illustrates how major investigations not only provided better tools and knowledge for investigators (e.g. investigation and recovery techniques) but also led to safety developments on aircraft and in the industry. Whether it is new equipment for increased safety, the creation or remodelling of procedures for better interpretation, or the development of training, each major accident led to actions that improved the state of aviation safety.

Date	Accident	Aftermath/ Lessons learn and safety improvements
Nov. 1973	Smoke emergency, diversion and Crash of Pan American World Airways Inc., Clipper flight 160	Equipment and procedure changes regarding smoke emergency New status for hazardous material regulations, international hazmat safety initiatives at ICAO and changes in hazardous materials package shipping regulations and practices for air transportation and other modes
June, 1975	Crash during approach at New York JFK due to wind shear	Identification of Wind Shear as a phenomenon: change of focus from pilot error to consideration of pilot's environment Development of instrumentation to help pilots cope with these constraints
March 1977	Collision between KLM Flight 4805 and Pan Am flight 1736, Tenerife	Standardisation communication terms between pilots and ATC with English as working language, development of first CRM training mandatory for all pilots
Nov.1979	Crash of Air New Zealand 901, Mount Erebus disaster	1980: pilot decision as principal cause, followed by inquiry 1981, dominant cause: alteration of the flight plan in the ground navigation computer without advising the crew Subsequent litigation Being re-investigated due to blaming report Knowledge gained on body, data and wreckage recovery
Aug. 1985	Crash on approach at Dallas - during thunderstorm, largely attributed to wind shear	Specific changes in crew training, reprogramming of simulators to simulate wind shear phenomenon Development of runway instrument to provide pilots with wind speeds and directions information
Aug. 1985	Aborted take off and fire of charter flight at Manchester airport	Industry developed fire resistant cabin interiors to increase survivability
Sept 1994	Crash of USAir Flight 427: mysterious low level upset	Extensive simulations to understand what happened (and during other similar events) Research on cockpit warnings, training pilots for different emergency situations Revision of data captured by FDRs Better relationship with families of victims
June 2009	Disappearance of Air France flight 447 in the Atlantic Ocean	Pitot tubes replacement, new measures for data and wreckage recovery Pilot Training and CRM changed, guidance on stall conditions provided Recommendations about longer FDRs beacons transmission
March 2014	Disappearance of Flight MH370	Better knowledge on satellite location Improvement on FDRs transmission and location Consideration of real time tracking system

Table 1: How major investigations improved safety, adapted from "ISASI, 50 years of investigation", (Benner, 2014)

For many decades, accident investigation has been a synonym of safety improvement.

However, in recent years, Stoop and Dekker (2012) questioned how relevant and proactive accident investigations are and criticise their low cost effectiveness. Single events such as AF447 or MH370 (see table 1) cost millions of pounds just for the search phase and although they have helped improve technologies such as Flight Data Recorders (FDR) transmission, they are still of reactive nature. Flight Air France Flight 447 crashed in the middle of the Atlantic. Its recorders were only found nearly two years after the event. Flight MH370, which departed from Kuala Lumpur for Shanghai, disappeared, and the search for the wreckage and FDR are still on going. "*Even in aviation, safety investigations are criticised, despite their long lasting performance and proven value. Investigations should have become obsolete and should be replaced by more modern concepts*" (Stoop and Dekker, 2012, p1422). They recognise nonetheless the evolution and development of accident investigation and therefore conclude, "*In this respect, they do not differ from modern safety management systems*" (Stoop and Dekker, 2012, p1422).

These more modern concepts, as referred by Stoop and Dekker, include Safety Management Systems (SMS) and Resilience (Hollnagel, 2004). SMS are implemented to reduce the risk of incidents and accidents by identifying hazards and managing the risks that could compromise safety (Stolzer et al, 2008). Considerable evolutions of the cockpit were developed as a result of previous events. Amongst the important ones are wind speed and direction indication (see table 1) and Traffic Alert and Collision Avoidance System (TCAS). Hollnagel (2004), a key researcher on resilience, emphasizes the necessity of predicting accidents in order to prevent them, by using accident analysis models. According to Hollnagel, accident prevention by understanding the role of barriers, as opposed to single event investigation, would be the future of safety (i.e. equivalent to those of risk assessment and risk analysis). Hollnagel (2004, p35) argues that "*The value of finding the correct cause or explanation is that it becomes possible to do something constructively to prevent future accidents*". Understanding the nature of the accidents, as opposed to finding the "cause" would be the way forward to improve safety.

There is also a strong relationship between accident investigation and Safety Management Systems (SMS), particularly in large companies with formal safety management: SMS defines the process and the aim of accident investigation and accident investigation can be used as a "*learning process*", or feedback loop that can improve the system with its recommendations (Harms-Ringdhal, 2004). Harms-Ringdhal (2004) identifies another relationship: that accident investigation's output is important for risk analysis and that, in turn, risk analysis should be able to identify types of events and therefore influence accident investigation.

Alternatively, Lundberg and Johansson (2006) not only insist on the important role of accident investigation in safety but also on the necessity to focus on the resilience and the stability of a complex system. Safety recommendations from different types of events (regular, irregular and unexampled) identified by Hollnagel's accident models (linear model, complex linear model and systemic non-linear model) (2006) should increase both stability and resilience of a system in order to maintain safe performance. The recommendations published in the aftermath of an accident, which are intended to prevent a similar event from happening again, imply a pro-active philosophy in accident investigation. So where the investigation process in itself is reactive, since it is undertaken after a single event, the production of safety recommendations makes it a recognised tool for safety improvement.

Therefore, accident investigation and modern safety management systems should not replace one another but instead complement each other. "*Both instruments are neither obsolete, nor modern, but each require a careful positioning in the risk decision making spectrum*" (Stoop and Dekker, 2012, p1430). Accident investigation is the most widely used tool (Roed-Larsen et al, 2004) for safety improvement. It can help ensure a state of safety by producing safety recommendations, and is relevant as long as it is adapted to the type of event that occurred. However, it is not perfect and has limitations, which is why it should not be undertaken in isolation.

II-2-2 The goal of an accident investigation

ICAO's definition of an accident investigation is "*a process conducted for the purpose of accident prevention which includes the gathering and analysis of information, the drawing of conclusions, including determination of causes and, when appropriate, the making of safety recommendations*". In other words, it is understanding what happened, how and why it happened and how its recurrence can be avoided. Accident investigation originated in the early days of aviation when the first events started to occur. The development of international commercial aviation led to the creation of numerous organisations for regulation and investigations (Smart, 2004). Amongst them, ICAO was created in 1947 after the publication of its Chicago Convention that took place in 1944. It published a number of annexes, including Annex 13, which provided international standards and recommended practices on accident and incident investigation, which have been variously updated (latest edition from 2010) and complemented since then (e.g. ICAO Doc 9756 and ICAO Doc 9156). At a European level, the European Commission produced in 2010 the "Regulation EU 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and repealing Directive 94/56/EC", which regulates the investigation of accident and incident investigation. As opposed to ICAO Annex 13, which provides standards and recommended practices, EU 996 is a regulation that each European member state has to follow. It takes precedence over the regulator from these countries.

In addition to the determining of causes of the crash and providing safety recommendations, ICAO recommends that the investigation authority be fully independent from any manufacturer, operator or governmental agencies from its country. This is to avoid any conflict of interest with the industry, its purpose being: "*the sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability*" (ICAO annex 13).

In practice however, investigators have different views on investigation purposes: Rollenhagen et al (2010) found that among the Swedish investigators community, the majority considered the purpose of investigation as being finding the causes of an event and only a minority to produce safety recommendations. In contrast, in a previous study, Roed Larsen et al (2004) found that industry and transportation organisations mostly considered the primary objective of investigation as being "*prevention of accidents or recommendation to reduce or eliminate the identified threats*" (p9).

An alternative view is proposed by Van Vollhenhoven whose purpose of investigation is more orientated towards the impact it has on the society and the organisations: "*Independent investigations into disasters, accidents and incidents are invaluable to society in general and to ensuring safety. They put an end to public concern in the wake of an accident, help the victims and their families to come to terms with what has happened, teach lessons for the future, and prevent the same thing happening again. They are an important aid in safeguarding democracy by making our actions transparent*." (Van Vollhenhoven, 2002, p19)

Although the purpose of accident investigation is clearly defined by ICAO, in reality, its objectives can be conflicting depending on the point of view from which it is considered: researcher or practitioner. But rather than considering a single view, this research sees the objectives described previously as challenges.

In one hundred years, accident investigation challenges have evolved with the development of the aviation industry, whether general, commercial or military. Roed-Larsen and Stoop (2012) have identified external and internal challenges for modern accident investigation: the allocation of blame, the shift towards more complex system and non-linear system approach, the independence of investigation, the scope of the organisation (uni modal or multi modal), the methodology used by the investigators and their training and competence. Stoop and Dekker (2012) also emphasize the challenges of the new missions that accident investigators have to face: public trust, support to victims and relatives and emergency services response.

II-3 Accident investigation challenges

II- 3- 1 Causation terminology

Starting with the definition of accident investigation, the determination of causation terminology has always been controversial. The term 'cause', which implies the nomination of guilt, conflicts with the 'blame-free' character of an Annex 13 investigation and this issue is widely debated in the industry.

The interpretation and definition of the term 'cause' influence the whole investigation, by impacting what one looks for but also what one considers as being part of the accident itself (Wood and Sweginnis, 2006).

A number of recommendations have been made in recent years to try and improve accident investigations. For example, ISASI recommended ICAO to define two types of causes: the descriptive causes, which describe what happened, and the explanatory causes, which explain why the accident happened (Wood and Sweginnis, 2006). In order to avoid apportioning blame, the Australian Transport Safety Bureau (ATSB) advises the removal of the word cause from investigation reports. It is using the concept of 'safety factors' (Walker, 2009), which is "*an event or condition that increases safety risk*", that can be contributory or not. Their argument is based upon the principle that, unlike a legal investigation, determining causation is not essential to enhance safety. It therefore supports Hollnagel's (2004) concept of understanding the nature of accident instead of finding the causes to improve safety. Another benefit of adopting the term 'contributing safety factor' instead of 'cause' is that it provides more accuracy about its degree of relation with the event. It would also avoid any misinterpretation during an inquest following the publication of the report (Walker, 2009). This approach is contradictory with Woods and Sweginnis (2006), who insist on the fact that the general public, the media as well as organisation need causes and too much discussion "*would be a waste of time*".

ICAO has nevertheless published working papers on the topic, concluding that it is unlikely a consensus would be obtained about removing the term 'cause' from annex 13 (ICAO, 2008). Therefore, the amendments that were suggested to balance and attenuate the legal implications of the word 'cause' were that the definition of the latter was edited by adding the no liability factor and that states could report causes and/or contributory factors. Walker (2009) also added that not only definitions should be made clear, they should be completed by a detailed analysis framework to assist the investigators' task. Nonetheless, there remains considerable disagreement regarding this issue.

II- 3- 2 Shift in investigation focus: from looking for a single cause to understanding complex systems

In the early years of aviation safety, the focus of accident investigation was mostly on finding a unique cause to an accident and then shifted towards finding several causes that needed to be categorised (primary cause, root cause etc.) (Wood and Sweginnis, 2006). The determination of causes, in terms of definition and implications, evolved with the development of accident models. The first accident causation model developed was Heinrich's domino theory (1931, in Katsakiori et al, (2009)). It implied the linear progression of an event, i.e. one event causing another and eventually causing the accident. It meant looking for a single primary or root cause. During this period, accident investigators were mainly looking for technical failures (Dien et al, 2012; Stoop and Dekker, 2012). After the Second World War, aviation technology became increasingly reliable and the investigator's focus shifted to the human operator (Dien et al 2012). In the 1970s, the concepts of Human-Machine Interaction (HMI) and ergonomics were developed and started to be incorporated into investigations. At the time, accidents were caused by a technical failure, a human error or another factor that was put in a category called 'other' (Hollnagel, 2004). So although the human factor was considered during the investigation, the blame was put on the operator doing the error. From linear causality, accident investigation models moved towards multi-causality with Reason's introduction of active and latent failures concepts, in the late 1980s, early 1990s. It brought the notion of organisational factors as causal factors. Accident models became an interaction between more factors. As the aviation system became more complex, more complex accident models were developed. Figure 2 shows the evolution of the type of causes, from single to complex. (Hollnagel, 2004, p33).

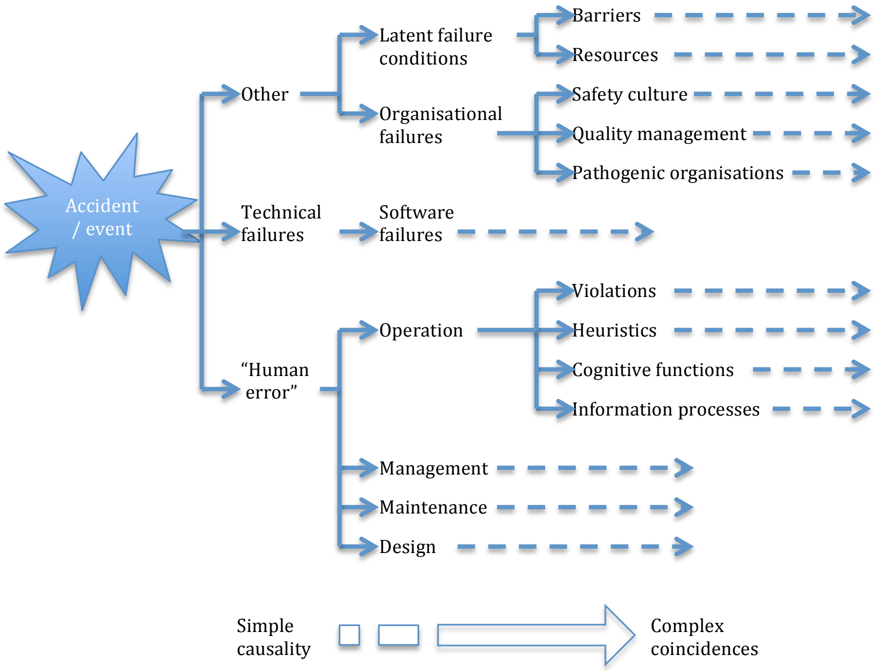

Figure 2: Development in types of causes (Hollnagel, 2004, Barriers and Accident Prevention, p33)

The evolution of the type of causes occurred with the development of technology and knowledge but also in parallel with the development of accident models (from linear to complex).

Moreover, Hollnagel (2004) studied the evolution of attribution of causes over the years (see figure 3). It coincides with the different focuses of the investigation described by Dien et al (2012), from technical failure, to operator errors and then to organisational errors.

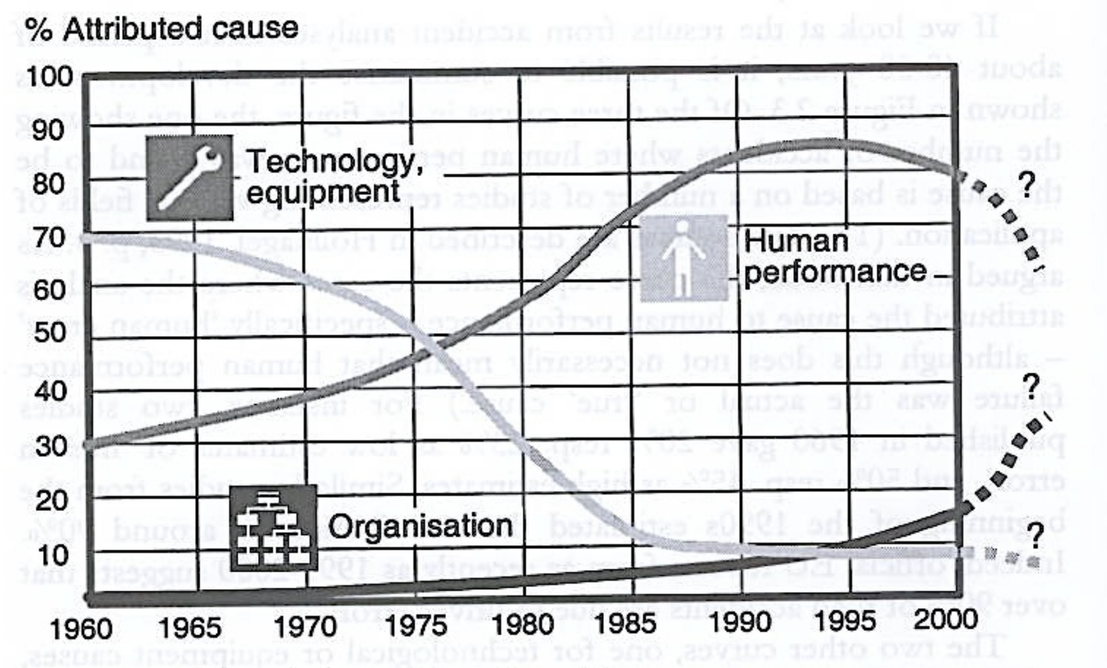

Figure 3: Trends in the attribution of accident causes (Hollnagel, 2004, Barriers and Accident Prevention, p46)

Figure 3 shows an increase in accidents attributed to human performance. It is, however, unlikely that operators' performance diminished. Instead, the industry started to understand it in greater detail, different types of error were identified and the impact of the environment on the operators' performance was considered. Equally, technical failures still occur, but investigations are now focusing on the reason why they occurred, i.e. why the equipment failed, considering its design phase up to its operation and maintenance. Reason (2008, p131) refers to a "*widening of the scope of accident investigation*". This evolution is cumulative and not exclusive (Reason, 2008; Dien et al 2012). Figure 4 illustrates the shift in focus during accident investigation.

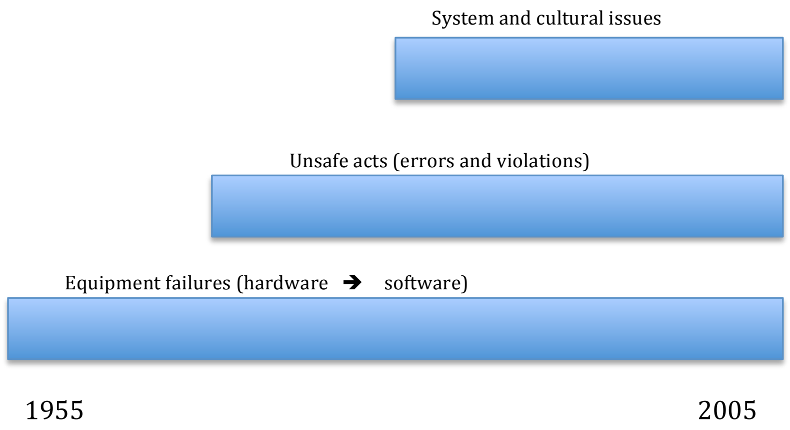

Figure 4: Shift in emphases of accident investigation (Reason, 2008, The Human Contribution, p131)

As well as adapting to the increasing knowledge and development in technology, accident investigation had to adapt to the ever-growing aviation industry. More recently, the interpretation of safety and its emphasis was confronted by a big change: the need for shifting from a reactive attitude to safety, to a more proactive approach. This is best illustrated by Eurocontrol's Safety I vs. Safety II document, which illustrates how the organisation broadened its vision of safety (see table 2). The proactive approach (or Safety II), which it aspires to, implies a constant desire to anticipate events whereas previously, Safety I consisted in adapting only after an event had occurred, i.e. react after a major event.

	Safety-I	Safety-II
Definition of safety	That as few things as possible go wrong.	That as many things as possible go right.
Safety management principle	Reactive, respond when something happens or is categorised as an unacceptable risk.	Proactive, continuously trying to anticipate developments and events.
View of the human factor in safety management	Humans are predominantly seen as a liability or hazard.	Humans are seen as a resource necessary for system flexibility and resilience.
Accident investigation	Accidents are caused by failures and malfunctions. The purpose of an investigation is to identify the causes.	Things basically happen in the same way, regardless of the outcome. The purpose of an investigation is to understand how things usually go right as a basis for explaining how things occasionally go wrong.
Risk assessment	Accidents are caused by failures and malfunctions. The purpose of an investigation is to identify causes and contributory factors.	To understand the conditions where performance variability can become difficult or impossible to monitor and control.

Table 2: Shift in the meaning of Safety, Redrawn from Safety I vs. Safety II: a white paper (Eurocontrol, 2013)

Table 2 highlights the need for investigating what goes right as opposed to just concentrating on what goes wrong. As with the evolution of investigative focus from technical failure to organisational factors, Safety I and Safety II are two complementary views and should not replace one another (Eurocontrol, 2013).

II- 3- 3 Investigating incidents

According to ICAO Annex 13, entitled "Aircraft accident and incident investigation", accidents and serious incidents should both be investigated. The definition of an accident is often pretty straightforward and clear for the industry and investigation organisations. It is "*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/ a person is fatally or seriously injured [...]

b/ the aircraft sustains damage or structural failure [...]

c/ the aircraft is missing or completely inaccessible [...]" (ICAO annex 13, chapter 1)

When it comes to incidents however, although the definition is provided, there is room for interpretation. The definition found in Annex 13 is: "*An occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation*". But, in order to know the type of incident that needs to be investigated, it is necessary to refer to ICAO Doc 9156, The Accident/Incident reporting manual. EU996/2010 stipulates it is to be applied for both accidents and serious incidents investigations. A serious incident is defined as one "*involving circumstances indicating that there was a high probability of an accident*". Member states are obliged to investigate such an event should it occur on their territory (Article 5, EU996/2010). It is however the investigation authority that decides to what extent it is going to be investigated and that same organisation might decide to investigate other types of incident if it is believed that would be beneficial for safety.

Eurocontrol's Safety II concept advocates the investigation of what went right (see table 2), for example an incident with a positive outcome. Investigating what went right on that day might help prevent what could have gone wrong. Rose (2004), inspired by Reason (1997), associates incidents with no loss of life with 'free lessons', particularly for organisations, encouraging self-reporting. It is one concept used by Reason (1997) for his definition of safety culture (see figure 5). Incident reports and investigations allow the identification of barrier failure as well as barrier efficiency. It also enables trends analysis.

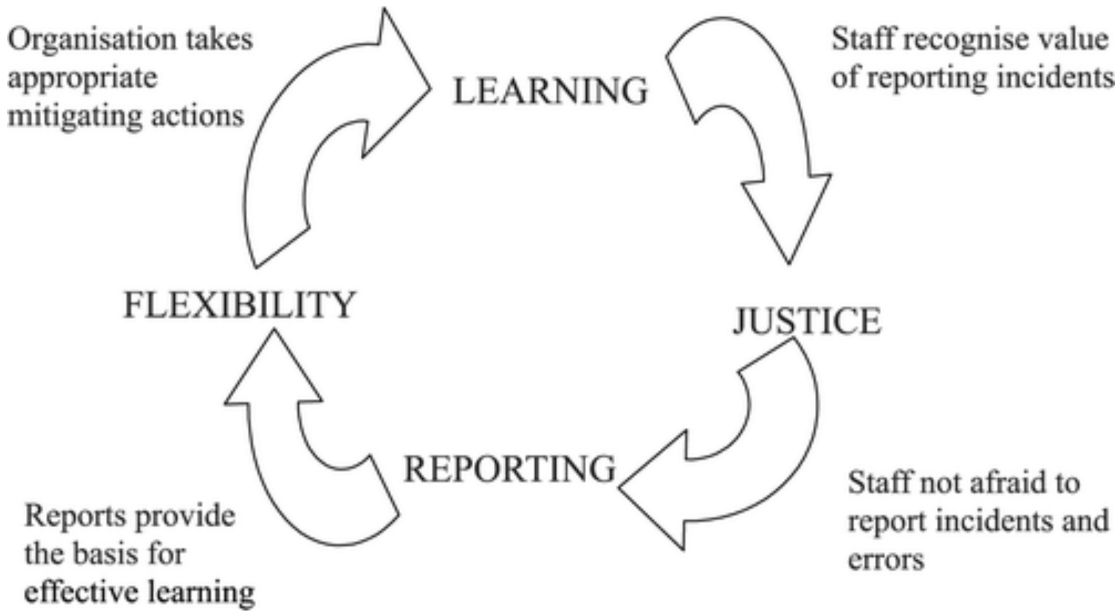

Figure 5: Learning from incident, from "'Free lessons' in aviation safety", Rose, 2004

Baker (2010) defends the necessity to investigate incidents because they are more frequent than accidents. They therefore provide more data on which to build lessons that could help improve the system. She adds that positive outcome and 'successful performance' should also be mentioned in order to show that improvement could be made as well as providing motivation. When referring to minor incident investigations, Strauch (2002) mentions 'proactive investigations'. This adds further to the view that accident investigation can be a proactive tool.

However, Rose (2004) points out that where more organisations do investigate some of these incidents, they tend to do it in the same way that they investigate accidents. He adds that this is not necessarily the most appropriate way since it does not provide good information on the circumstances of the event: incidents should not only be treated as an isolated occurrences but instead organisations should learn from them and outcomes shared with the industry for a wider learning.

II- 3- 4 Independent and blame free investigations

In order to maintain public trust and remain credible, aircraft accident investigation faced the necessity to be independently run from any state regulatory agency as well as being blame-free (Smart, 2004; Stoop and Dekker, 2012).

EU 996/2010, requires that "*The safety investigation authority shall be functionally independent in particular of aviation authorities responsible for airworthiness, certification, flight operation, maintenance, licensing, air traffic control or aerodrome operation and, in general, of any other party or entity the interests or missions of which could conflict with the task entrusted to the safety investigation authority or influence its objectivity*."

According to Stoop (2009, 2012), this need for independence from the state appeared after the Second World War and increased the requirements for quality and credibility. It therefore created the necessity for quality training and certification for accident investigators. Smart (2004) details three major government reviews of aircraft accident investigation (in 1945, 1948 and 1961) that led to firmly establishing the independence of investigation bodies. For Smart (2004, p112), former head of the UK AAIB, the independence is "*perhaps the most important prerequisite for public and industry trust. [...] It ensures that there can be no perception of conflict of interest which reduces the scope for "cover-up" or conspiracy theories*." Independent investigations are now a citizens' right and society's duty (Van Vollenhoven, European Transport Safety Council, 2001). This independence can be demonstrated to the public and industry in the report published after an event, by demonstrating objectivity and transparency in the investigation. Besides the independence from regulators and the transport industry, the investigation needs to be independent from the judicial authorities (Marinho de Bastos, 2004). The safety investigation shall indeed not apportion blame or liability (ICAO Annex 13, EU996/2010) whereas it is the role of the judicial investigation to prosecute an individual or an organisation. In countries where judicial and safety investigations are run in parallel it can become a challenge for the organisations to gain political support in order to have free access to evidence and necessary resources (such as FDRs).

Remaining independent from other agencies enables accident investigators to maintain an objective view on the culture of these organisations, should they become involved in an event. The final report would therefore provide facts only, based on evidence as opposed to opinion. Adopting a blame-free policy forces the investigators to move away from only focusing on the individual and in theory leads them towards investigating technical issues as well as human factors and organisational issues, in other words, understanding the impact of the environment on the operators. The environment is, among other things, the organisation culture.

II- 3- 5 The accident investigators

Accident investigators are the main actors in accident investigations. They are the people gathering evidence, analysing the data and writing the final report that contains the safety recommendations, which intend to improve aviation safety. It is the reason why they need to be highly skilled.

According to Smart (2004, p113), "*the most important factors in establishing trust in the investigation process is that of the professional qualities of the individual investigators*". Since they are dealing with the people involved and their relatives, their credibility is essential: knowledge and expertise will allow them to gather relevant information and evidence; respect, sensitivity and personal qualities are essential when dealing with survivors, next of kin and witnesses to make sure they do not feel isolated. ICAO's Manual of Accident Investigation (ICAO, 2003b) provides guidance on the qualities required for an accident investigator. Agencies need to recruit someone who is more than just an aviation expert since accident investigation is a specialist task in itself. Marinho de Bastos (2004) emphasizes the fact that credibility is gained by availability of adequate expertise, as well as keeping a close contact with industry and regulators to be able to adapt to the evolution of technology, while keeping their independence.

Stoop and Roed Larsen (2009) describe two essential skills for accident investigators as being familiar with a broad range of disciplines and the ability to multi-task, i.e. run several lines of investigations simultaneously, and this to enable them to determine the causes of failure that led to an event. Tench (1985) adds another important point: investigators need to be able to appreciate how human beings behave under stress. Personal skills are therefore of greater importance in accident investigators' character. Flaherty (2008), in her study of the skills and behaviors required for an effective investigator, identified that interpersonal and communication skills were essential, whereas technical skills could be acquired during specific training. Like Tench (1985), Smart (2004) and Stoop and Dekker (2012) identified dealing with family and relatives as one major challenge that investigators have to face. Flaherty therefore suggests recruitment policies to be more orientated towards non-technical skills such as report writing and the ability to deal with people. Recruitment policies are indeed personal to each investigation body. Some countries like France often hire young engineering graduates (from aeronautical school), while others like the UK hire engineers or pilots with decades of experience. Regarding HF skills, not all organisations look for human factors or psychology background in their new recruits.

Training is also unique to each organisation. ICAO's manual for accident investigation (2003b) mentions training as an essential part of the investigator's career, due to the almost unlimited task of investigating accidents. This is to allow the inspectors to keep developing their skills and knowledge and stay up to date. Despite its importance and necessity, training for accident investigators does not have any standard qualification. In 2002, Braithwaite notes that there is no high-qualification recognising the training undertaken by accident investigators, or any accredited training. According to Braithwaite (2004), doing so would benefit the entire aviation industry.

Being independent but keeping close contact with the industry, no allocation of blame, public trust, quality of the investigators, keeping them up-to-date with technology and research, are all inter-related challenges that accident investigation bodies and investigators need to balance as best as they can in order to improve aviation safety. All these aspects of accident investigation, as well as the determination of causes from different disciplines, highlight the multi-disciplinary character of aircraft accident investigation and the difficulties concerning the recruitment and training of investigators. Independence, transparency, credibility and influence are four principles that accident investigation should follow (Marinho de Bastos, 2004). As demonstrated in II-3, keeping to these principles can be challenging. Vuorio et al (2014) list points that occupational accident investigators should learn from aircraft accident investigations: independence of the investigation; real time investigation, which means investigating as soon as possible after the accident, and including interviewing the witnesses in order to get as much information as possible; guidelines and education, referring to ICAO Annex 13 and its standardised approach; the systemic view; and finally the responsibility towards the relatives of those involved in the event. These learning points are, as detailed in II-3, also the greatest challenges that aircraft accident investigators have faced over the years.

II- 4 Human factors in accident investigation

Amongst all the disciplines approached during an accident investigation, human factor has attracted considerable interest. As illustrated by table 1, the largest aviation accidents often involved a major human factors element that needed to be investigated in order to make safety improvement and avoid the similar reoccurrence. The accidents that occurred at Tenerife in 1977, mid Atlantic in 2009 (see table 1) and in Kegworth in 1989 are used as examples.

II- 4- 1 Human factors in aviation: from human factor to human factors

Human factors is an umbrella term that encompasses multiple fields, such as psychology, physiology and ergonomics; more precisely it is built upon those disciplines: "*it relies on the knowledge base and research results from multiple fields (from computer science to anthropology) to do so*" (Woods and Dekker, 2000). The term human factors in itself appeared in the 1950s and was regarded as a synonym of ergonomics. The discipline however appeared in the early days of aviation, with the first manned flights (Edwards, 1988, in Wiener and Nagel). Although definitions are plentiful Edwards (1988, p9) selected the following as an introduction to human factors:

"*Human factors (or ergonomics) may be defined as the technology concerned to optimize the relationships between people and their activities by the systematic application of the human sciences, integrated within the framework of system engineering*".

Edwards described the evolution of the discipline from its appearance until the 1950s. The early days of aviation saw a rapid development in instrumentation, putting emphasis on cockpit layout, which has remained in the human factors discipline and is today referred as flight deck design. Between the two wars, the focus was more on the pilot's flying skills and whether or not one should rely on the instruments, an issue that remains key to this day, particularly with the increase of automation in the cockpit. It then shifted towards pilot selection and training and research was conducted into stress and fatigue.

Amalberti (2001) illustrates the development of the discipline from the 1950s until the year 2000 (see figure 6). He highlights the fact that the 1970s and 1980s were mainly focused on the individual, understanding psychological processes and human behaviors. Big scale events such as Tenerife (see table 1) and Three Mile Island (nuclear accident that occurred in 1979 in the US) in the late 1970s triggered a change towards organizational focus. This timeline correlates with the shift in focus detailed by Hollnagel (2004) and Reason (2008) (see figures 3 and 4).

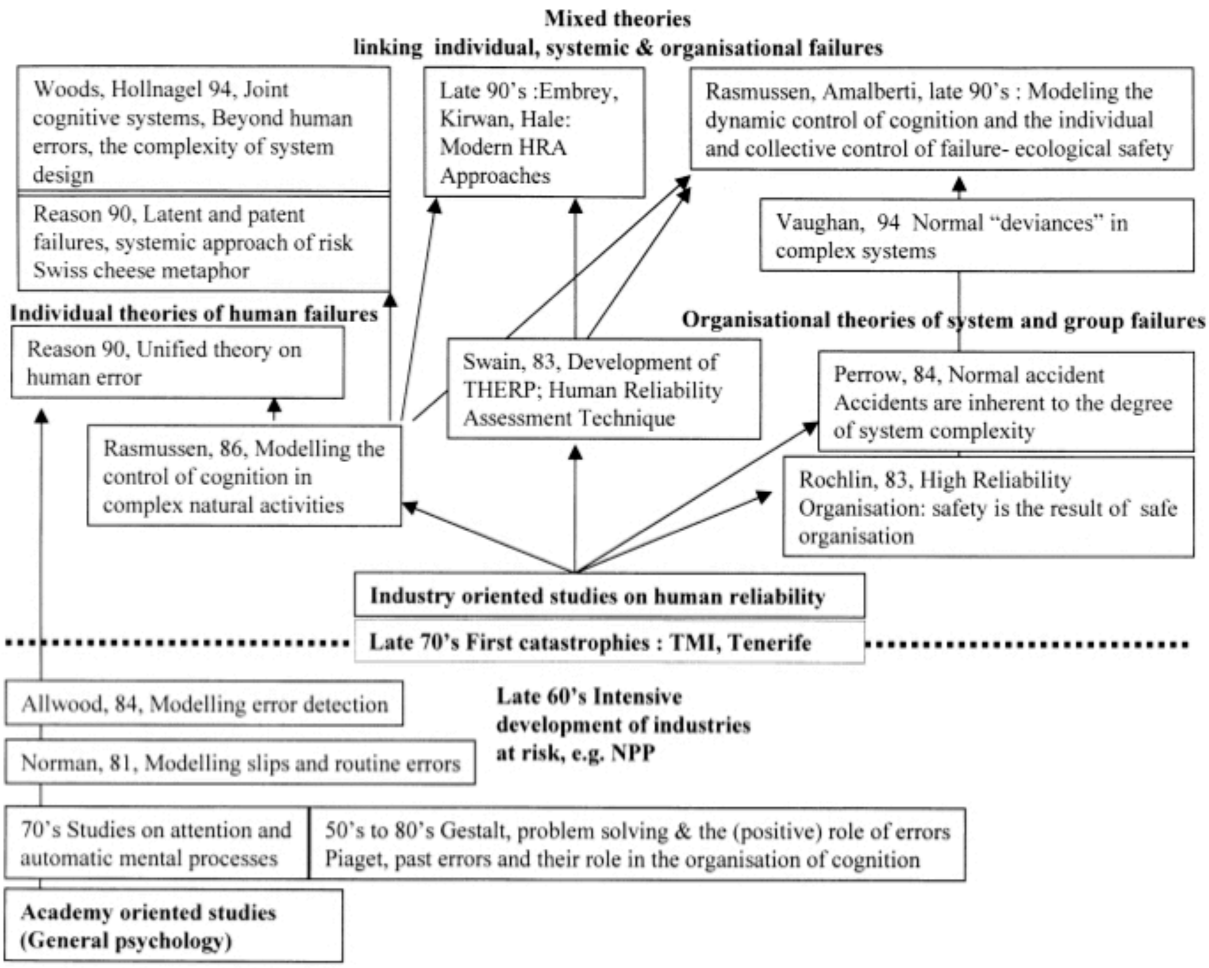

Figure 6: Evolution of human error research, from "The paradoxes of almost totally safe transportation systems", Amalberti (2001)

Research development in human factors therefore influenced the accident investigation process and it could also be argued that the evolution of aviation industry and the accident investigation process had an impact on the research focus.

In the early days of aviation, the focus was on looking for human error and failure (Heinrich, 1931). As Korolija and Lundberg (2010) highlight, this process lasted until the late 1950s, when there was a better understanding of cognitive process (Amalberti, 2010). In the 1990s, the terms then evolved with Reason's research (1990). The blaming terms such as error, failure, recklessness, nervousness gave way to slips and lapses, and 'ignorance of regulations' turned into 'violations' (Korolija and Lundberg, 2010).

II- 4- 2 The importance of the consideration of human factors in accident investigation

Human factors is involved in almost all aircraft accidents or incidents (Wiegmann and Shappell, 1997, 2001, 2003, 2009), in one-way or another. A stagnation of accident rate, or more accurately an asymptotic reduction (i.e. as the rate decreases towards zero, it is harder to improve), has also been observed during the past decades and this is where authors have different views: on one hand Shappell and Wiegmann (2009) attribute the stagnation of aviation accident rate to the remaining error and therefore developed research to classify these errors in order to understand why they happened and avoid their recurrence. O'Hare (2000) also attributed the stagnation in the high proportion of human error accidents to the lack of common taxonomies. However, Maurino (2010) relates it to "*systemic nature in the safety problems faced by contemporary aviation*" (p953) and offers to reduce the allocation of focus and blame towards operational people and instead have a "*macro view of the aviation system*".

In accident investigation, the major shift happened when the trend in research moved from the 'bad apple theory' to the 'good apple theory' (Dekker, 2002). That is to say the attention shifted towards people in higher management positions and organisation culture, as opposed to focusing only on operators. In

1990, Reason published his organizational accident model (also known as the Swiss cheese model, see figure 7) that describes the types of defenses that stop an accident from happening, but also how they can fail.

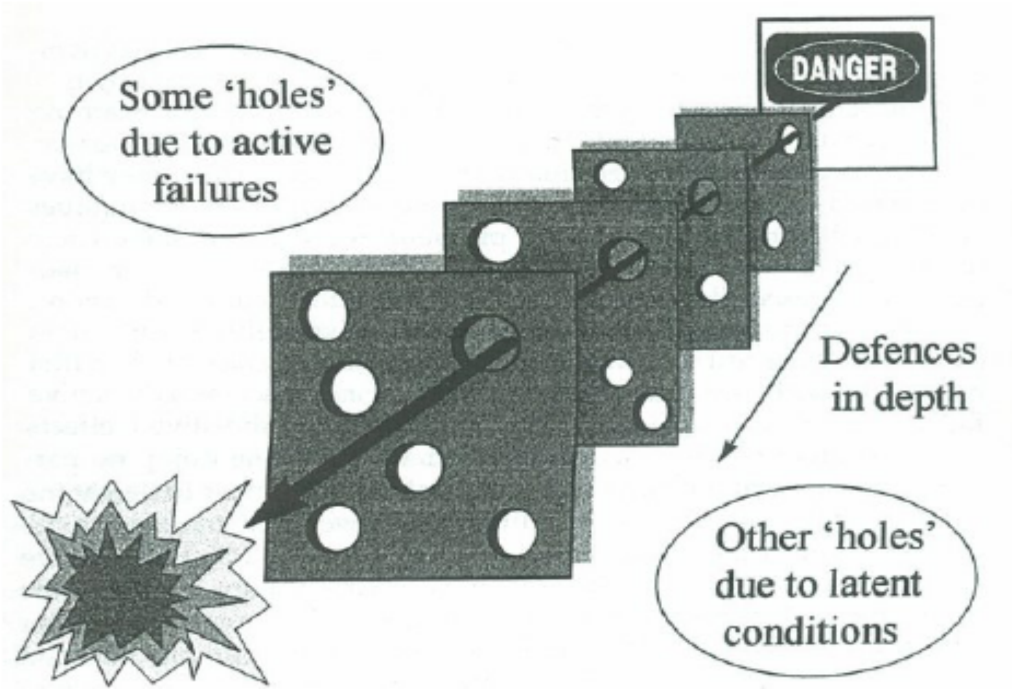

Figure 7: Reason's Swiss cheese accident causation model (Reason 1997, p12)

New terms such as 'pre-condition for unsafe acts', 'active failure' and 'latent failure' appeared. The term 'unsafe acts' still remains in use but is followed by some understanding of why they are happening (e.g. attentional failure, memory failure), avoiding blaming interpretation. The term 'error' loses its negative meaning when balanced against 'violation'. Dekker's 'good apple' theory puts the human in the center of a system and places human errors as a symptom of a failing system (Dekker, 2002). According to him, the way human error should be investigated is by putting oneself in the situation of the operator and trying to understand why that person took the decisions that were taken at the time and most of all, why they made sense (Dekker, 2006). The key is to avoid hindsight bias (Dekker, 2002, 2006; Dismukes et al 2007), because it will "*forever keep you* *from really understanding human error*" (Dekker, 2006, p28). Dekker's approach on understanding human error has been widely approved, used and adapted. Maurino's comment on this book was "*this is the kind of message the industry needs to listen to".*

Investigating human error following the 'Good apple theory', i.e. considering the human as part of a system, understanding the environment in which the operator (pilot, air traffic controller, maintenance engineer) is performing, corresponds more to Edward's definition of human factors. Human error is a symptom of the system, i.e. the human should not be considered without its environment. Human performance should be analyzed within context, without neglecting organisational influences (Maurino, 2000). The SHEL model (see figure 8), developed by Edwards in 1972 and later adapted by Hawkins illustrates what this environment is. It "*addresses the importance of human interaction*" and "*helps the investigator apply the Reason model on accident causation, which treats the accident as an outcome of a series of interactive and enabling events*" (ICAO, 1993, p16). The most critical component is the Liveware in the centre (human operator). It is surrounded by Liveware (other humans), Software (rules, regulations, procedures), Hardware (aircraft, equipment, displays) and Environment (internal and external environment such as weather, terrain but also the economic, social, politic context in which the operator is performing). Investigating human factors consists of understanding the interfaces between those components and considering the Liveware means understanding human performance within this environment.

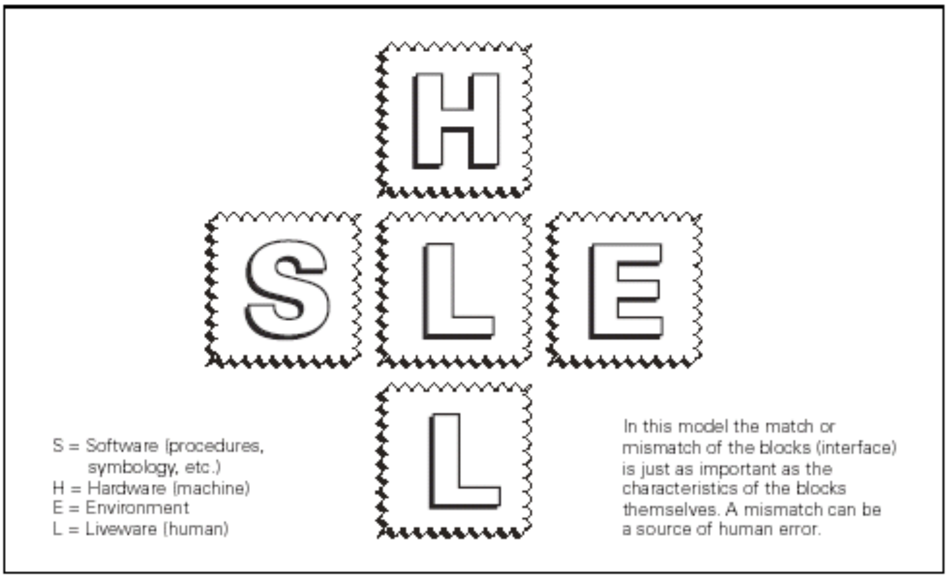

Figure 8: SHEL model, adapted from Hawkins, 1975 (1993, ICAO Digest n°7, p16)

In Safety I, or reactive approach, investigating Human Factors would mean understanding what went wrong between each of the components. Safety II however, would look at where the barriers in place or the interfaces were effective and avoided a dramatic outcome.

Up to the 1990s (when Reason published his accident model), it was more about investigating the human factor (e.g. Beaty, 1969) that was in focus, i.e. studying the pilot's behavior to understand what he did 'wrong'. The human error was attributed to either a failure in the technology or a human error (Maurino, 2000). But nowadays, human error should be considered the starting point of an investigation (Dekker, 2002; Maurino, 2000). Findings should lead to "*error tolerance and error recovery*" rather than "*error suppression*" (Maurino 2000, p956); because error is human.

Although there has been a real effort to reduce blame of a single individual in accident reports, a lot of investigators consider 'the human factor' or 'human error' as one of the most common causes for accidents (Rollenhagen et al, 2010).

Contemporary investigation should understand that error is normal to human performance (Dismukes, 2010, in Salas and Maurino). Baker (2010) emphasizes the fact that although the field of human factors is increasingly taken into account, "*there is still a degree of apprehension*" (p28-3) and it is still considered as "*speculative*" and not as credible as other disciplines. The shift in safety described in II-3 will only be possible if investigators acknowledge the importance of human factors and consider it as a 'core discipline'. They need to address the collective as opposed to the individual. Often investigators fail to address the 'why' properly because they stop too soon. Deeper consideration of human factors is necessary (Maurino, 2000, Kletz, 2006,, Baker 2010), because if HF issues are ignored, they cannot be learned from for the future (Baker, 2010).

II- 4- 3 HF investigation in practice

Several guidelines for how to consider human factors exist. ICAO published two documents outlining human factors and human factors training for accident investigators: ICAO "Human Factors digest n7: investigation of human factors in accidents and incidents", published in 1993, and the Human Factors Training Manual published in 1998.

The first one provides general information on the purpose of investigating human factors and guidelines on how to conduct such an investigation. It suggests the use and application of Hawkins's SHELL model (1975) (see figure 8) and Reason's Swiss cheese model (see figure 7) and provides checklists and solutions to existing issues such as the belief that human factors is too soft and human nature cannot be changed. It also suggests more training for accident investigators, in order to get a better understanding and therefore a better consideration:

"Better Human Factors training for investigators will develop a more thorough understanding of what the investigation of Human Factors entails" (ICAO, 1993, p4).

The other main relevant document is ICAO's HF training manual, doc 9683, published in 1998. It presents contemporary aviation human factors and the importance of a systemic approach. It dedicates its chapter 4 to HF training for accident investigators. However, like digest n7, it uses the Swiss cheese and SHELL models as main model, which is limiting. For example, no detailed information is given about what information should be collected.

Reason's Swiss cheese model (see figure 7), published in 1990 was the first accident model introducing active and latent failures. And although Edwards approached it earlier in his SHELL model (see figure 8), Reason also developed the importance of environment and organisational factors. Numerous organisations have adjusted this model for their need. The ATSB has adapted it and train all their investigators in the use of their new model. However, some researchers have identified limitations to Reason's model. Dekker (2006) considers it as an oversimplification of an accident. It focuses too much on the holes (failures) and does not allow the consideration of the whole system. According to Dekker, the Swiss cheese model does not explain why a system failed nor allows an understanding of why the operator's decisions made sense at the time of the event.

It is important to note that this model was only a small part of Reason's work and that he was one of the first to advocate the importance of effective risk management and that human error can be moderated but not eliminated (Reason, 1997).

Wiegmann and Shappell (2003) consider that Reason's model does not give any indications of what the failures are or how to identify them. They also mention that its academic tone is not easily applicable by practitioners. It is with these limitations in mind that they adapted it to create their analysis tool: Human Factors Analysis Classification System (HFACS).

Since the 1980s, there has been a major increase in the number of human factors trainings developed for aviation operators (Edkins, 2005). Human factors training has proven itself effective in the aviation industry, with for example the evidence of better human performance after Crew Resource Management (CRM) training (Salas, 1999). Although Edkins (2005, in Harris and Muir) highlights the lack of cost effectiveness evidence for human factors training, he suggests the consolidation of the "*existing evidence on the commercial benefits of human factors training*" (p 117, 2005). In the UK rail industry, Rose (2009) and Evans (2013) published research on the development of a human factors investigation course. The latter reports the positive impact of human factors awareness training on accident investigators. The results of the research include evidence of a better investigation process and improvement in the way organisations consider and investigate human factors. Rose's (2009) training was aimed at line managers at Network Rail, in the form of an e-training and its impact has not been fully identified yet. There has not been any published research on the benefits of human factors training for aviation accident investigators.

The quality of the training is also of essential importance. Braithwaite's (2004) identification of the need for training accreditation would be even more relevant in human factors. There are numerous training programs available for accident investigators but only a few of them provide a follow up on their effectiveness, or refresher courses to allow investigators to stay up to date. Besides, each of these courses is different in content, length and focus. There has been no published research on the sort of knowledge air accident investigators should acquire in human factors nor to what extent they should apply it during an investigation. Rollenhagen et. al. (2010) are some of the only researchers giving some specifications on the type of human factors training accident investigators should receive. They discovered that Swedish investigators often had, within each other, different understanding about human factors and safety culture, which therefore should be approached more accurately during training.

In 1997, Wiegmann and Shappell developed a taxonomy of unsafe operations to facilitate the investigation of human error that evolved into a worldwide use and adapted analysis tool: HFACS. It was created with the intention of making human error investigation accessible and understandable to general investigators and bridge the gap between theory and practice (Wiegmann and Shappell, 2001, 2003). Saleh et al (2010) also recommend greater partnerships between academia and other parties (industry and government) in order to develop better research and education and enhance safety. They also emphasize the need for more interactions between the different academic disciplines that could be involved in accident investigation research and system safety. Rollenhagen et al. (2010) found that amongst one hundred Swedish accident investigators from different sectors, only a few of them actually knew about the different academic models available.

As mentioned earlier, accident models have evolved from linear to more systemic approach. In the literature, a lot has been developed on these systemic accident analysis methodologies (Reason, 1990; Rasmussen 1997; Hollnagel, 2004; Salmon et al, 2012; Underwood and Waterson, 2013). In fact, according to Salmon et al (2012), HFACS, Accimap and Systems-Theoretic Accident Model and Processes (STAMP) (Leveson, 2004) are the three analysis methods that dominate HF research. However, the way Wiegmann and Shappell (2003) noted regarding the Reason's model low applicability, Underwood and Waterson (2013) identified a gap between theory and practice (i.e. safety practitioners do not always practically employ these analysis methods) that needs to be bridged in order to investigate accidents more thoroughly and develop safety recommendations addressing systems failure.

Strauch (2002) provides guidance on how investigators should understand, consider and investigate human factors by providing comprehensive definitions and information on error within a complex system, as well as guidance on data gathering and analysis.

HF should be considered as a core discipline and dealt with by experts. In 2002, the CAA published its Fundamentals in Human Factors concepts. It stipulates (2002, chapter 2, page 1):

> "*Curiously enough, we retain a lawyer for advice about a legal problem, or hire an architect to build a house, or consult a physician when trying to establish the diagnosis of a medical problem, but when it comes to solving Human Factors problems, we have adopted an intuitive and in many cases perfunctory approach, even though many lives may depend on the outcome. A background of many years of industry experience or thousands of flying hours may have little or no significance when looking for the resolution of problems which only a thorough understanding of Human Factors can provide.*"

There is no reason why this principle should not apply to human factors in accident investigation (ICAO, 1998). Being a human being does not make oneself a human factors expert. Baker (2010) also supports the presence of human factors experts but for a different reason: "*To accept the principle that anyone with training can conduct human factors investigations, is to denigrate the role of human factors in the investigations and is also likely to lead to the collection of data of a lower quality than the one that might otherwise have been achieved*" (p28-4). Besides, the presence of a human factors specialist within the investigation team would bring more assurance of the objectivity of the conclusions drawn from the investigation i.e. that the results are not the subject of only one individual's point of view and do not come from biases or preconceived ideas (Baker 2010).

II- 4- 4 Human Factors Integration

The importance of integrating and applying human factors is not limited to air accident investigation. As identified previously, Rose (2009) and Evans (2013) conducted research on HF training for investigators and managers in the rail industry. Similarly, regarding accident investigation, the importance of taking a system approach and considering organisational factors is applicable to a range of industries beyond aviation. This is illustrated by the wide variety of research that has employed or adapted the Reason's Swiss Cheese model (Larouzee and Guarnieri, 2015) or Wiegmann and Shappell's tool HFACS. For example, Ren et al. (2008) and Fukuoka and Furusho (2016) applied the latter in the context of the maritime industry whereas Jennings (2008) applied it in defence. Conversely, Kamoun and Nicho (2014) used a similar approach in a healthcare setting.

The challenges faced by human factors in air accident investigation are also common to other industries. Meister (1967) found that engineers and designers lacked interest in human factors due to the fact that it is a social science. Later research by Meister (1982) pointed out that engineers and government personnel were not convinced about the value of HF and were lacking training on the topic. More recently, Helander (2000) found that there were a number of possible reasons why HF was not implemented, including consideration of HF as common sense and being too abstract to be useful. Waterson and Kolose (2010) found that this attitude of considering HF as common sense still remains. In 2011, Peterson et al pointed out that in the maritime industry, engineers need to acknowledge that social sciences such as HF are more than common sense but that in order for HF to have more impact, HF experts need to understand the heuristic nature of engineering.

Perrow's work (1983), cited by Jensen (2002) and Dul and Neumann (2005, 2009) attribute the difficulty of HF acceptance to organisational issues. Amongst these issues is the small number of ergonomists actually working for these companies and that it is not always accepted by business managers. These problems limit HF specialists' influence and restrict their perspective.

Moreover, the integration of human factors is not only important in the investigation process (i.e. considering the human within a system) it is also essential from the design of a system to its manufacture and in turn to its operation and possible failure (i.e. investigation). As an example, Cullen (2007) highlights that it is essential for the designers in high hazard industries to integrate HF in the early design phase of a system, i.e. consider the system end users in order to avoid operational problems and in turn potential safety issues. Thus, multiple sectors such as aviation, rail, nuclear, defence and also healthcare rely on quality Human Factors Integration (HFI) to produce safe systems.

Seeing that HFI is as essential in other industries as it is in aviation and in air accident investigation, and that many challenges are shared amongst these sectors, the benefits of the research for other industries are clear.

II-5 Conclusion of the literature

As demonstrated in this literature review, accident investigation is strongly related to safety and to human factors. The shift of focus, the evolution of the aviation system as well as the evolution of human factors occurred at the same time and are complementary. Addressing the challenges faced by investigation organisations such as independence, blame-free policy, dealing with relatives, quality of investigators, training, public trust and the improvement of safety could be greatly assisted and benefit from a full acknowledgement, understanding and integration of human factors.

Much has been developed on the importance of human factors, human factors integration and the need for more thorough HF investigations. A large part of the existing literature also focuses on accident investigation cases and methods and tools for accident analysis, in multiple high hazard industries. Numerous methods have been developed in order to assist accident investigators in their task. According the Sklet (2004) these analytical methods may be needed to help the investigators to organise and structure all the data from an accident and be able to understand the complexity of the system involved (multiple and inter related causal factors). Each of them can be used at the different stages of the investigation, have different areas of application and have strength and weaknesses as described by Sklet (2004). He therefore suggests the use of several analysis methods for a more thorough investigation and the necessity to have, within the multi-disciplinary team, one person familiar with these tools in order to make a relevant selection depending on the circumstances of the event.

In fact, whether the tools and methods created for accident analysis are human factors orientated or not, they are not always accessible or relevant to the needs of accident investigators who often don't have the academic mind that the developers of these tools have. Although some efforts are being made, the industrial constraints are not always taken into account and there is a need to bridge the gap between academics and the industry (Dien et al, 2012). Some researchers such as Saleh et al (2010), Rollenhagen et al (2010), and Underwood and Waterson (2013) have identified the need for more partnership between academic and industry worlds so accident investigators are more aware of the tools available and how to use them. Such partnership could also enable the development of more practical tools. Underwood and Waterson (2013) insist on the fact that more effort should be made to ensure that systemic accident analysis tools meet the needs of practitioners.

This weakness in training is also present in the actual meaning of human factors (Rollenhagen et. Al., 2010).

But overall very little is made explicit about the type of knowledge investigators should acquire, the sort of training they should receive in HF in order to conduct relevant HF investigations and whether organisations should hire an expert. (Rollenhagen et. al. 2010). Training requirements do exist but no standards have been defined and this creates different level of understanding and therefore disagreement on the depth into which HF should be looked into during an investigation. There is a need to keep asking why (Kletz, 2006), which naturally raises the challenge of the scope of the investigation: the depth to which accident investigators need to dig in order to understand why operators behaved the way they did at the time of the event and why it made sense to them.

Original human factors problems create new ones and this will continue to happen with, for example, the development of automation.

Human factors has been demonstrated as an essential part of accident and incident investigation. There are several guidelines provided by ICAO or regulators regarding the importance of these issues but there are no strict requirements regarding how to integrate them in investigation reports. This could be one of the reasons why it is not always acknowledged in a satisfactory way. It is likely that there are other factors involved, but they remain unclear. Moreover, no practical solutions to address these issues have been provided. This research is attempting to address these deficiencies and bridge this gap between research and industry, in other words providing practical recommendations on how to better integrate HF in an accident investigation.

Chapter III – Research design

III- 1 Introduction

Chapter III details the research design adopted for the thesis, which represents the plan to conduct the research (Creswell, 2009). It is influenced by three key related elements: the research paradigm, the research objectives and the research strategy. Each of these three elements is outlined in following section. This is followed by addressing the methods of data gathering and the analysis employed to fulfil the aim of this research, which is:

To examine the training needs of air accident investigators in order to develop more thorough integration of human factors in accident investigations.

The final part of this chapter describes the role of the Training Needs Analysis (TNA) process and its application to the research.

III- 2 Research Design

Three important components are involved in constructing the research design: the research paradigm (also commonly referred to as the philosophy or 'worldview' of the researcher), the research objectives that help accomplish the goal of this thesis, and research strategy. The research design for this thesis is presented in figure 9.

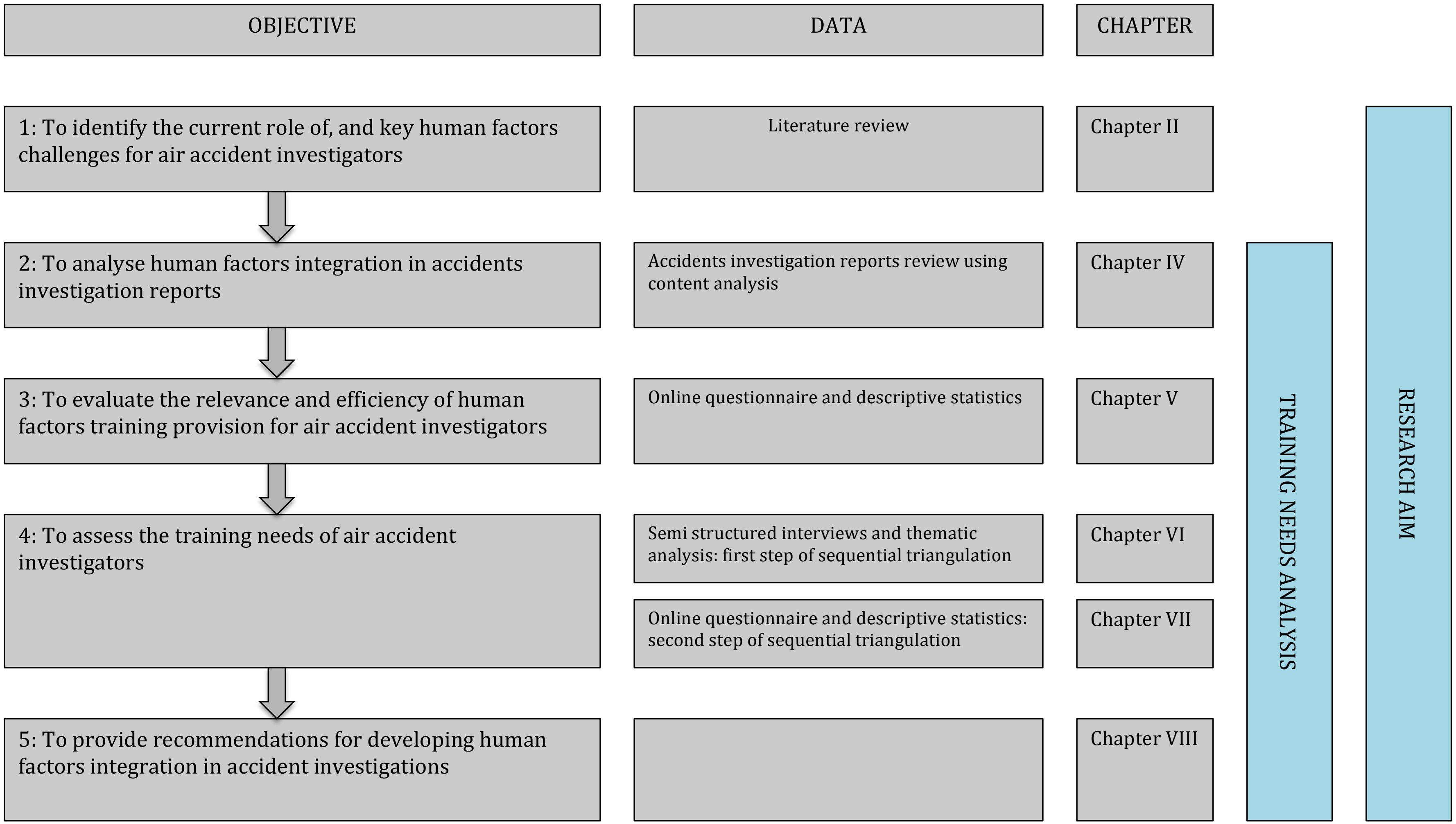

Figure 9: Research design

III- 2- 1 Research paradigm

The research paradigm, also called a researcher's 'worldview', represents the assumptions taken by the researcher on their belief and view of the world (Creswell and Plano Clark, 2007). It is important to establish this research paradigm at the start because it will have an effect on how the research is designed and conducted, i.e. which methods are employed to fulfil what objectives. These worldviews are defined and categorised by a range of different elements known as ontology, epistemology and methodology (Healy and Perry, 2000; Creswell and Plano Clark, 2007). While ontology represents the nature of the reality being investigated, epistemology defines the relationship between the researcher and the research. The methodology is the process by which the research is conducted.

In the literature, four main paradigms are developed (Healy and Perry, 2000; Robson, 2002; Creswell and Plano Clark, 2007; Denscombe, 2008; Creswell, 2009; Bryman, 2012). These can broadly be viewed as representing part of a continuum (Newman and Benz, 1998), with purely quantitative approaches sitting on one end of the scale and qualitative techniques on the other (see figure 10). A purely quantitative approach to research can be referred to as a 'positivist' approach. Positivism adopts a quantitative and deductive approach to research, stating that research should place value on objectivity and rigour, as opposed to subjective intuition. A researcher with a positivist view separates him/herself from the world they are studying. There is a need to identify and assess cause-effect relationships, in the most objective way, to obtain objective conclusions on the reality. This is to say that there is an objective 'truth' which the researcher seeks to find.

Worldview element	Positivism	Pragmatism / Realism	Advocacy and Participatory	Constructivism
Ontology	Reality is real and apprehensible	'Real-world' research: Reality is real but imperfectly and probabilistically apprehensible	Political reality	Multiple realities
Epistemology	Objectivist: true findings, researcher separated from the world that is being investigated	Objectivist and Subjectivist (modified objectivist): researcher collects what works to answer the research question	Subjectivist / Collaboration: Researcher involves participants	Subjectivist researcher and reality are close and inseparable
Methodology	Deductive (verification of theories)	Deductive and inductive	Mainly inductive	Inductive (generation of theories)

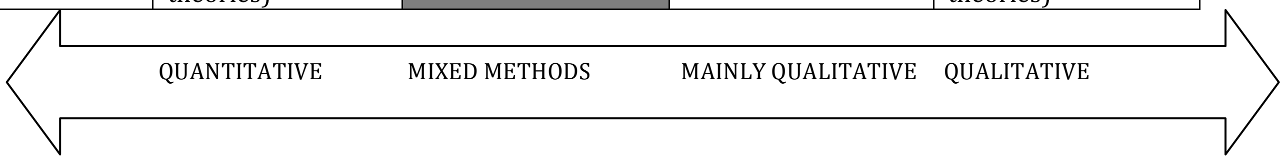

Figure 10: The research paradigm continuum (adapted from Healy and Perry, 2000, p119; and Creswell and Plano Clark, 2007, p24)

At the other end of the spectrum sits constructivism, which embraces a purely qualitative approach and adopts an inductive approach to research. This means that theory is generated from individual perspectives. In contrast to the positivist paradigm, a researcher following a constructivist philosophy acknowledges the close link between himself/herself and the research, and that multiple 'realities' exist deduced from observations of reality (i.e. an inductive logic).

There are two further schools of thought that adopt different elements of both the positivist and constructivist paradigms to varying degrees. They acknowledge the value of adopting a mixed-methods approach. Researchers following an advocacy and participatory philosophy position themselves more on the qualitative side of the spectrum, advocating an ontological position that there exists a political reality, with a mostly subjectivist epistemological standpoint. Like constructivist philosophies this also adopts a largely inductive logic (Healy and Perry, 2000; Creswell and Plano Clark, 2007; Creswell, 2009).

The remaining paradigm located on the spectrum is commonly referred to as pragmatism, or realism. It too can be considered as a mixed-methods approach, adopting both qualitative elements but also quantitative components (more so than advocacy and participatory). Like positivism it claims that there is an objective 'reality', but that this reality is imperfectly and probabilistically apprehensible (Creswell and Plano Clark, 2007). In other words, there remains an inescapable question mark (however small) regarding the absolute 'truth' of the observed reality. As a paradigm it seeks to remain largely objective throughout, whilst acknowledging that subjectivity and external factors exist within research. It can also adopt either a deductive or inductive methodological approach.

With this in mind, this research positions itself in the pragmatism paradigm (greyed on figure 10). It uses a mixed-methods research design, which means it recognises the importance of both qualitative and quantitative research methods. It uses all the approaches available to understand and solve the problem (Johnson and Onwuegbuzie, 2004; Johnson et al. 2007; Creswell, 2009). Creswell and Plano Clark (2007, p18) describe this research design:

"*Mixed methods research is a research design with methodology and methods. As a methodology, it involves collecting, analysing, and mixing qualitative and quantitative approaches at many phases in the research process … As a method, it focuses on collecting, analysing and mixing quantitative and qualitative data in a single study or series of studies*."

While it is useful to categorise research paradigms in this way, it is acknowledged that 'real-world' research often does not fall neatly into any particular category. It may be that different parts of the research lend themselves to different paradigms, or that different parts of various paradigms appeal to the researcher. It may also be that different researchers with different paradigms may approach the research differently. Having said this, considering the researcher's philosophical view of the world, a pragmatic view is adopted here to fulfil the aim of the research. Its pragmatic approach necessarily focuses around the problem, and the questions (or objectives) asked are of primary importance to the methods adopted.

III- 2- 2 Research Objectives

The second element that occupies a large part in the research design are the objectives. Fulfilling these objectives is how this research contributes to knowledge: they are the steps the research is taking to fulfil the aim, a list of tasks to accomplish the goal of the research. These objectives are extremely important since they strongly influence the strategies, or methods, employed to reach the aim of the research. The objectives guiding this research are listed in figure 9 and are as follows.

1- **To identify the current role of and key human factors challenges for air accident investigators.**

A review of the literature was undertaken in chapter II to consider the context of aviation safety within which accident investigation and human factors are essential elements. The challenges faced by accident investigators and their organisations are identified.

2- **To analyse human factors integration in accident investigation reports.**

Chapter IV presents the review of accident investigation reports using content analysis, and evaluates the consideration and integration of human factors within it.

3- **To evaluate the relevance and efficiency of human factors training provision for air accident investigators.**

In chapter V, a survey by means of an online questionnaire was conducted amongst the air accident investigators' community to examine the content and efficiency of their current training in human factors.

4- To assess the training needs of air accident investigators.

Chapter VI and Chapter VII together fulfil this objective using a methodological triangulation. Chapter VI presents semi-structured interviews completed with human factors investigators. Given their different views on different points, and the somewhat subjective limitations of qualitative analysis of interviews, another questionnaire was conducted with the same participants in Chapter VII. This allowed the development of valid findings regarding human factors expertise involvement and training provision for accident investigators.

5- To provide recommendations for developing human factors integration in accident investigations.

Chapter VIII provides a discussion and conclusions on the use of TNA on the way accident investigation organisations should integrate human factors, via expertise, training and methodology.

III- 2- 3 Research Strategy

The third element that influences the research design is the strategy used to fulfil the objectives. It represents the different methods used to answer the research question, which could be called the 'plan of action'. While the research paradigm determines the type of methods that are used, the research strategy determines the actual methods that are employed.

From the beginning it was possible to discount a number of possible research strategies. For example, given that the research concerns current events, archival or historical analyses were discounted. Purely experimental designs were also not considered given that these require the researcher to have full control over events in the study so they can be replicated. Given the philosophical position of the researcher, (i.e. the adoption of a mixed methods approach), the objectives, the findings from the researcher's previous study, and the conclusions emanating from the literature review, an adaptation of a Training Needs Analysis (TNA) was selected as the most appropriate method for conducting the analysis and fulfilling the overall research aim. This technique will be used as a logical guide to link the different studies and draw conclusions about the overall purpose of this thesis. The nature of the TNA required several different methods to be used. These are introduced and discussed in detail in their relevant chapters. However, the overall justification for the use of TNA as a broad strategic approach to conducting the research is presented here. The role of the TNA and its relationship to the thesis is shown in figure 9. An introduction to TNA, its purpose and the process for conducting a TNA are addressed in the following section.

III-3 TNA

This research is designed as an adaptation of a Training Needs Analysis (TNA), analysing the need for human factors training provision to air accident investigators. By gathering and analysing data from different sources of evidence, it aims to examine the training needs of air accident investigators in order to develop more thorough integration of human factors in accident investigations. This method has been chosen to attempt to answer the challenges faced by accident investigators in integrating human factors in accident investigations and bridge the gap between research and industry, identified in chapter II.

III- 3- 1 TNA purpose

Training Needs Assessment or Training Needs Analysis is a process that consists of gathering and analysing information about the need to fill a gap or improve a performance, or correct a deficiency, in order to identify whether training could meet that need. (Brown, 2002; Barbazette, 2006). It is "*an on going process of gathering data to determine what training needs exist so that training can be developed to help the organisation to accomplish their objectives*" (Brown, 2002, p569). Where it traditionally applies to one organisation or one department within an organisation, this process is here applied to air accident investigation organisations. Accident investigation organisations' objectives are to understand why an event happened without apportioning blame, and avoid similar occurrences by providing safety recommendations. Moreover, despite the fact that this tool is mainly used by human resources (Boydell, 1990; Bee and Bee, 1994) and driven by business needs, the extent of the literature on the use of TNA is very wide. Griffiths and Lees (1995) referred to TNA as a human factors analysis tool because it offered them a structured tool to facilitate information gathering and the identification of gaps between current operators performance and the one required with new technology and new design. This thesis will use this process similarly, as a structure to draw conclusions supporting the aim of the research.

TNA is the first stage of a systematic training cycle (see figure 11) and is itself a multiple stages process.

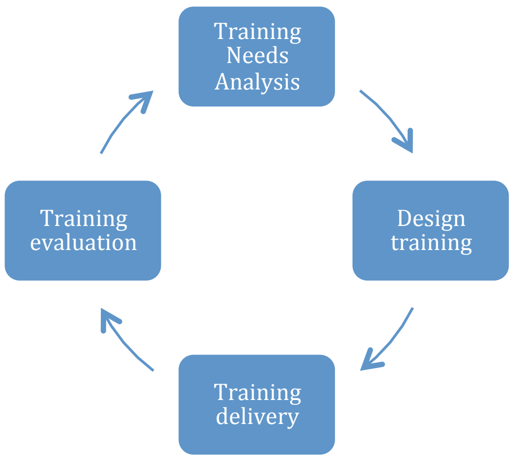

Figure 11: Training cycle, from Buckley and Caple, 1995, p27

TNA should be undertaken before training design to make sure it addresses the relevant issues and is aimed at the right people. Bowman and Wilson (2008) add that it is important to consider the needs of the individual and those of the organisation when conducting a TNA. It is also important to note that TNA can also help identify issues that cannot be solved by training and therefore suggest and provide different solutions (Brown, 2002; Barbazette, 2006).

III- 3- 2 TNA process

Barbazette (2006) describes TNA as being a three-phase process: 1- Gather information, 2- Analyse information and 3- Create a training plan that offers to resolve the performance deficiency. This structure will be followed for this thesis, however since the conclusions drawn from a specific set of data will be the basis for collecting the next pieces of information, all the information will be initially analysed independently. They will then be analysed altogether and define whether or not training is the solution to enhanced human factors integration in air accident investigations. Brown (2002) adds that a thorough analysis examines training needs on the organisational level, the task level and the individual level. Since this thesis is an adaptation of a TNA, it will focus on looking at the organisational and task levels. It means identifying the sort of training and knowledge investigation organisations need to implement to better integrate human factors.

At the task level, it consists of identifying the needs depending on the role of the investigator. TNA's purpose is to identify the gap between the performance and the job requirements and the target population (Bee and Bee, 1994; Barbazette, 2006), i.e. who should potentially undertake the training, should training needs be identified. It also enables the research to identify the deficiencies of the current training. Applied to this research, the process of TNA identifies the training needs depending on the investigators' role as well as the non-training related solutions to produce more thorough human factors investigations.

Typically, the information to gather to undertake a TNA comes from observation, questionnaires, face-to-face interviews and documentation review (Anderson, 1994; Brown, 2002; Barbazette, 2006). Consequently, the researcher's previous study in Chapter I, the literature review in Chapter II and the review of accident reports in Chapter IV are here identifying the gap between the requirements of a thorough investigation where human factors is essential and the challenges faced by the investigators to do so. The questionnaire amongst a sample of 89 accident investigators identifies the deficiencies of the current training, and the variations depending on the investigators' role. Semi-structured interviews with HF experts and HF investigators and a subsequent questionnaire conducted with these same interviewees provide valuable insight on the content of that training and on additional solutions.

III- 4 Summary

This research design is characterised by three main components: its pragmatism paradigm, or worldview, its objectives and its mixed methods approach, that follow a TNA process. Both quantitative and qualitative analysis methods are employed in order to fulfil each individual objective and overall answer the aim of the research. The purpose of the TNA is to identify the training needs for accident investigators in order to more thoroughly integrate human factors in accident investigations but also to provide additional solutions addressing these issues. The first step to identify training needs, i.e. whether training could be a solution to the challenges highlighted in the literature, is to determine whether these challenges are identified in actual accident reports by evaluating the human factors integration within these reports. This phase is presented in the following chapter, Chapter IV.

Chapter IV –Accident investigation reports analysis

IV- 1 Introduction

Accident investigation reports are the product of safety investigations. NIAs from the member states are required to publish a report based on the ICAO Annex 13 format, detailing the facts, analysis and findings from an investigation, as well as providing safety recommendations if necessary to avoid similar occurrence. Therefore, accident reports are appropriate documents to examine in order to understand how human factors issues are approached in accident investigations.

This chapter presents a content analysis of the analysis section of 15 accident investigation reports from five different NIAs. The purpose of this study is to understand how human factors is dealt with and how it is integrated within accident reports, thus fulfilling the second objective of this thesis, which is to analyse the human factors integration in accident investigation reports.

The following section presents the sample of accident reports selected to undertake this study, while section 3 describes the method of content analysis employed for the analysis of this part of the research. In turn, findings from the analysis are presented and a conclusion is provided in the final section of this chapter, section 5.

IV- 2 Accident reports

IV- 2- 1 The use of documents in research

In social research, documents, whether written, visual or oral, can be treated as data, the written format being the most common source of documentary data used (Robson, 2002; Denscombe, 2003). Document or text is a term here used to describe data, consisting of words, that have been recorded without the intervention of the researcher (Silverman, 2001).

Using documents for social research presents the advantage of being an unobtrusive method, that is to say the researcher is not present when the document is being written and therefore the person producing it is not influenced, nor his/her behaviour affected by the research (Robson, 2002).

Different types of written documents exist: books and journals, the internet, newspapers, magazines, records (e.g. official documents from organisations), personal documents such as letters, memos and diaries, and finally official government publications or documents, such as official reports (Denscombe, 2003; Bryman, 2012). While books and journals are often valued from an academic point of view due to the peer review process they undergo, the credibility and authenticity of sources from other sources, such as the internet, can be harder to establish.

Accident investigation reports can be considered as official government publications since NIAs are governmental agencies, although they must also remain independent from the state and the regulator (see Chapter II). In the UK for example, the AAIB is part of the Department for Transport. Analysing official publications such as accident investigation reports published by NIAs presents numerous benefits for the researcher. These documents are credible and authoritative, since they are produced by experts investigators employed by the state (Denscombe, 2003). They are also necessarily objective and impartial, which is an essential attribute of safety investigation. As identified in chapter II, all accident reports must also be independent and blame free, as stipulated by ICAO Annex 13.

Nonetheless, a number of considerations need to be taken into account when using documents as a source of evidence. Namely, as a researcher it is important to assess a documents authenticity, credibility, representativeness and meaning (Denscombe, 2003).

In this context, authenticity reflects the genuine nature of a document to ensure that it has not been copied or reproduced in some way. Here, reports were downloaded directly from the website of the NIA in question to ensure that the reports studied were original. Credibility is here ensured as far as possible by the fact that the reports are written by trained investigators who, as part of their role, have to limit biases and conduct blame-free investigations, which are published by independent NIAs. It is recommended that the subsequent reports are then published following the format outlined in ICAO Annex 13. The reports selected for examination in this research are representative and typical of this approach. Moreover, as each analysed document reports an occurrence of its own, there can be no relationship existing between the reports. Thus, the analysis could not ignore the context of each accident. Finally, considering that accident reports are aimed at the industry and the public, their meaning has to remain unambiguous, accessible and understandable to non-experts.

IV- 2- 2 Accident report format

After an accident or serious incident, the NIA is notified and then must decide whether to conduct an investigation. While ICAO Annex 13 (2010) provides international standards and recommended practices on how to conduct as investigation, it is the responsibility of the relevant national or international regulator to adapt and enforce them. For example, in Europe, EASA enforces Annex 13 guidelines via EU996/2010 (see Chapter II). The latter document, and part IV of ICAO's manual of Aircraft Accident and Incident Investigation (doc 9756, 2003b) give, amongst other documents, clear and detailed guidance on the format of the final report that needs to be published after the investigation. The purpose of this is to provide a standardisation on the most appropriate and relevant way to present a final report from an accident investigation (ICAO, 2010). The first part of the report should therefore contain factual information, which provides the evidence gathered and explained regarding the event, and enclosing the following:

- History of flight
- Damage to aircraft and other damage
- Personnel information
- Aircraft information
- Meteorological information
- Aids to navigation
- Communications
- Aerodrome information
- Flight recorders

- Wreckage and impact information
- Medical and pathological information
- Fire
- Survival aspects
- Tests and research
- Organisational and management information
- Additional information
- Useful or effective investigative techniques

The second part of the report is the analysis, which details the analysis of relevant factual information covered in the first section. It should also make clear what is pertinent for the determination of conclusions and causes. It is this second part of the reports that is being analysed in this study. The third part of the report lists the conclusions, which are findings and causes (immediate and systemic), based on the previous analysis. The fourth part of the final report states safety recommendations if appropriate to the occurrence. A common approach to document analysis is content analysis (Robson, 2002) and is detailed in the third section of this chapter, section IV- 3.

IV- 2- 3 Sampling

In order to get a rich understanding of the content of human factors in an investigation, and identify the type of attributed causes that investigators considered important to the occurrence, the researcher focussed only on the analysis section of each report (Cedergren and Petersen, 2011). Overall, 15 accident reports were selected for analysis from reports published by five different NIAs (three for each organisation). The process by which these were selected is explained below.

Accident investigation reports from NIAs are published on their respective website after the investigation and are therefore available to the public. It was decided to analyse reports from accidents or serious incidents, where the final reports are commonly made available. Additionally, only fixed-wing, scheduled passenger commercial aircraft occurrences were selected, and not cargo or general aviation occurrences. This was due to the higher public interest and media attention usually associated with the former, meaning that full-scale investigation reports are not always generated for general aviation instances.

According to ICAO Annex 13, the state in which the instance occurred is responsible for undertaking the safety investigation of the incident or accident, and is responsible for publishing the final report. Additionally, the nationality of the aircraft manufacturer, the operator and/or the state where the aircraft was registered may all send accredited representatives to assist the investigation and sometimes publish their own reports.

Consequently, when selecting the reports on which to base the analysis a balance had to be reached between methodological considerations regarding the need for a broad, representative sample on the one hand, and more pragmatic considerations concerning the accessibility of the reports and the time required to conduct the research on the other hand. This approach involved an element of subjectivity on the part of the researcher, in that a decision had to be made regarding which reports (and by association NIAs) were included in the analysis, and conversely those which were to be excluded.

With this in mind, it made sense to focus on reports from NIAs based in mature (and by association), larger air transport regions. They also needed to be current members of ICAO. The rationale for this was to maximise the spread of the sample in terms of geographical coverage and the number of flights included, as well as ensuring that the reports studied had all been published recently under current ICAO Annex 13 guidelines. Given that the analysis sought to assess up to date, contemporary use of human factors in accident investigations, it made little sense to focus on reports from relatively minor NIA whose most recent reports may have been published some years ago. Additionally, since NIAs in mature regions are more likely to lead and influence 'best practice' in accident investigation and reporting in smaller regions than vice versa, it made sense to focus on the former.

According to IATA, the United States is the largest scheduled passenger air transport market in the world, with over 632 million passengers handled in 2014 (IATA, 2015). In Europe, the United Kingdom is the largest scheduled passenger market (188 million passengers), while South Africa is the largest in Africa (over 20 millions). Additionally, Australia is the largest market in the Southwest Pacific region (84 million passengers). Consequently, the NIA from each of these key markets was selected for inclusion in the analysis: the NTSB (United States), AAIB (United Kingdom), the Accident and Incident Investigation Division (AIID, South Africa), and ATSB (Australia).

Ideally, it would also have been beneficial to analyse reports from China (the largest passenger market in Asia), Saudi Arabia (Middle East) and Brazil (Latin America). However, these reports were not freely available in English via the respective agency websites, which made them difficult to analyse.

To address this potential limitation, a fifth NIA, the Bureau d'Enquetes et d'Analyses (BEA) from France was included in the analysis. While representing only the 5th largest passenger market in Europe in terms of scheduled passengers handled (IATA, 2015), Airbus, one of the two largest commercial aircraft manufacturers in the world, is based in France (the other manufacturer, Boeing, is based in the United Stated, which was already included in the study). Collectively, Airbus and Boeing aircraft account for the majority of air passenger traffic worldwide (IATA, 2015). Given that the nation of the aircraft manufacturer in question is permitted to send an accredited representative to assist the investigation, the BEA was added in the sample accordingly as representing a 'mature' organisation.

The selection of NIAs for inclusion in the study also related to the variations in their organisational structure, and how this may relate to how human factors is addressed within them. The ATSB and NTSB are both multi-modal organisations, which means that they investigate all type of transportation accident (air, rail, marine and sometimes road) whereas the BEA, the AIID and the AAIB only conduct air accident investigation and are therefore considered unimodal. Baxter (1995), Cedergren and Petersen (2011), Stoop (2004) suggests that the multi modal format is the most beneficial way to undertake transportation accident investigation because it enables the sharing of resources, particularly in technical investigative specialties such as human factors and human performance, which are believed to be non-modal specific and where the knowledge can therefore be applied across all modes. Furthermore, multi-modal organisations may also emphasize the fact that accidents are not isolated technological events that can be understood in their specific context (Jakobsson, 2011). Collectively, human factors and particularly methodology could therefore become a priority in the investigation, and thus lead to more harmonised investigations (Stoop, 2004; Jakobsson, 2011).

There are nevertheless arguments against the multi-modal format, such as the loss of in-depth knowledge and expertise specific to the mode (Stoop, 2004). This can be overcome to some extent with multi-modal organisations, like the ATSB, who still have human factors experts specialised in one mode. Selecting both multi (ATSB, NTSB) and unimodal (AAIB, AIID, BEA) NIAs for the analysis provides a more representative sample of how human factors is investigated in main accident investigation agencies. Of the NIA selected, the 3 most recently published reports (prior to January 2016) were selected for the analysis. This gave a total of 15 reports in total, which are summarised in table 3, including the dates of occurrence. The pages of the analysis are indicated for reference purposes.

Report number	Pages of analysis section	Organisation	Human factors expert involved (as indicated on the report)	Date of accident	Accident
1	82 to 103	AAIB	Yes: external	24-05-2013	Accident: Fan cowl doors from both engines detached from the a/c, causing damage. Return to land, fuel leak, fire.
2	56 to 67	AAIB	No	16-04-2012	Accident: Smoke warning in cargo hold despite extinguishers triggered, Return to land, injuries during evacuation
3	23 to 26	AAIB	No	26-09-2009	Serious incident: Crew took off from wrong taxi intersection
4	77 to 125	NTSB	Probably in-house specialist	06-07-2013	Accident: Descent below visual glide path and impact with seawall
5	40 to 58	NTSB	Probably in-house specialist	20-12-2008	Accident: Runway side excursion during attempted take off in cross wind conditions
6	78 to 118	NTSB	Probably in-house specialist	15-01-2009	Accident: Loss of thrust after bird strike, and subsequent ditching
7	86 to 98	BEA	Yes: external and only for fatigue issues	29-03-2013	Accident: Un-stabilised approach, runway overrun
8	44 to 49	BEA	No	16-10-2012	Accident: Longitudinal runway excursion during landing on a runway contaminated by water
9	167 to 195	BEA	Yes: HF working group including external experts and investigators	01-06-2009	Accident: Loss of control and stall after pitot probes obstruction, impact with the sea
10	131 to 141	ATSB	Yes: in-house	04-11-2010	Accident: In-flight uncontained engine failure
11	75 to 90	ATSB	Yes: in-house	20-03-2009	Accident: Tail strike and runway overrun
12	191 to 211	ATSB	Yes: in-house	07-10-2008	Accident: In-flight upset
13	82 to 130	AIID	Unknown	22-12-2013	Accident: Collision with building near taxi lane
14	103 to 118	AIID	Unknown	07-12-2009	Accident: Runway overrun
15	8 to 9	AIID	Unknown	03-05-2008	Serious incident: Tail strike

Table 3: Reports selected for the analysis

IV- 3 Content analysis

IV- 3- 1 Definition

Qualitative research is the "*kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification*" (Strauss and Corbin, 1990, p17). Robson (2002) noted that there are four broad approaches to qualitative analysis; quasi-statistical, template, editing, and immersion, as presented in table 4. These four approaches can also be put on a continuum regarding their objectivity: from very objective (nearly quantitative) to more subjective (high level of interpretation from the researcher).

Type of analysis	Example of method	Attributes
Quasi statistical	Content analysis	Word and phrase frequencies in the text Transform qualitative data into quantitative format
Template	Thematic analysis	A priori codes (but flexible because can be changed) called 'templates' used to categorise parts of the text
Editing	Grounded theory	No a priori codes Codes developed on the researcher's interpretation of patterns in the text
Immersion		Least structured Very interpretive Emphasizing researcher's insights

Table 4: Types of qualitative analysis approach (based on Robson, 2002)

All of these analytical methods involve coding the text to be analysed (Robson, 2002), in a more or less flexible way. A 'code' consists of different categories, or themes, to which specific bits of the data will be assigned. To run a more objective analysis, the code is determined prior to the analysis, based on previous research or theories. In this instance, the coding process is used to organise and objectively describe the content of communication (Berelson, 1952 in Bryman 2012; Kondracki et al, 2002). At the opposite end of the spectrum, methods such as grounded theory develop codes as the analysis is being conducted and can be considered as less objective because it involves greater interpretation and insight from the analyst. The particularity of grounded theory is that it allows the researcher to build, as opposed to test, theories.

For this study, it was considered important that a more systematic, objective approach was used in order to generate objective, and comparable research findings. Content analysis was subsequently selected as the method for analysis. Content analysis is "*an approach to the analysis of documents and texts that seeks to quantify content in terms of predetermined categories and in a systematic and replicable manner*" (Bryman, 2012, p290). It is a methodology that allows the systematic, objective and quantitative description of the content of documents. Krippendorff (1980) refers to content analysis as a tool to process scientific data that needs to be replicable by other researchers (systematic) and therefore of high reliability.

Content analysis can be quantitative or qualitative, and consists of transforming text into quantitative data (numbers). For example, this may include counting the frequency of terms or words in a text and comparing it with other words or units, or coding words using numbers (weight) (Krippendorf, 1980; Bos and Tarnai, 1999; Neuendorf, 2002; Bryman, 2012). However, purely quantitative content analysis, also referred to as text quantification, has been criticised for ignoring the context and meanings of what is being analysed (Bos and Tarnai, 1999; Hsieh and Shannon, 2005).

To some extent, qualitative content analysis can overcome these limitations. Kondracki et al (2002) defines the qualitative content analysis as being a way to examine latent meanings inside the document. Bryman (2012) describes qualitative content analysis as the most prevalent approach to qualitative analysis of written documents. Additionally, he notes that the types of questions well suited to content analysis include *what* gets reported, and *how, why* and *where* it gets reported. In this sense it can be considered well adapted to the nature of this study, seeing as it seeks to evaluate what is the human factors content in accident investigation reports, and how deep it is. Moreover, according to Denscombe (2003), content analysis is suited to texts that are descriptive and factual, and less open to interpretation (as is the case with accident investigation reports).

As each accident will have different causal and contributory factors, merely counting human factors related terms (i.e. a quantitative approach) would not be a fair representation of the way human factors was approached and considered in the accident investigation. Here, *what* is being said, and *why* it is being said, are as important to the analysis as to how often a particular term occurred in the text. Ultimately, the process of content analysis, whether qualitative or quantitative, should remain a systematic tool to highlight the presence or absence of particular ideas or themes, and the extent to which they are covered in the document (Kondracki, 2002).

For this analysis of accident investigation reports, predefined categories were initially applied to the documents (i.e. a largely deductive approach). With the framework in place, the researcher then analysed passages of text around each code, how deeply it was approached in the relevant paragraphs, which brings this part of the analysis closer to a qualitative content analysis approach. This way of conducting content analysis can be broadly seen as adopting a summative approach, which starts by counting and quantifying predetermined words, and then exploring their usage (Hsieh and Shannon, 2005). This way, the study also remains consistent with the mixed-methods approach undertaken for the thesis.

IV- 3- 2 Process

The process of conducting content analysis can be summarised in very clear steps (Robson, 2002; Denscombe, 2003; Bryman, 2012): identify the research question, decide explicitly on the sample strategy, define the recording unit, develop categories for analysis, and carry out the analysis. These steps need to be applicable to all units of analysis and made explicit in order to be replicable (Krippendorff, 1980).

The objective of this chapter is to analyse the extent to which human factors is addressed in accident investigation reports. By examining the analysis section of accident reports, the study identifies the nature and scope of human factors in air accident investigation reports, as explained in section IV- 2.

Once the documents have been chosen, the text needs to be broken down into smaller units to be analysed. Here, paragraphs concerning 'human factors' were selected as the unit of analysis, and sections of text identified as concerning human factors were then analysed in more detail. Within each section, relevant categories were developed. These related to the two main topics of the human factors discipline for aircraft accident investigation, *human performance and error*, and *organisational issues* and were determined from the literature review (see also Chapter II). To help identify these categories within the text, a number of keywords related to human factors were used. These keywords were taken from the ICAO Human Factors Digest number 7, a document that focuses on human factors in incidents and accidents investigation (1993, p39 to 44, see Appendix A). This includes two checklists, A and B, which provide a complete overview of the different human factors issues that could be relevant for an accident or incident investigation. The checklists were designed specifically to assist investigators in determining HF issues that need further investigation and analysis, which make them a reliable source to identify HF content in a report. Examples of these keywords were 'fatigue', 'reaction time', 'circadian rhythm', 'stress', 'training', and procedure'.

For the purpose of the analysis, each of the keywords were searched for and identified in the text. Paragraphs containing these words were then analysed in detail to examine the context, identify how specific human factors terms were employed, whether they are explained, whether they are linked to references and whether they answer the question 'why' a specific event occurred.

IV- 4 Findings and discussion

IV- 4- 1 Findings from individual reports

Having downloaded each of the 15 reports from the investigation organisation websites, the analysis section of each report was identified and analysed using content analysis (see table 3 for list of reports). This was done by identifying the human factors content using the ICAO keywords, as previously discussed. The analysis for each report is presented individually below.

Reports 1, 2, and 3 are AAIB reports as indicated in table 3. The first report investigates an accident involving the detachment of engine cowl doors, causing damage. A fuel leak and a fire consequently occurred when the aircraft returned to land. The report has a strong human factors focus, with two sections fully dedicated to human factors issues, one section regarding human performance is entitled "*Engineering human factors*" and one section regarding organisational issues, entitled "*Organisational aspects*". The main causal factor of the accident is described as being "maintenance error". Analysis in the report emphasises human factors issues involved in the accident, such as fatigue (mentioned 7 times) and the swap error (identified as a slip, which is when the technicians intended to return to the right aircraft but their actions did not meet the plan) that occurred. Indeed, the term 'error' appears 18 times in the analysis section. Related terms are also explained in the analysis, and, where appropriate, are supported with evidence. For example, the term 'fatigue' is used with the employment of metrics, or bio mathematical model, to 'measure' the level of fatigue of the workers involved and to help determine that it may have had an impact on their performance. Other areas are approached such as 'barriers', 'workload' and 'visual cues'. In this report, the human factors content could be considered to reach its purpose of explaining 'why' people did what they did and why it made sense for them at the time in question.

Report number 2, relates to an accident injuring passengers on evacuation after the cargo hold smoke warning was triggered. In contrast with the previous report, it does not develop any human factors issues. It is apparent that human factors experts were not consulted during the investigation, as shown by the relative lack of human factors related terms in the text. The causal and contributory factors of the accident listed in the analysis section related mostly to technical failures. The only human factors terms present are 'communication' and 'decision making', but these only appear once and twice, respectively, and in any case were not considered to be either contributory or causal factors. They were therefore not developed deeply in the analysis. Clear communication issues are reported between cabin crew and the cockpit, as well as with the ATC but they are not analysed in any great detail, despite there perhaps being a compelling case to do so.

The third report, investigating a serious incident concerning a crew who took off from the wrong taxi intersection, clearly states "*the investigation focused on the human factors issues relating to the crew and the ATCOs, the infrastructure of the airfield and the regulator who had oversight for SKB*" (p23). Indeed, within the contributory factors, human factors issues play a significant role throughout. For example, two out of four such factors were listed as "*the crew did not brief the taxi routine*" and "*The trainee ATCO did not inform the flight crew that they were at Intersection Bravo*" (p27). The analysis section of the report is relatively short (only three and a half pages) and human factors are not developed in great depth. Human factors terms such as 'disorientation' and 'confirmation bias' are only mentioned very briefly in the report, and in each case are not developed in any detail in the analysis. For example, in the case of 'confirmation bias', the term is referred to once, with only three sentences relating to it in the analysis. Moreover, no references are used as supporting evidence. Furthermore, the report does not make any reference to the use of human expertise, which was surprising given that the nature of the accident would suggest that this could have at least been considered as a factor.

The reports from the NTSB, reports number 4, 5, and 6 did involve a human factors specialist because the organisation has their own in-house HF investigators who are part of the investigation team. In the investigation reported in report number 4, which investigated an accident involving an aircraft descending below visual glide path and impacting the seawall, human factors is deeply embedded in the analysis and has been investigated and reported in considerable depth. As an illustration, an entire 8-page section of the report is dedicated to flight crew performance, treating issues such as fatigue, monitoring, and communication. 'Fatigue' for example appears 22 times in the analysis section, with very specific related terms such as 'circadian' (as in circadian rhythm) and 'sleep' occurred 6 and 15 times, respectively. In the case of the latter, the number of hours of sleep the pilots received before the accident was also provided as evidence to support the analysis.

The analysis in report 4 also approached issues brought by automation and indicated that part of these issues were identified from interviewing the crew: "*the pilot flying made several statements that indicated he had an inaccurate understanding of some* *aspects of the airplane's autoflight system*" (p93). The depth of human factors understanding in the investigation was also highlighted by the fact that on several occasions in the text, reference was made to key human factors literature. For example, references to mental models (p93) were supported by reference to key published texts in the area. This indicated a high degree of expertise and understanding in human factors, more so than many of the other reports where human factors terms were generally mentioned only briefly, if at all. The probable causes and contributory factors were attributed to human factors issues.

Report 5 concerned a runway excursion during an attempted take off in cross wind conditions. Amongst other areas, the analysis section focused on the pilots' actions, training, and experience as well as the ATCs' obtaining and dissemination of wind information, which are all related to human factors. Regarding the pilots' actions, the sequence of events is very detailed and the report provides explanations that are likely to be the reasons why they acted this way, depending on the instruments output. Environmental conditions (gusty wind) are also analysed in details, which provided a clear image of the conditions at the time of the accident and how it impacted the crew's decision. This element is significant in human factors, as identified in the SHELL model. Another human factors element is also assessed here, namely the nature of the crew's training. Thus, the analysis looks deeper than just the pilots' actions because it also assesses the level of training the crew received regarding the specific conditions they faced preceding the accident. In this sense the analysis went 'one step further' and also investigated why the training received by the crew was insufficient.

The sixth report investigates the ditching of an aircraft after loss of thrust caused by a bird strike. The analysis in report 6 focused primarily on crew performance, training, checklist design, and procedures, as well as some more technical issues. Of these, crew performance, training, and checklist design are considered human factors issues and together represented about a quarter of the analysis section. A key aspect of the incident related to the crew's failure to complete a mandatory checklist. Here, human factors issues were explored and examined in some considerable depth to ascertain the reasons why this may have occurred. For example, "*they were not able to start part 2 and 3 of the checklist because of the airplane's low altitude and the limited time available*" (p87).

In addition to the checklist itself, the analysis also discussed the decisions made by the crew that had a positive impact on the sequence of events. For example, descriptions of tests run in a simulator are given, where the aircraft was subjected to similar conditions to that of the accident in question. Considerable depth is given in report to other factors that are important from a human factors perspective, including pilots' stress level, workload, tunnel vision, or visual illusion. Academic references are also used in the report to help support different human factors phenomenon, as discussed in the text.

While Reports 4, 5 and 6 all address human factors issues to varying degrees, none mentions a specific tool or methodology that could have been used to run the accident analysis. While it is not possible to say whether this was a deliberate omission on the part of the investigative team and that they decided not to employ such tool, or whether there was indeed a lack of understanding of available accident analysis tools or methodologies, it was still notable given that other reports such as 10, 11 and 12 did use these tools.

Reports 7, 8 and 9, from the BEA did not involve internal dedicated HF expertise. They however did refer to external expertise in reports 7 and 9. Report number 7, which related to an un-stabilised approach leading to a runway overrun, in the absence of technical issues, approached numerous human factors issues regarding the crew's performance as well as organisational issues such as the airline's culture. For example 'fatigue' (which appears 14 times in the analysis section) was identified as a factor responsible for the crew's poor situation awareness. The report also looked at the different 'layers' or barriers protecting the accident from happening described by the Reason's model, a key model for accident investigation (Reason, 1990). For this investigation, an external expert in fatigue was consulted. References to academic papers do not appear in this analysis but do appear in the expert's report provided in appendix of the report (in French). Apart from the fatigue issue, the analysis section of this report does not go into deep details regarding the crew's performance, by for example not looking further as to why the crew did not prepare adequately for the approach. It however looks thoroughly into the organisational factors such as training that had an impact on the crew's performance.

Report 7 further illustrates the value of incorporating human factors expertise and understanding in an investigation report. In this case, by examining fatigue as a possible cause of why the crew had not performed as expected, it was possible to produce a more complete assessment of the incident and help improve the airline's policy as a direct result.

In the next report, report 8, which involves a runway excursion due to aquaplaning, the analysis also develops human factors issues to a certain degree. For example, while the report does not draw upon any specific academic literature it does examine organisational issues by investigating the safety culture of the company. However, this level of detail was not found throughout the report, with some potentially important human factors issues receiving only brief recognition in the text. For example, when describing the difficulty for the crew to estimate their altitude, the report merely noted, "*he* [the pilot] *seemed to focus on control of the aeroplane because he did not know how far from the threshold he was landing. The crew did not realise that the runway was contaminated and that the landing was long*". This passage appears to allude to several potentially important human factors related issues, including attention or workload but these are not explained in any great detail.

Report number 9, which concerns the loss of control of the aircraft followed by a stall and impact with the sea, was published after a number of interim reports and the HF element was investigated by a team of external experts. The first section of the analysis is based on the group's work, and provides considerable detail on the crew's behaviour and decisions. From this, the report attempts to establish whether the findings were specific to that crew in question or whether they could be generalised. Thus, the analysis is attempting to remove any bias. The analysis section does not provide references as evidence of the statements but many human performance terms are employed to describe the event (e.g. 'lack of confidence', 'workload', and 'attention selectivity'). As with the two previous reports, the investigation is not restricted to the crew's performance, it also looks at the crew's training, ergonomics issues with some display and other 'latent' issues. It does however produce a report showing a much deeper understanding of human performance issues than reports 7 and 8.

Reports 10, 11, and 12, produced by the ATSB, involved internal human factor expertise since the ATSB has a team of in-house human factors investigators. Moreover, the ATSB is also known to base their analysis on their own tool that was developed using James Reason's Swiss cheese model. The first part of the analysis of report number 10, which concerns an in-flight uncontained engine, mainly focuses on technical issues that occurred with the engine. It however looks further than the technical failure and investigates the manufacture of the engine in detail, from the manufacturing of specifications to inspections. For example, considerable attention is paid to the wording of the inspection procedures ('procedure' is mentioned 10 times in the analysis section). Thus, it can be considered to investigate organisation issues with considerable depth. Like a number of the other reports, reference to human factors literature is not made.

While some of the reports did not employ an analytical framework, Report 11 uses the ATSB tool as a framework for analysis. This investigation relates to a tail-strike and runway overrun event. In the introduction of the analysis section it is stated, "*The analysis begins with an examination of the occurrence events, before discussing the individual actions and local conditions that affected the performance of the flight crew* (p75)". It follows the ATSB analysis model explained at the beginning of the report and clearly provides a clear and easy to understand structure. The issue of human error is covered extensively in the report, which also looks at procedural issues, uses references and explains in great detail human performance phenomena. Additionally, the report investigates why the aircraft's crew did not detect any errors during take-off. The report found that this was due largely due to crew distraction, which consequently formed a large part of the analysis.

Analysis in report 12 mainly focused on the investigation of a technical failure, leading to an in-flight upset and resulting injuries. However, it investigates how this limitation was not identified by the manufacturer failure mode analysis or safety assessment. Besides, it investigates human performance by analysing the crew's response, communication and workload during the event. Due to the absence of human error, the depth of the human factors content in this analysis section is limited.

Reports 13, 14 and 15 were selected from the AIID from South Africa. Unlike the other NIA, a few reports had to be discounted, as they did not contain any of the keywords listed on the ICAO checklist. Hence, reports 13, 14 and 15 represent the 3 most recent reports which also have at least one human factors issue mentioned. In each case (perhaps unsurprisingly), it is evident that there has been little, if any, input from human factors specialists. It was however unknown to the researcher whether the team has an in-house HF expert. In each of the reports human factors issues are mentioned infrequently, and where they are discussed, the discussion is largely superficial and lacking detail or depth.

Report 13, which concerns the collision with a building near a taxiway, does not address human factors issues separately within the report but includes it within wider discussions of the technical aspects of the incident. This varies notably from the majority of the other reports, where human factors issues are treated separately, usually in its own specific section. This is not to say that the report is entirely without mention of human factors. For example, the performance of the ATC and the cabin crew was detailed following the sequence of events. The flight crew's performance was also considered in an attempt to explain why the aircraft taxied the wrong way. As with several other instances where potentially significant human factors issues arose but were not examined in detail, the report does not analyse why the pilots did not read the correct information concerning the taxiway in their brief. This is merely referred to as 'loss of situational awareness', but this is not explained further.

Similarly, analysis in report 14 is limited in terms of human factors content. The accident refers to a runway overrun. The crew's performance and why the pilot took 4 seconds before applying the brakes was not analysed, although it is likely that at least to some degree this decision could be seen as having an important human factors element. Organisational issues are nonetheless approached in considerable detail. For example, the regulating authority oversight of runway adherence assessment and regulations are analysed. It discusses the relevance of specific checklists regarding runway frictions and the limitations in the process of testing runway frictions.

The final report in the sample, report 15, refers to a tail strike on take off. It has only a very short analysis section (one page), and as such its use was limited. However, it does mention the crew's wrong input and lack of error identification due to distraction, albeit with little analytical depth. Similarly, potential organisational issues are also not addressed. In this sense the content of the report in terms of its human factors content is consistent with the other reports from the South African NIA.

IV- 4- 2 Discussion

The content analysis of the 15 reports highlighted different levels of depth, understanding and application of human factors in the reporting of incidents and accidents. While each of the incidents varied in terms of their specific nature, geographical location, timing, and aircraft involved, the majority of the reports made at least some reference to human factors issues, albeit to varying degrees. In terms of the issues most commonly addressed in the reports, the majority of investigations examined organisational issues. Additionally, issues relating to human error and performance were cited in a number of reports, while the content of the procedures, organisational policies, and regulatory oversight, were examined where relevant to the investigation.

While it is possible that the sample reports merely lent themselves to the type of issues mentioned, it is also possible that there were other potentially important human factors issues that were not considered. As addressed in the literature, and as illustrated by the extensive list of ICAO keywords, human factors as an issue is much broader than suggested by the content of some reports. Indeed, on a number of occasions the reports appeared to refer to important human factors issues, and particularly human performance issues, but then more often than not failed to assess them in any depth. This raises some important questions about the role of human factors in the accident investigation process. For example, it is not known to what extent investigators are even aware of the role of human factors in investigations, or whether they have the confidence to address them properly even where they are known about. Conversely, it may be the case that human factors issues are understood well, but for whatever reason are overlooked. In any case, such questions require further investigation.

Certainly, the significant variation in the length of the analysis sections of each of the reports gives a clear indication of the varying degrees to which human factors were considered. While the nature of the event itself will inevitably dictate the extent to which a report is more technical, operational or human factors focussed to some degree, it was clear that the investigations utilising a human factors expert (either internal or external) generated the longest and most in-depth human factors analysis. This too raises important, unresolved questions, such as whether human factors experts were allocated to the investigations precisely because of the nature of the event, or because the incident occurred under the jurisdiction of an NIA that happened to have an in-house human factors team and a culture of addressing human factors issues (i.e. the NTSB and ATSB). If the latter is the case, it raises the possibility that some events could fail to be investigated sufficiently simply because of where they occurred in the world.

On occasions where human factors expertise is provided by an external specialist, it makes sense that the non-HF investigators and Investigator In Charge (IIC) are able to understand such specialist information in order to integrate the relevant findings into the investigation process and link it to the facts developed in the first part of the investigation report. However, it is not clear to what extent these people do (or do not) receive relevant training in human factors issues, how it is administered, what this training entails, or how it is viewed by practitioners. Addressing these unresolved questions subsequently form a key priority for this research.

IV- 5 Conclusion

The content analysis of fifteen air accident investigation reports from five different organisations highlighted different levels of depth in terms of the human factors content. It was highlighted that the involvement of a specialist has a positive effect on the structure and content of the human factors element. It was found that the organisations with in-house expertise were generally producing more detailed and thorough reports in terms of human factors. Some reports were treating HF in considerable depth with references to academic literature. It also raised questions about the comprehension and perception of human factors issues by investigators.

This study also pinpointed the importance of a good understanding from the non-HF investigators in order to correctly integrate HF element to the investigation report, draw conclusions and make safety recommendations if necessary. However, it was not clear to what extent these individuals receive specific human factors training.

In this sense, findings from the analysis lend support to issues from the literature. More investigation is nonetheless necessary to understand why some reports still have a limited HF content, why some investigators seem to have a better understanding than others and why for the organisations without in-house specialists, a HF expert was involved only for some investigations. Thus, the next chapter examines the depth of training received by accident investigators, particularly in human factors, from all over the world, using an online questionnaire.

Chapter V – Accident investigators' training

V- 1 Introduction

As developed in chapter III, TNA implies the gathering of data from different sources in order to identify whether or not training would be the most appropriate method to improve performance. In order to find out whether or not training would benefit human factors integration within air accident investigations reports and safety recommendations, it is important to first obtain data on the sort of training accident investigators are undertaking as well as its relevance. Therefore, an online questionnaire was conducted amongst the accident investigators community, using the tool Qualtrics. The purpose of this survey was to evaluate the relevance and efficiency of human factors training provision for air accident investigators, thus fulfilling the third objective of this thesis (see chapter III).

The survey sample was targeted at current air accident investigators from around the world. This was done to ensure that the survey was widely distributed to maximise survey responses, but also to enable comparisons to be made between different types of accident investigators in different agencies to see how their approaches to human factors vary. The following section addresses the method for conducting the survey. This is followed by an analysis of the main findings from the survey.

V- 2 Method for conducting the survey

An online self-completion questionnaire was chosen for conducting the survey. A questionnaire format was chosen because its function is to provide an accurate form of measurement (Oppenheim, 1992), in this case the proportion of investigators who receive training in human factors and the content and significance of this training. Questionnaires are widely used in this type of research as they allow the researcher to reach a large number of participants at minimal cost, provide flexibility in the type of questions that can be asked, and leaves the respondent flexibility in place, timing and manner in which they decide to complete it. An online questionnaire was chosen here over a traditional mail, one-to-one or phone format because it enabled the questionnaire to be distributed worldwide rapidly and at no additional cost, with completed questionnaires automatically saved and thus easily accessible. The software used to conduct the questionnaire, Qualtrics, also enabled the download of data directly into SPSS, the software used for the quantitative analysis of the results.

Although these attributes are recognised benefits of online survey, there were also a number of potential limitations that needed to be taken into account when designing the questionnaire (Evans and Mathur, 2005). The lack of control of who the respondents were was mitigated by two filter questions, "*Are you an accident investigator?*" and *"Did you receive formal training?"* The possibility of a low response rate was balanced by sending invitations to complete the survey to a large number of investigation organisations and accident investigators, whose email addresses were available to the researcher through ISASI membership and on the ICAO website. As noted by Evans and Mathur (2005), some respondents may perceive survey invitations as unsolicited 'junk' mail. To counter this, the link to the questionnaire was attached to an email coming from a Cranfield.ac.uk address. The Cranfield Safety and Accident Investigation Centre (CSAIC) runs an accident investigation course, which will have been attended by many of the investigators included in the survey sample. Therefore, it was thought that most people who were sent the email invitation would have recognised its origin and therefore would not have merely dismissed it as 'junk' mail.

The e-mail invitation sent to potential participants initially explained the aim of the research and introduced the researcher. A right of withdrawal, anonymity and the researcher's contact details were also made available to the respondents. The survey did not ask the name of the respondent nor the organisation for which they were working to encourage honesty in their answers. Full ethical approval for conducting the research questionnaire was granted by Cranfield University Research Ethics System (CURES).

V- 2- 1 Survey structure

Considering the nature of the survey, and the need to obtain relevant data from a range of respondents, questions in the survey were designed so that they closely aligned with the overall purpose of the survey. This meant that the vast majority of questions in the survey were closed-ended, or pre-coded open questions (Brace, 2004) and structured because they enabled the respondents to answer succinctly, helped facilitate the analysis with direct coding, and were useful to test hypotheses and compare different answers (Oppenheim, 1992; Robson, 2002; Neuman, 2006).

In total, the questionnaire contained 21 questions. Of these, nine questions were measured on a five-point Likert scale, while one question was measured on a four-point Likert scale. These allowed for more accurate measurement on depth of training, importance and confidence. For the remaining questions, four were YES/NO or YES/NO/NEUTRAL questions and the rest were pre-coded questions, in order to categorise the participants but also in order to list the different categories of training. A category "*Other, please specify*" was added to questions that might need further explanation from the respondents. For example, the question "*What type of investigator are you*?" had available response options of *"1- Operation, 2- Engineering, 3- Human factors, 4- Other, please specify",* in case the respondent did not identify their role with either of the first three options. The final question, *"For the purpose of feedback please provide your email address"* was the only open ended question included in the survey. It was clearly indicated as an optional question and that the information will stay strictly confidential (see Appendix B).

A pilot was run amongst the CSAIC department, from which a 10 minutes average completion time was determined. The pilot also led to some wording modifications, by changing potentially ambiguous or misleading questions. The pilot also raised the need for classifying the questions into sections, and to indicate clearly how some questions were not a repetition but instead similar inquiries about a different topic. The questionnaire appears in Appendix B. The sections were as follows.

- Background: questions permitting the description of the sample
- Initial training: questions regarding the depth and importance of different areas related to the accident investigation process. The list of the different topics was listed in ICAO training guidelines. This section was mainly to identify the sort of

initial training accident investigators received, depending on their role. Its intent was also to put the respondent at ease and not just start with human factors related questions.

- Additional and refresher training: questions about the type of additional and recurrent training and the frequency of refresher training investigators may have received. Each of the topics was also taken from the recommended practices provided by ICAO training guidelines for accident investigators.
- Human factors: regarding content of HF training, importance and confidence.

V- 2- 2 Summary of the survey sample

The questionnaire link was then sent to a large network of accident investigators and accident investigation organisations, who were then asked to share it with colleagues or those they thought would be appropriate to also complete the survey (known as 'snowball' sampling), when possible. Around 120 invitations were sent. The link stayed 'live' and the data was gathered for a period of three months from November 2013 to January 2014.

A total of 124 responses were gathered including 115 respondents who replied YES to the filter question *"Are you an accident investigator?"* Of these, 112 also replied YES to the question "*Did you receive formal training?".* Finally, in order to obtain valid and reliable results, the statistical analysis was only run on the 89 fully completed questionnaires (23 respondents failed to complete all questions in the survey). Consequently, the final survey sample consisted of 89 respondents. All the questions are presented in Appendix B, which is the questionnaire sent to the investigators.

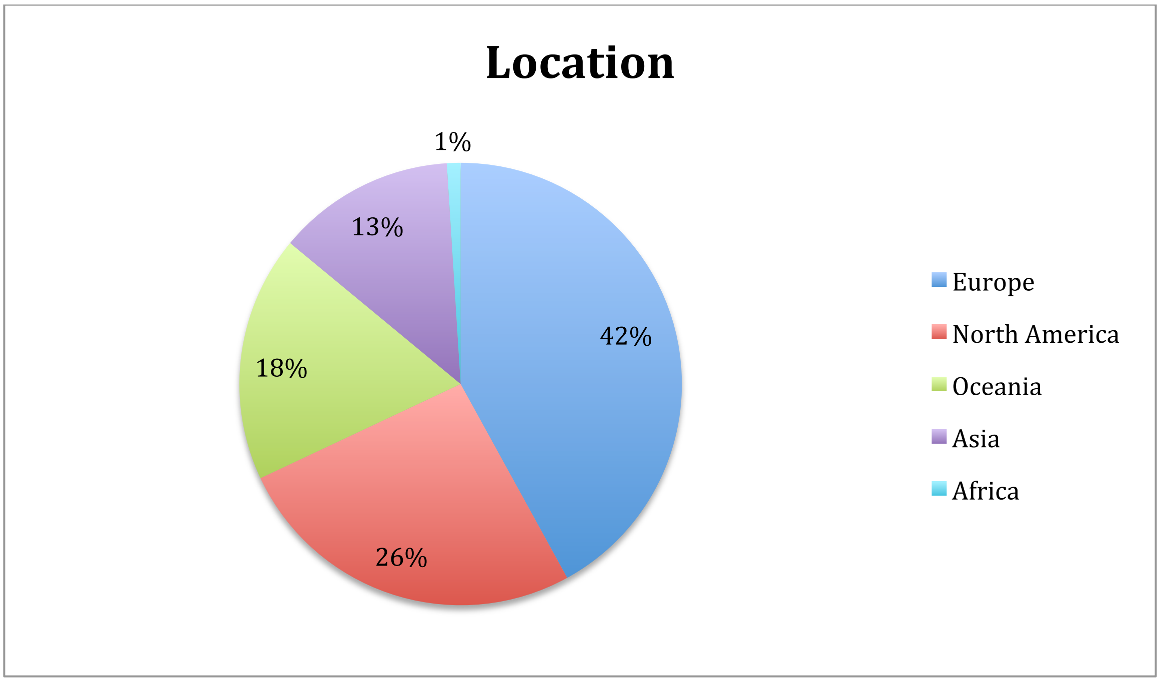

Figure 12: Location of the respondents

The 89 respondents were located all around the world, with the majority residing in Europe (42%) and North America (26%) (see figure 12), and the majority were working for National Investigation Agencies (83%) i.e. the national organisations that run independent safety investigations (see figure 13) in their country.

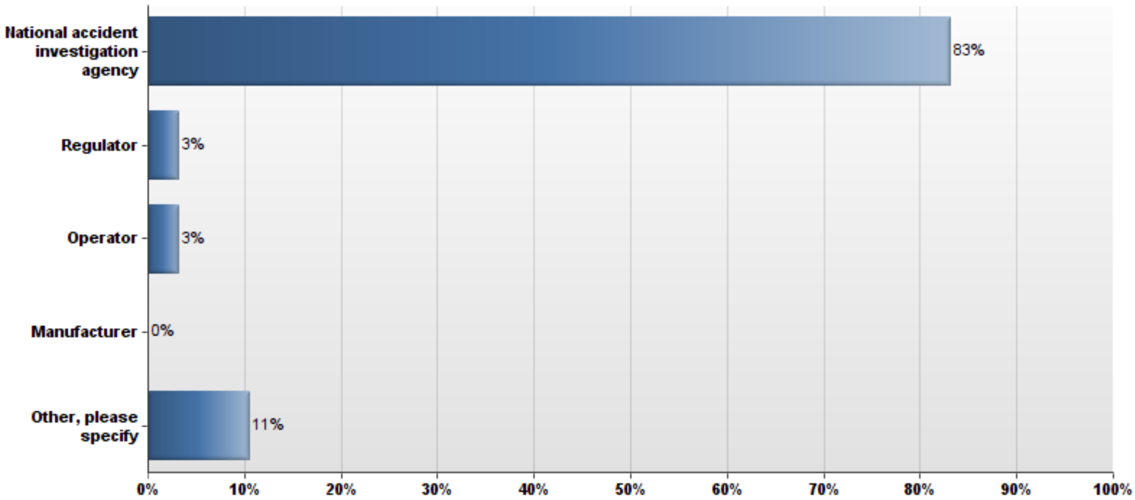

Figure 13: Type of organisation respondents work for

The level of experience of the investigators was measured by the number of investigations they had undertaken to date. The results show that the majority of investigators in the sample were relatively experienced, with two thirds of them having conducted 20 or more investigations in their career (see figure 14). In comparison, 11% of respondents had conducted 11-20 investigations, while 9% and 12% of the sample had conducted between 6-10 and 1-5 investigations, respectively. One respondent had not yet completed any investigation.

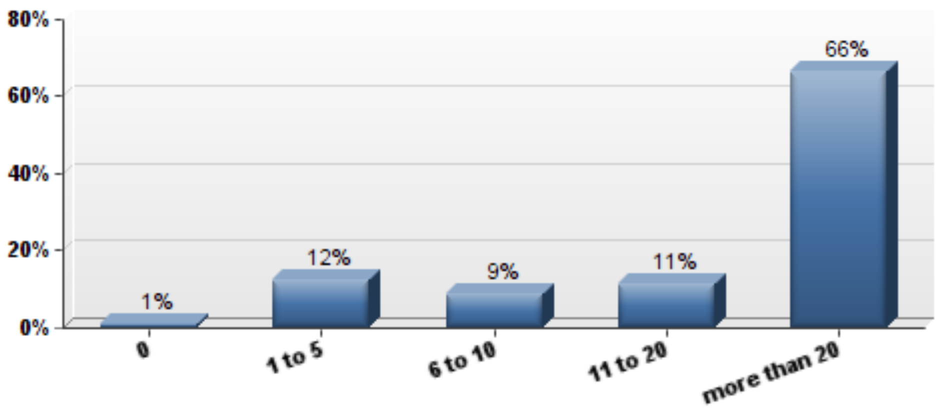

Figure 14: Investigators' level of experience: number of investigations undertake

The investigators also held different roles within their organisation (see figure 15). Most of them were "operations" and "engineering" investigators. This implies that during an investigation their role would mean that they focus mainly on the operations side (pilot, cockpit, flight) and the engineering ones would focus more on the technical side (aircraft, engines, maintenance). 20% of the sample identified themselves as being "*general*", "*all types*" or lead investigator. For the purpose of the analysis this group are considered and labelled as "*General*".

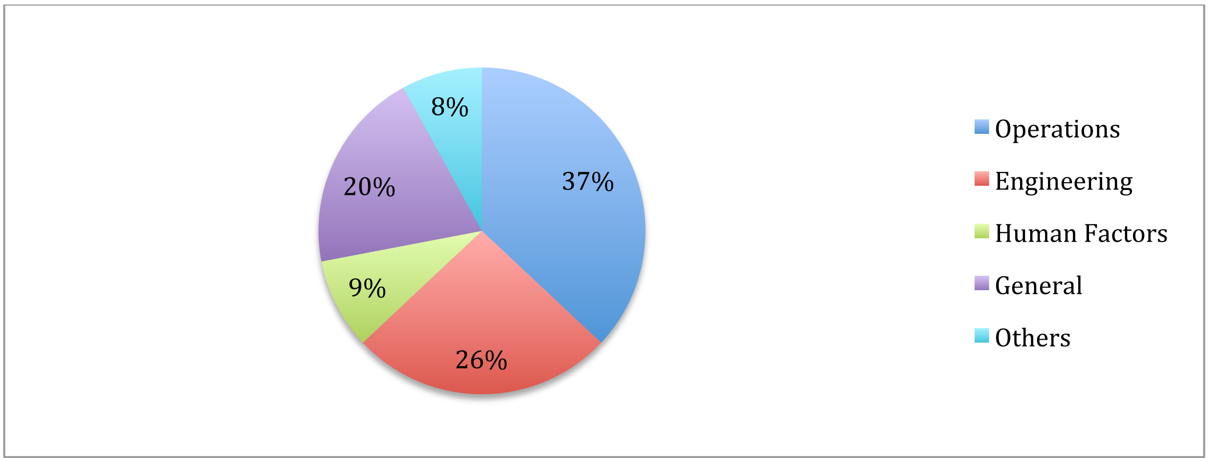

Figure 15: Types of investigators

The 89 respondents therefore formed a representative sample of the population of air accident investigators with formal training, since it covers all level of experience, different roles and a variety of places.

V- 3 Survey findings

V- 3- 1 Initial training

According to the ICAO Training guidelines for aircraft accident investigators (Circ. 298, 2003a), a large number of topics should be covered during the investigators initial training, undertaken before they start the job. It should provide them with a good introduction to the job and the running of an investigation. This coincides with the multi-disciplinary aspect of investigating an accident. All the different topics are detailed in the ICAO guidelines, and were used in the questionnaire as the categories to describe the content of initial training.

The question *"How deep was your initial training in these areas?"* asked respondents to rate the depth of training they had received in each of these 20 separate topic areas. This highlighted a number of important areas for analysis, namely that despite being listed as important topics to be approached in the ICAO guidelines, some training areas were not part of the initial training of some of the respondents. For example, 10% of them did not receive any training on the examination of maintenance documentations, 9% of them on power plants, and 8% of the respondents had no training on how to write recommendations and deal with media and families. This could imply that the guidelines are not always being applied properly nor considered. ICAO only provides recommended practices and has no regulatory power. Nonetheless, it shows that some investigators do not have the recommended initial training skills.

Information gathering techniques (72% of respondents), accident site safety (70%), administrative arrangement (70%) and interviewing (70%) were all areas where the majority of investigators had received deep or extremely deep training. In comparison, 26% of the engineering investigators and 25% of the human factors investigators claim not to have received any training, or received only brief training, on interviewing during their initial training programme. While this might have been covered in further training as part of their specialisation, this still seems like a relatively low proportion considering that interviewing is considered as an important source of evidence and witness interviewing is a topic that, according to ICAO's training guidelines (2003a), should be covered in basic investigators' training courses.

The examination of maintenance documentation was approached deeply for only 25% of the respondents. Amongst the engineers, for whom maintenance documentation are essential pieces of evidence, 45% of them received no training or only brief training on this subject. Similarly to interview techniques, this figure might reflect the fact that experienced engineers who become investigators are expected to be familiar with such documentations, or that this aspect will be covered in their further specialist training. Analysis techniques, which should be approached in order to allow the investigators to know how far the investigation should be pursued as well as testing hypotheses (ICAO, cir 298) had been approached in depth for only 45% of the respondents. Report writing and recommendations is also a crucial topic since the main objective of an accident investigation is to publish a report that, where appropriate, provides safety recommendations to avoid similar occurrences. This, however, does not appear to have been reflected in the depth of initial training received by the investigators, seeing as 31.5% of them claimed to have received no training or only brief training on that topic.

In turn, those who claimed not to have received this training were roughly equally split between human factors investigators (50%) and engineers (48%).

ICAO training guidelines emphasize that "*no accident investigation can be complete without a thorough consideration of Human Factors issues involved*" (ICAO, 2003a, p11). Of the twenty topics outlined by ICAO, two can be considered as directly relating to human factors investigation: human performance and organisational factors. During their initial training, it was found that 55% of the respondents (i.e. a little over half) received deep training in human performance and 37% in organisational factors (including 37.5% of the human factors investigators). While 55% might seem like an encouraging figure, particularly when compared to other disciplines, these findings would suggest that there is still room for improvement with regards to the depth and scope of human factors training in initial training regimes, particularly regarding organisational factors. Importantly, it could also imply that the initial training provided is not as well adapted to the needs of running a thorough accident investigation as it could be. Figure 16 shows the percentage of respondents who received in-depth or extremely in-depth training for each of the 20 topic areas. The two areas relating to human factors are indicated.

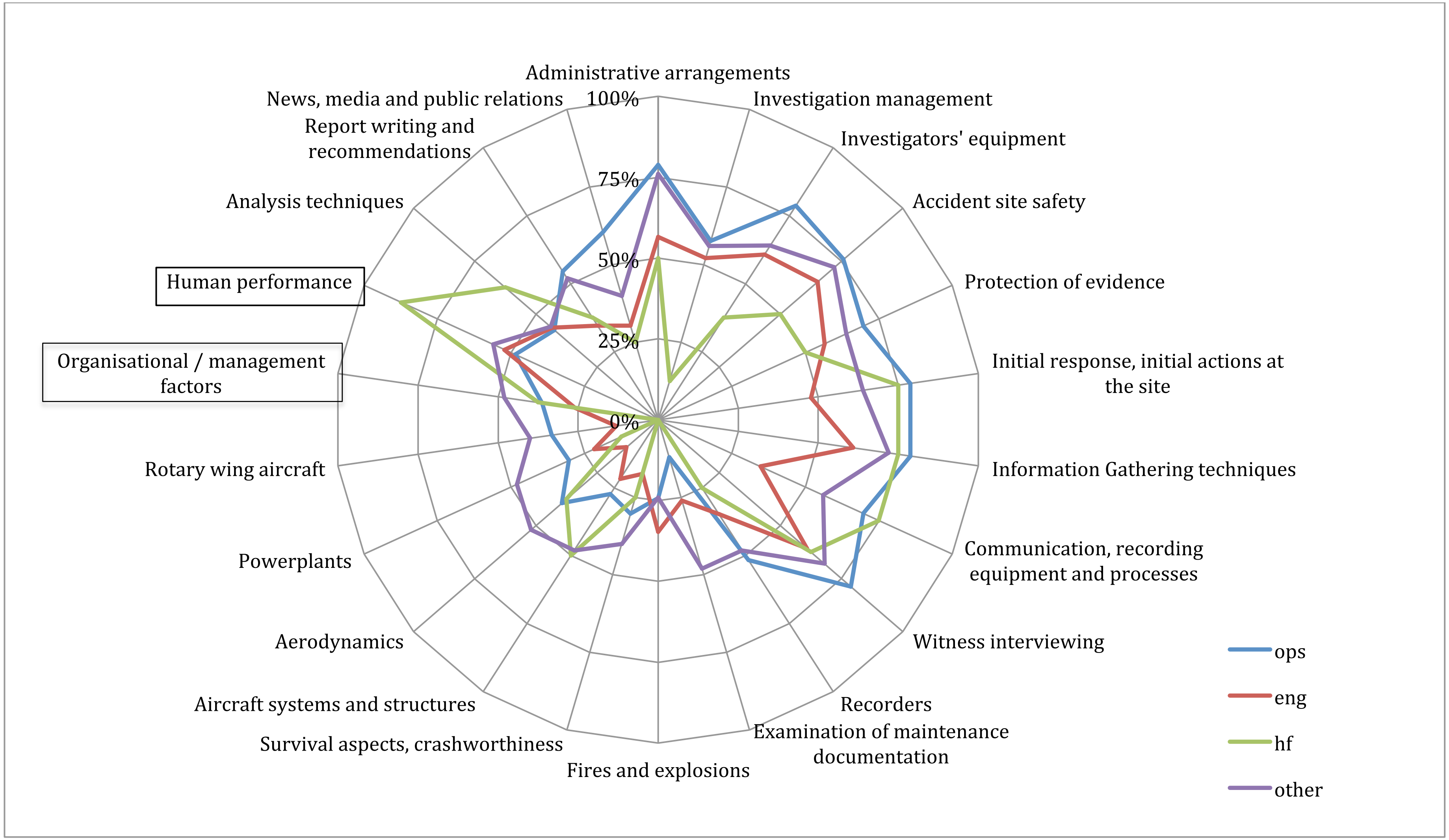

Figure 16: Percentage of investigators who received in-depth training in different topics

The apparent disparity or lack of standardisation in terms of the range of topics covered in initial training schemes raises some important issues. While there will inevitably be some time restrictions with regards to training provision, meaning that in reality it may be impractical or unnecessary to provide in-depth training to all applicants for all topic areas, it is significant the extent to which respondents varied in terms of the training they had received. While it is possible that respondents may have forgotten or lost track of the initial training they had received, given that in some cases this may have been several years ago, it seems unlikely that this would explain these variations alone. Furthermore, it appears that the role of the investigator has little impact in terms of the training they receive, given that few discernible patterns emerge from the data in this regard. Rather, it seems more likely that the findings are a function of the large number of courses available around the world, the lack of accreditation (and the standardisation this would bring), the organisations' policy with regards to training, and the limited resources and access to skilled trainers available to different organisations.

V- 3- 2 Advanced courses

As well as initial training and on-the-job training, some investigators undertake specialised courses in order to gain more responsibilities and develop their knowledge. The different courses may vary depending on the investigator's role and the organisation. Overall, media relations and human factors are the specialist courses that most investigators undertook (72% and 67%, respectively). This indicates that although human factors is not always approached deeply during initial training it is often taught in a separate, specialised course. Figure 17 shows the percentage of investigators who received advanced courses. It illustrates that human factors investigators do not receive many of the very technical specialised courses such as helicopter investigation or fire and explosions. The fact that only a small number of HF investigators receive training in management of a large site and dealing with an inquest, would suggest that they tend not to be deployed on site or are the investigator in charge. Regarding the latter, it is important to note that there are of course fewer IICs, which inevitably means that fewer investigators will undertake such specialist courses. There is very little difference between the advanced courses operations, engineering and general investigators undertake.

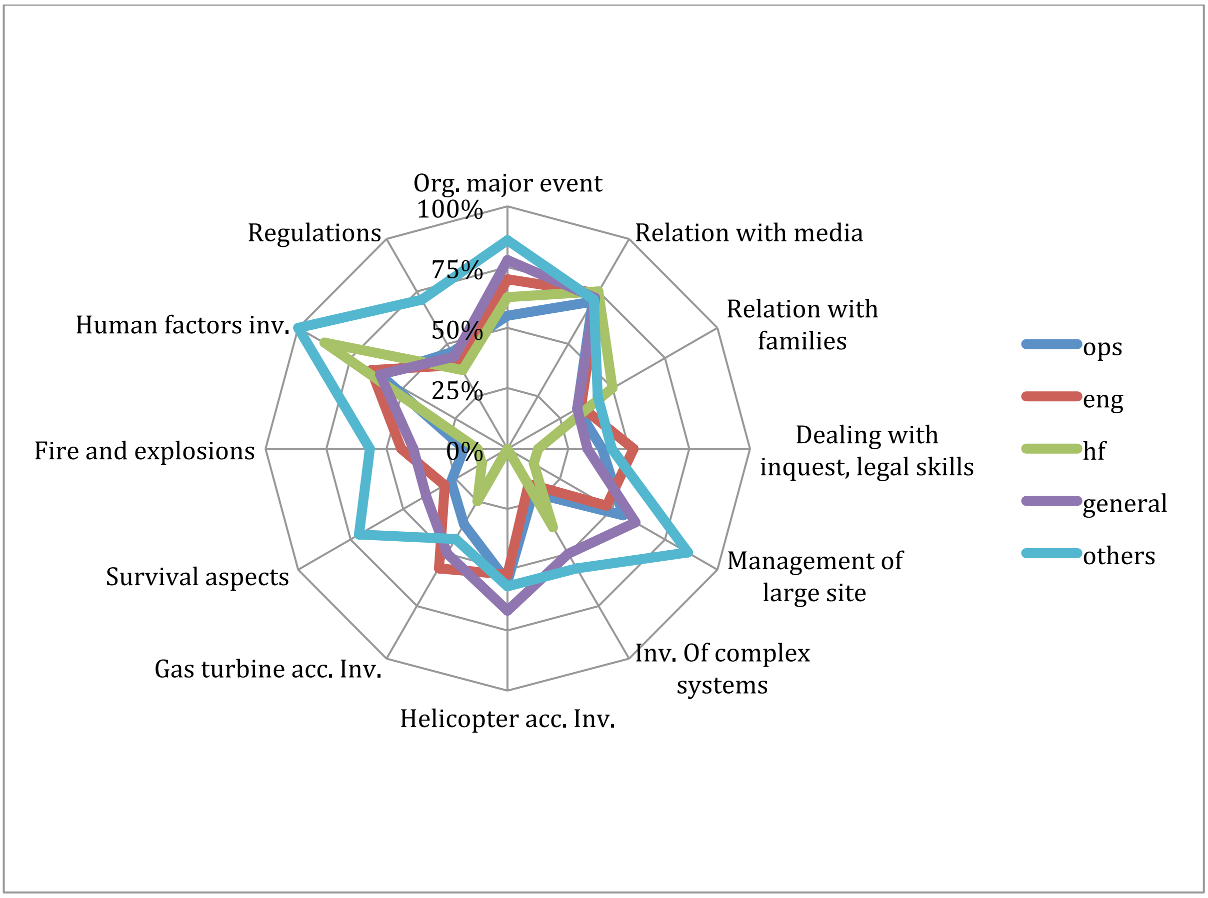

Figure 17: Advanced courses undertaken by accident investigators

V- 3- 3 Recurrent courses

Many accident investigators also regularly undertake refresher training in order to maintain their skills and stay up to date with for example new technologies. However, findings from the survey suggested that human factors training is not always a part of this. To the question *"in which of these areas do you receive refresher training?"* only 47% of respondents ticked human factors. Regarding the frequency with which refresher training was undertaken, 43% of investigators replied that they never or very rarely (less than every 5 year) received human factors refresher training. While it was initially thought that this may have been the result of less experienced investigators not having been in post long enough to have received refresher training, on inspecting the data it was shown that the majority (70%) of these responses came from investigators who had completed more than 10 investigations in their careers.

Looking now at the different type of investigators (figure 18), the main area where most of them do receive recurrent training at least every 5 years or more often is 'accident site safety'. This could be explained by the fact that in order to do their job efficiently, investigators also need to be working safely despite the different hazards that an accident site can present. This is a safety-critical subject. There is a large disparity in the frequency of recurrent training in 'regulations' (80% of the engineers never or rarely receiving refresher training on the subject, whereas it only affects 40 and 50% of the other types of investigators), in 'aircraft systems and technical knowledge' and 'human factors'. The engineers and operations investigators are the ones who seem to receive HF recurrent training the least frequently, despite the evolution of the discipline. This corresponds to respectively 40% and 50% of them, which is a high proportion considering that human factors was not approached deeply during their initial training (see figure 16). It therefore seems like that although they do undertake one specialist course in human factors, they do not update their knowledge via refresher training. Unsurprisingly almost all HF investigators (87.5%) undertake HF refresher training at least every 5 years. Accident investigation is a multi-disciplinary enterprise that evolves with new technologies, new methods, new aircraft, and new trends and it is why refresher training is essential. Figure 18 illustrates that this recurrent training is not undertaken consistently amongst investigators.

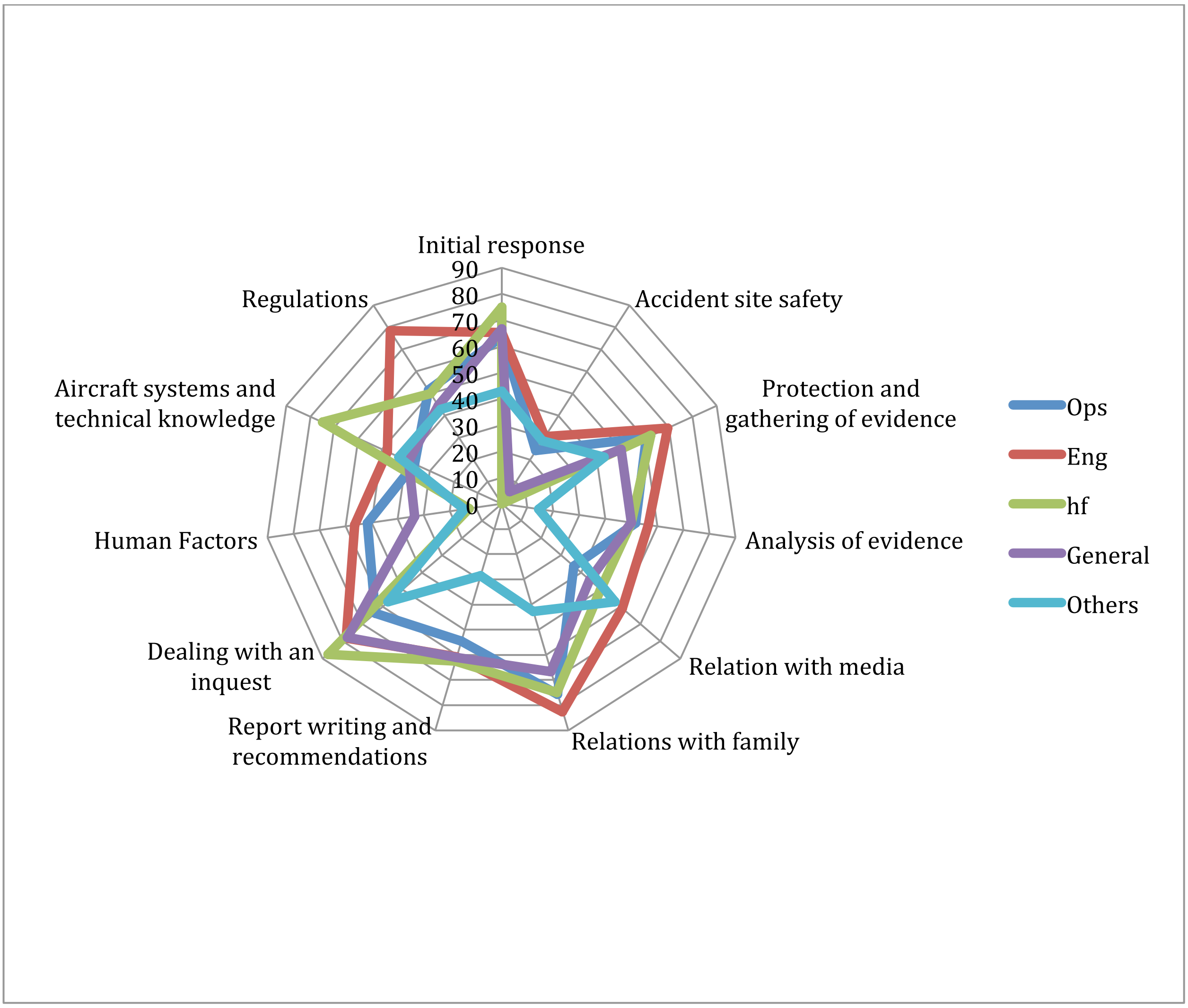

Figure 18: Percentage of investigators having received No, or less than once every 5 years, refresher training

V- 3- 4 Human Factors

The final part of the questionnaire approached questions more specific to human factors in order to obtain more accurate and detailed answers on the different areas that comprise human factors. As shown in a preliminary research conducted by the author and discussed in chapter I, it was clear that there was a need for more training in human factors, adapted to the investigators' needs but also to their role. This section aimed therefore at identifying whether that recommendation could apply to other organisations.

Virtually all respondents thought that it was important to investigate human factors as part of an investigation. Overall, 98% of respondents believed that it is "*very important*" or "*extremely important*" (see figure 19).

In terms of the quality of training they receive, 79% of respondents felt that the training they received in human factors was '*useful*', whereas 17% preferred to stay neutral on the matter. Only 3.5% of the sample believed that their training was '*useless*' (see figure 20). This suggests that there is generally a positive attitude towards human factors and the training they receive. Furthermore, 84% of respondents claimed that they "*would like to receive more human factors training*", which suggests that there is generally a desire from investigators to extend and develop their knowledge on the topic. Of the minority of respondents who replied that they did not wish to have more HF training, 5 were 'engineers' (21.7% of the engineering investigators who took the questionnaire), 4 were 'operations' (12.1%), 4 were identified as 'others' (16%) and only 1 was 'human factors'. This could mean that engineers are the more reluctant to know more about human factors, although it was not possible to determine this conclusively from the survey alone. Figure 21 illustrates these results.

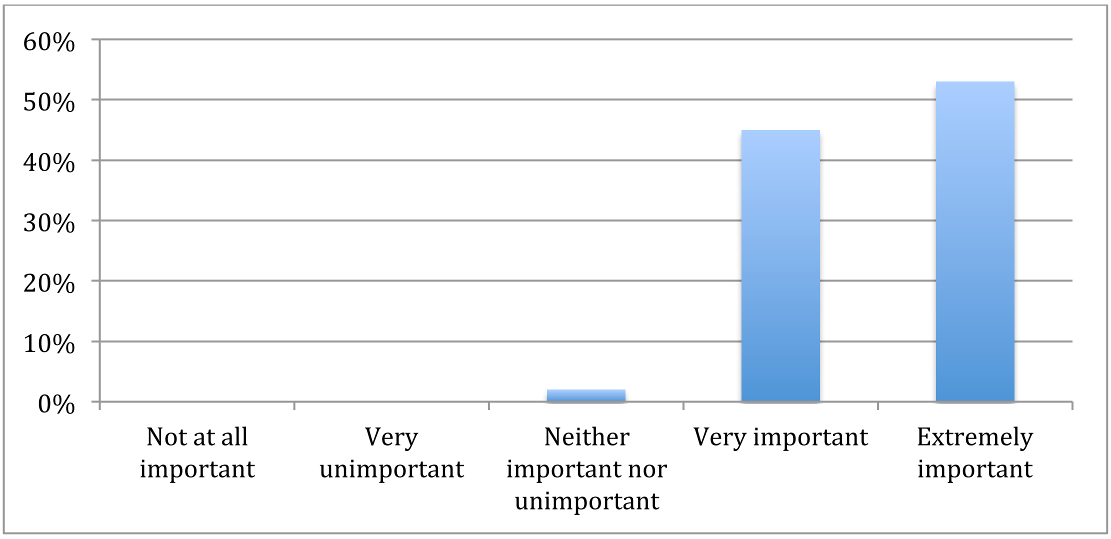

Figure 19: Percentage of respondents " How important is it to investigate human factors?"

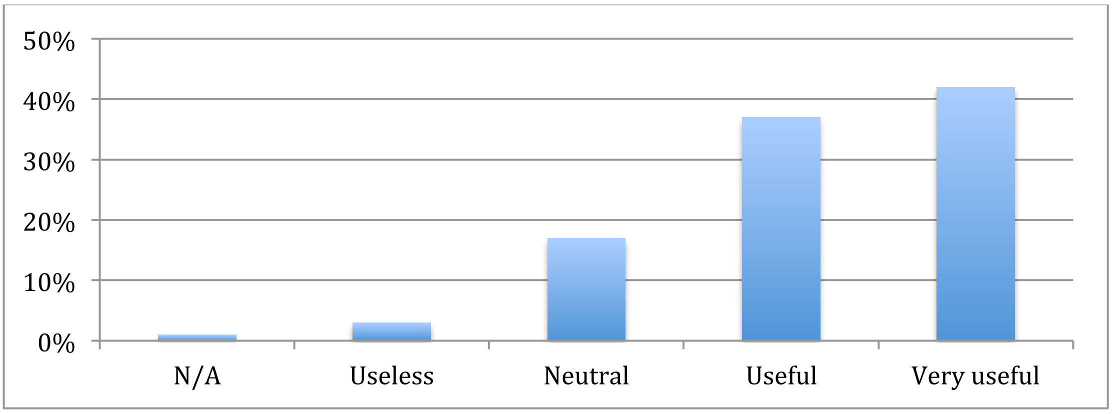

Figure 20: "How useful was your human factors training?" percentage of respondents

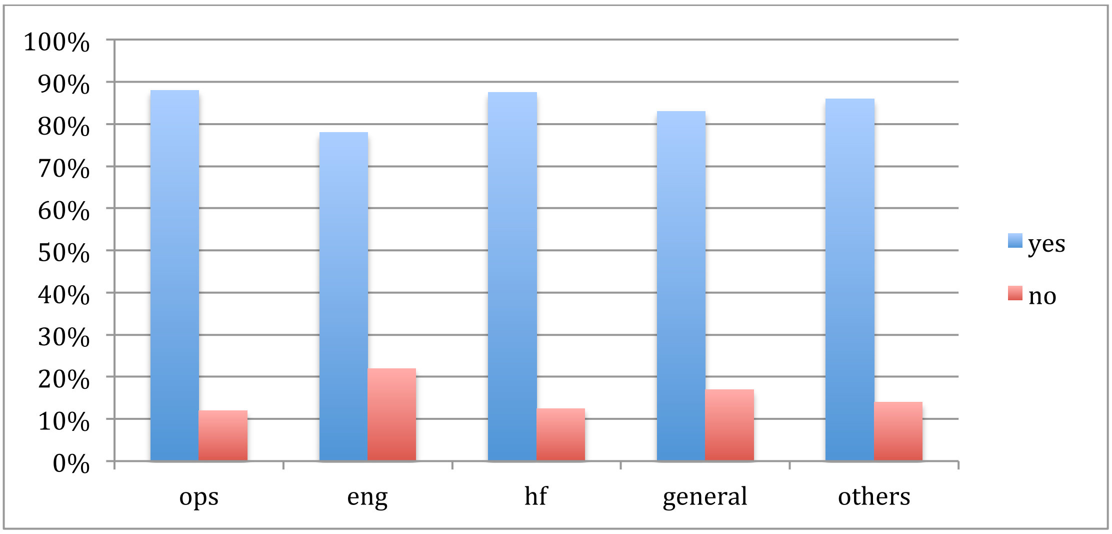

Figure 21: Number of respondents "Would you like to receive more human factors training?"

Human factors is an umbrella term that regroups a lot of topics, particularly in investigation, as identified in section II. In order to identify what was the content of human factors training, different categories were identified from ICAO's Human factors digest n°7 (1993) and the Human Factors training manual (1998). These categories were selected because they were the most relevant to human factors air accident investigation and are the following: interview techniques, what is human factors, tools and techniques, data that should be collected, use of HF specialists, HF in engineering and maintenance, HF in ATC, HF in flight operations, human performance and error, cultural and organisational factors, basics in aviation medicine. Figure 22 shows the different categories that were approached during the participants' human factors training. It excludes the 2% (1 'engineer' and 1 'operation') of respondents who ticked "Not applicable", suggesting that they never received human factors training.

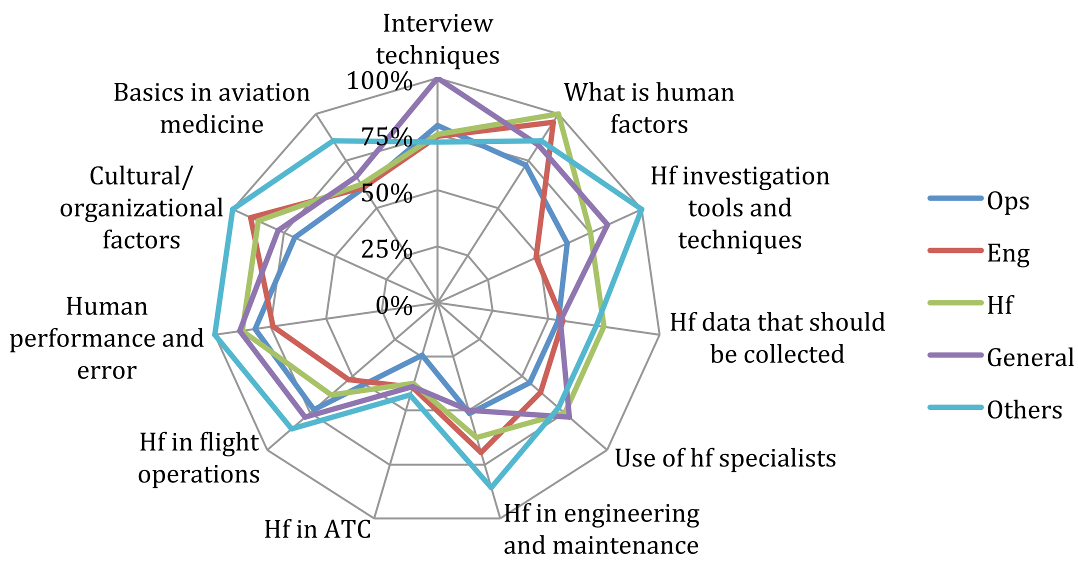

Figure 22: Human factors topics covered during training

It can be seen that, generally, the content of HF training seems fairly consistent across the different disciplines. However the topic that has been the least taught is 'HF in ATC'. This could be explained by the fact that it is a very specific area and that in this sample, only 2 respondents were 'air traffic control' investigators.

Overall, 'what is human factors', 'human performance and error', 'cultural organisational factors' and 'interview techniques' were taught to more than 80% of the participants. These four categories are the most generic topics and also the most likely to be used when describing a course because they could be applied to most of the investigations, since most accidents involve human error (Wiegmann and Shappell, 2001, 2006, 2009) and organisational issues (Reason, 1990).

Other areas were found to be taught less often. Significantly, it was found that only 58% of investigators received training on the type of data that should be collected. This implies that 42% of invetstigators were not taught what data they should collect, which is an issue considering the nature of investigation and the gathering of evidence. Similarly, for 27% of respondents, their training did not approach 'tools and methods', which is an essential part of accident investigation as demonstrated in section II. Moreover, 36% of the participants were not told how to make the best use of HF specialists and for 40%, 'HF in engineering and maintenance' was not approached during their HF training. The latter category, which by its name is likely to be relevant for engineering investigators and general investigators, was not part of their training for 30% and 50% of the sample, respectively. Amongst the 'engineering' investigators who did not receive 'HF in engineering and maintenance' as part of their HF training, a majority (57%) did not receive training on 'use of HF specialist'. Although it could be argued that 'engineering' investigators do not need to be trained in HF because it is not their specialism, it may be useful to consider training them on the 'use of HF specialist', i.e. who to refer to. As highlighted in the preliminary study in chapter I, identifying the adequate expertise might not be obvious. This could enable the involvement of suitable expertise. In addition, amongst the 'operations' investigators who were not taught on 'HF in flight operations', for nearly 78% of them, their training did not approach 'use of HF specialist'. This emphasizes another weakness in the HF training provided to accident investigators.

As mentioned earlier in the chapter, it was considered important to assess to what extent the approach to human factors varied by organisation. For example, Australia (the ATSB) was one of the first countries to integrate human factors within their investigation by the creation of their very own human factors team. Some organisations however, still do not have dedicated in-house expertise (i.e. no HF specialist) and do not always know who to refer to, as presented in the author's preliminary study in Chapter I. There, it was felt that this may have been reflected in terms of attitudes towards factors such as the use of specialists or not, the integration of a human factors report within the investigation, the use of specific methodology, the training of their investigators. Consequently, cross-tabulations between the areas covered during HF training and the location of the respondents are presented in figure 23.

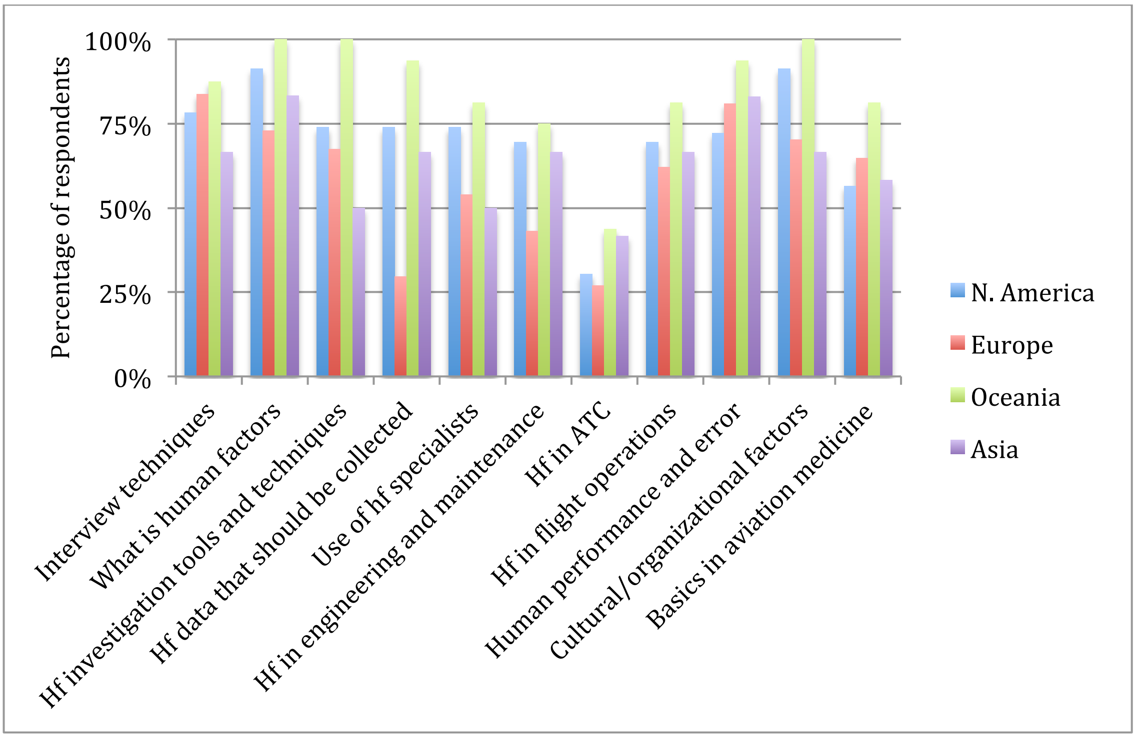

Figure 23: Human factors areas covered during training by location

Figure 23 suggests that the respondents who were located in Oceania do receive a more complete training. On the other hand, the Europeans' training appears to be the least complete. This could be attributed to the difference in culture and approach to human factors. For example, every ATSB accident reports does contain a human factors section. Besides, all ATSB investigators need to undertake the worldwide-recognised ATSB human factors course (undertaken by investigators from all over the world) as part of their training. For 100% of the Australian respondents, 'HF tools and methods' was part of their training. This seems consistent since the ATSB is using their own adaptation of Reason's model as a methodology to run an investigation. Every investigator would therefore need to be familiar with it. The 'HF data that should be collected' has also been taught to the majority of the Australians (93.7%) but only few (29.7%) of the Europeans who answered the questionnaire.

The next question regarding human factors training was " *how confident do you feel in practicing these human factors areas*?" The purpose of this question was to identify whether the investigators who undertook training in a specific area feel more confident than the others. As illustrated on figure 24, overall, amongst the investigators who received training in the different areas, under 10% (except for 'HF in ATC') of them ticked 'do not feel confident' in applying their knowledge. 'Interview techniques' is the topic where the most of them feel confident. However, it is interesting to note that for most areas, a third of those who received training do not feel confident enough to tick 'confident'! A lot of them answered 'Neutral'. This is particularly obvious for 'Tools and methods' (44.6% of the participants), 'engineering and maintenance' (35.8% of them), and 'human performance and error' (31%). It could suggest a lack of confidence but also the fact that they are actually unsure about their level. This could also be attributed to deficiency in training or the lack of refresher courses. Skill fade does occur when one does not use one's knowledge often enough. On the contrary, when practised regularly a skill is developed. This could therefore also explain why interview techniques scored the highest in this question.

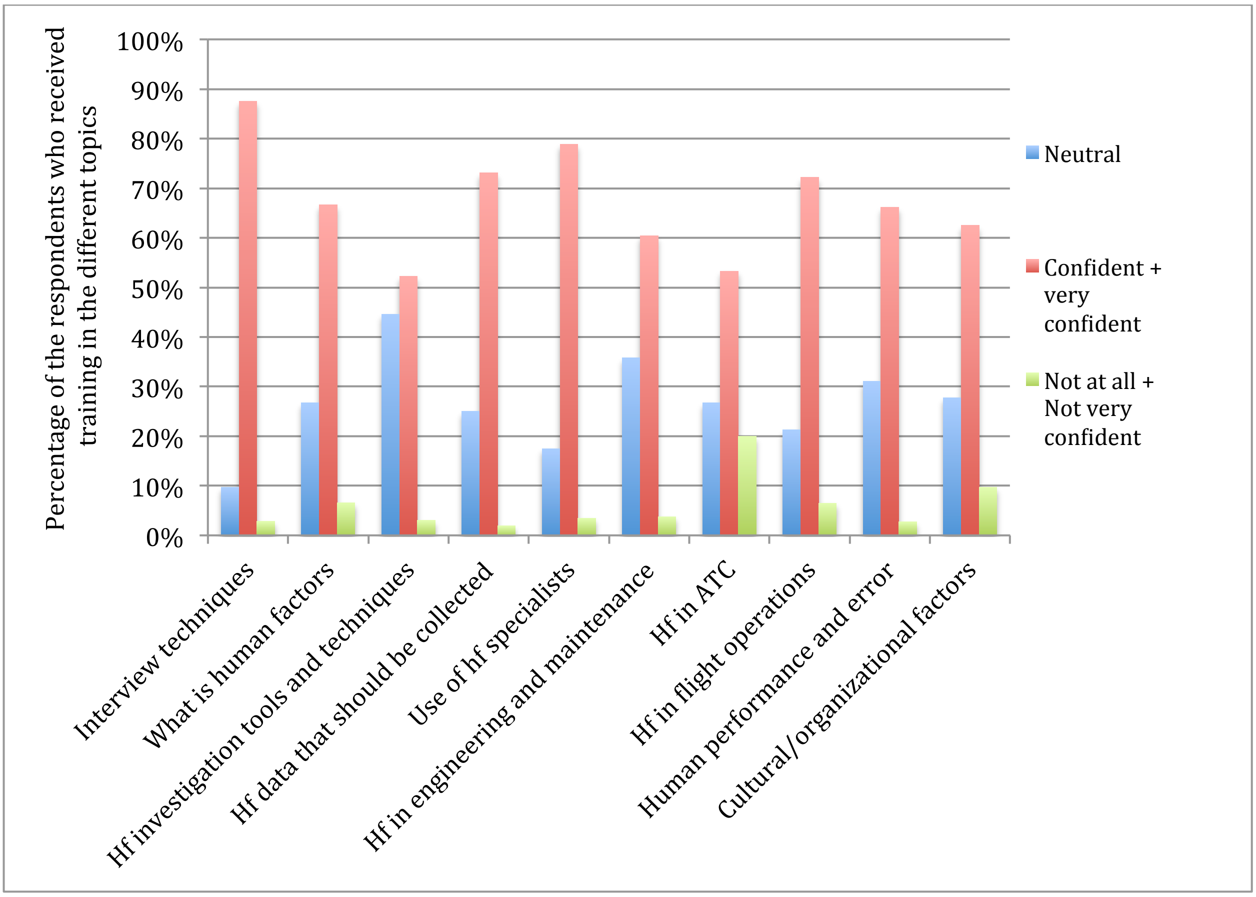

Figure 24: Level of confidence if received training in the different human factors areas

The next step was therefore to look at the level of confidence of those who received the training in the different HF areas, depending on their role. Figure 25 shows the percentage of investigators who feel sufficiently confident to apply the knowledge they have acquired during the training of the different HF topics. 'Interview techniques' is the topic where the most of them feel confident, as also shown on figure 24. 'Tools and methods' and 'human performance and error' are the topics where the fewer investigators feel confident, despite the fact that they did receive training. Only 57% of the 'operations' investigators, 46.7% of the 'general' and 31.3% of the 'engineering' feel confident in using 'Tools and methods', only 47% of the 'engineering' and 28% of the 'general' regarding 'human performance and error'. Figure 25 shows clearly that on the one hand the human factors investigators feel confident in all the areas. Since it is their role to run the HF component of an investigation, it shows their assurance in applying their knowledge and expertise.

On the other hand, the engineering investigators are the type who feel the least confident to practice HF. They also were the most (22%) who replied NO to receiving more HF training (see figure 21). This could be explained by the lack of practice but also by the inadequacy of their training. The majority (78%) of the engineering investigators of the sample were nonetheless willing to receiving more HF training. Considering the operations investigators background too, former pilots, they would all have received some sort of CRM. CRM approaches a lot of human factors issues, which could be why ops investigators overall feel confident in practising most of the HF areas during an investigation. These results suggest that the more HF knowledge investigators acquired during background experience and/or training, the more receptive they are to it, although this may not be a causal relationship.

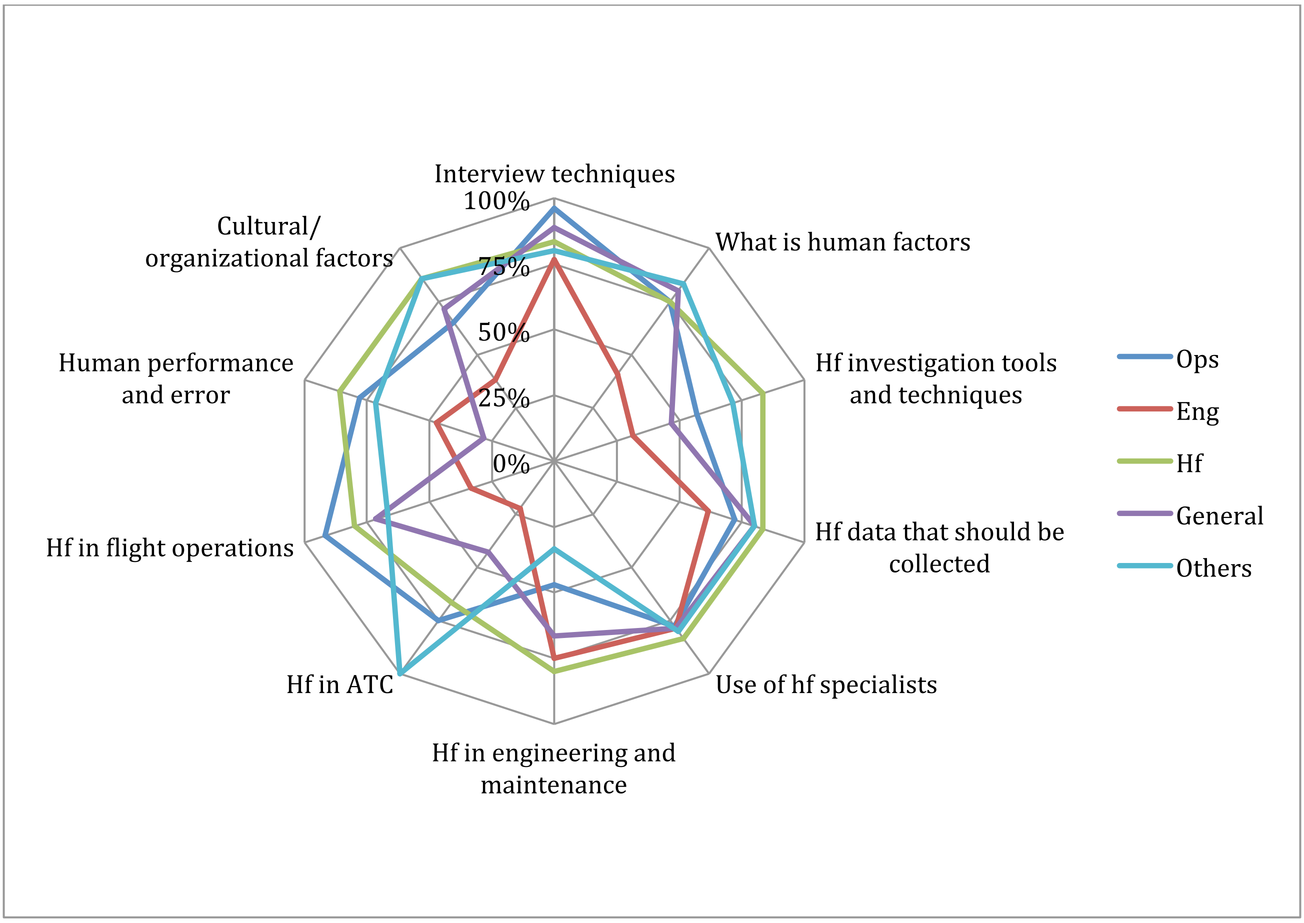

Figure 25: Percentage of investigators who feel confident in applying the different HF areas

Finally, the last question regarding human factors was "*Do you think human factors is investigated deeply enough in your organisation*?" Its goal was to measure the satisfaction of the investigators regarding the way HF is integrated during investigation in their organisation. Overall, 40% of the respondents said YES, 27% said NO and the other 34% stayed NEUTRAL. The results per investigator type are shown on figure 26 and per location on figure 27.

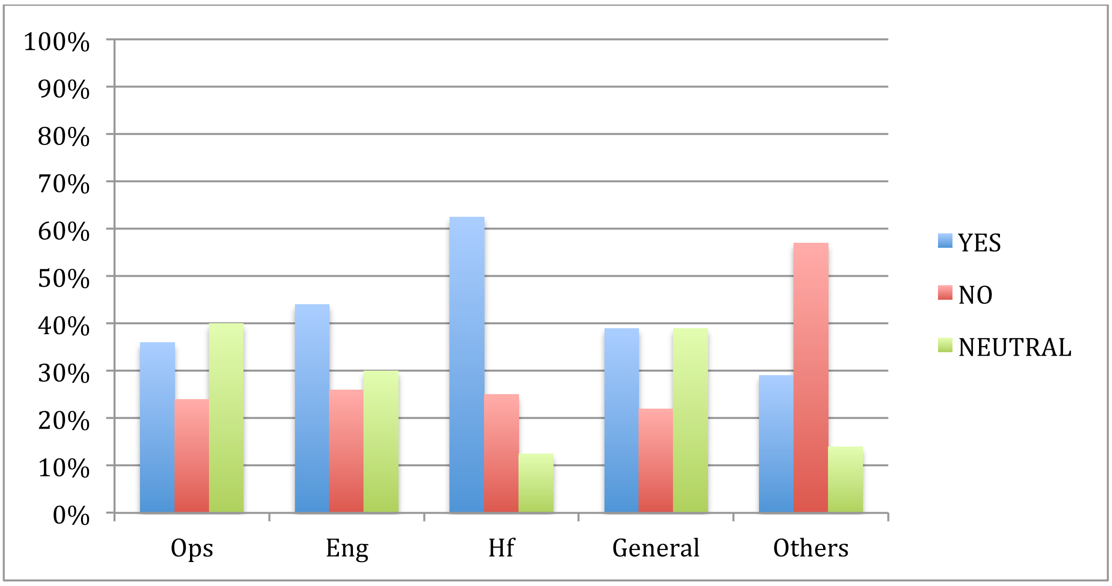

Figure 26: Satisfaction by type of investigator

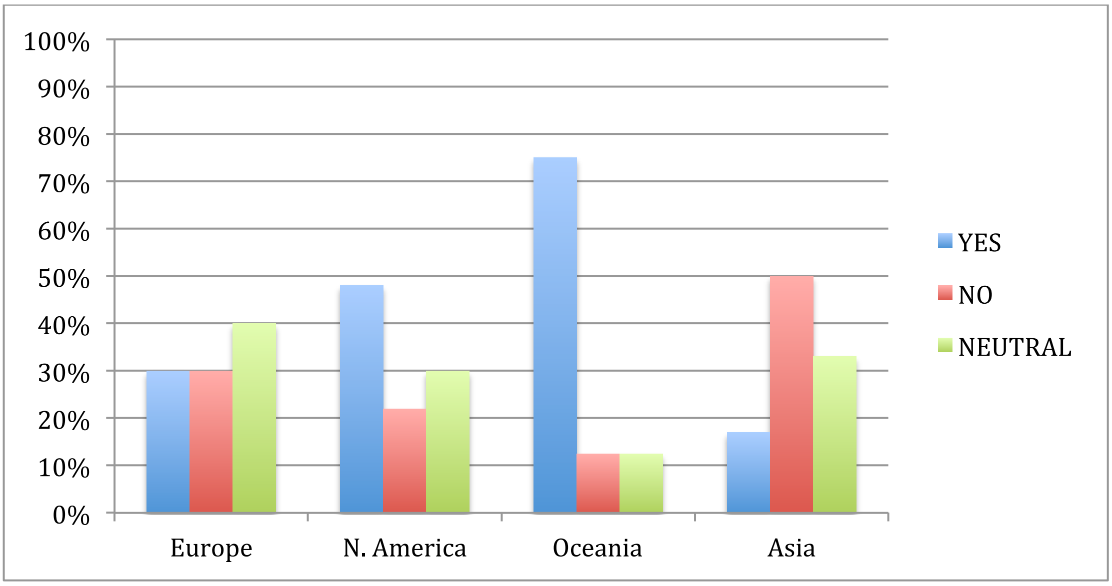

Figure 27: Satisfaction by location

Apart from the HF investigators, less than 50% of each category replied YES. The ‘others’ category seems particularly unsatisfied, however since they are different type of investigators, it is difficult to interpret this result. There is a high percentage of NEUTRAL responses, which would suggest that the investigators are not completely satisfied nor disatisfied with the way human factors is investigated in their organisation. It is particularly visible for the 'operations' and 'general' investigators, with 40% of 'Neutral' for both and 36% and 40% respectively of 'Yes'. After the 'HF', the 'engineering' investigators are the ones who replied the most 'Yes' (44%). Looking at the different locations (see figure 27), Oceania (Australia) has the higest percentage of YES (75%). This could be due to the fact that they do have their own team of HF investigators within the organisation, a compulsory week long human factors course and a methodology based on Reason's model. Overall, Asian investigators, do not feel satisfied with the way HF is considered in their organisations evidenced by 50% of 'No' and Europeans' point of view is equally split between YES (30%) and NO (30%).

V- 4 Discussion and conclusion

The results presented in this questionnaire regarding the content and relevance of the training provided to air accident investigators are extremely valuable and noteworthy, despite the limitations brought by the small sample size and small number in each category. They fulfilled the survey's objective to evaluate the relevance and efficiency of human factors training provision for air accident investigators. Whether it relates to initial training, specialist courses or more specifically human factors training, the courses that the investigators undertook show inconsistency. Within one organisation, or one country, the investigators did not receive the same training, nor in the same depth. This could be explained by the different levels of experience within the sample, i.e. training received at different times. While refresher training might overcome this potential issue, this was not specifically included in the questionnaire because this had not previously been highlighted in the literature.

The results show a lack of standardisation, which could imply the absence of accreditation and the need for it as emphasized by Braithwaite (2004). The limitations of training adequacy is also obvious, since the fact that 'Relation with families', although highlighted as one of the biggest challenges for accident investigators by Tench (1985), Smart (2004) and Stoop and Dekker (2012), was part of their training syllabus (initial, advanced courses and refresher) for only a very few (see figures 16, 17 and 18).

Regarding human factors training, this questionnaire has highlighted its limited relevance, since despite training, investigators do not often feel confident in applying their knowledge. It also lacks potentially important topics such as 'Tools and Methods' and 'Data to be collected'.

Moreover, the training could be more adapted to the investigators role: engineering investigators' training could focus more on engineering and maintenance issues and equally, operations investigators' training could concentrate more on flight operations issues. This could potentially develop their understanding of the specific issues related to their discipline. If however the organisations' goal was to train the investigators with a more generalist approach to HF, each topic could be approached to a similar depth. These results are consistent with the findings from the author's previous research (see Chapter I). The lack of confidence in investigating organisational issues also emphasizes, in part, the weaknesses of their training. This could certainly be one of the reasons why investigators fail to address the 'why' properly and stop too soon (Kletz, 2006).

Finally, the questionnaire has highlighted that where integrating human factors in an investigation can be an on-going challenge for many organisations, introducing the investigators to the HF expertise available (internally or externally) could be a relevant area of improvement. Human factors specialists are subject matter experts and the results of this survey show that they do feel confident in accomplishing their role. Their presence is essential to run a thorough investigation (Baker, 2010). Nevertheless, their integration within the investigation team and their role is questioned by the fact that only few of them, compared with other investigators, received deep training in investigation management or management of a large site. It would therefore be relevant to obtain a more detailed point of view on their involvement and their approach. Their background would also be important to understand. Who would the ideal expert, who understands the organisation's needs, be?

The researcher also identified this challenging question after running interviews within the organisation mentioned in the preliminary study in Chapter I. This explains why the next step of this research was to interview human factors experts who are involved in air accident investigation and therefore get to work with accident investigators. Getting a subject matter expert point of view would help in defining the extent to which investigators should be trained in human factors.

Chapter VI – Human factors experts interviews

VI- 1 Introduction

The initial research presented in Chapter I, the review of the literature in Chapter II, the analysis of accident reports in chapter IV, and the analysis of the questionnaire survey in Chapter V identified two main challenges for accident investigators; deficiencies in their HF training, such as inconsistency and lack of refresher training, and the perception that there is room for improvement with regards to involving a human factors expert in accident investigation. These issues, which are of prime relevance for conducting a TNA, are systematically assessed in in this chapter from the perspective of selected human factors specialists. To this end, the chapter presents the findings from a series of semi-structured interviews conducted with HF investigators. 'HF investigator', refers to a HF specialist that gets involved in accident investigation for his/her expertise in HF and as such investigating the HF element of the investigation.

In turn, the analysis presented in this chapter forms the first part of a two-part triangulation approach, which adopts both qualitative elements (this chapter) and quantitative methods (addressed in the following chapter) in order to 'triangulate' the various findings in order to establish a common consensus. Together, these fulfil the fourth research objective, which is to assess the training needs of air accident investigators.

The purpose of this study is to obtain their specialist opinion and experience on the provision of human factors training for accident investigators, i.e. to assess the training needs of air accident investigators. Their involvement within an investigation and their role within the organisations were also investigated in order to identify potential solutions to more thorough HF integration in investigation reports. Thus it partly fulfils the fourth objective of this thesis (see Chapter III).

The following section introduces the concept of triangulation, why it was selected and how it applies to the research. This is followed by a description of the method employed for conducting the interviews, with the subsequent analysis of these in section 4.

VI- 2 Triangulation

As a term, triangulation takes its origin from engineering and surveying. Using measurements of angles and distances, surveyors were able to determine the exact position of a point when knowing the location of two others (Richards, 2009). Similarly, navigators have long used the principle of triangulation to locate an accurate geographical position when two or more other coordinates were already known (Denscombe, 2003).

From a methodological standpoint in social research, triangulation involves looking at similar issues, challenges, or research questions from different points of view in order to improve the accuracy of any findings generated (Neuman, 2006). In qualitative research, validity can be threatened by various sources such as respondent's bias (e.g. withholding information), researcher's bias (e.g. assumptions) and by reactivity (effect of the researcher on people's behaviour) (Lincoln and Guba, 1985). Triangulation can therefore be used to reduce these problems by asking the same questions a different way, and thus help to improve the validity of findings (Richards, 2009). From a practical standpoint, conducting a triangulation means using different types of data gathering methods or different methods of handling data (analysis methods) to answer the same research question. For Oppermann (2000), triangulation should be used as a way to verify the results and eliminate investigator bias or shortcomings.

Flick (2004) recognises three broad categories of application for triangulation: a validation strategy, a generalisation approach and a way to get more knowledge on the research problem. In turn, there are four specific types of triangulation (Denzin, 1988 in Robson, 2002; Neuman, 2006; Silverman, 2006):

1. Data triangulation, which involves the use of multiple sources of data (e.g. documentation, observation, interviews)
2. Methodological triangulation that involves the use of both qualitative and quantitative methods
3. Observer triangulation that involves several observers in the study
4. Theory triangulation is used when the researcher has multiples theories or perspectives.

The benefits of using a triangulation approach are variously supported in the literature. For example, for Creswell and Miller (2000), triangulation is a validity procedure where the researcher relies on multiple sources of evidence to corroborate his/her findings. In other words, looking at a phenomenon from different perspectives is better than looking in only one way (Neuman, 2006). Robson (2002) describes triangulation as a valuable strategy to reduce threats to validity but nevertheless points out the possibility of contradictions between the different sources. Denscombe (2003, p133) believes that using different methods can enhance the validity of the data:

"*Seeing things from different perspective and the opportunity to corroborate findings can enhance the validity of the data. They do not prove that the researcher has got it right, but do give some confidence that the meaning of the data has some consistency across methods and that the findings are not too closely tied up with a particular method used to collect the data.*"

Denscombe, 2003, p133.

While triangulation can be a valuable research tool, there remains some debate regarding its potential limitations and, in particular, whether triangulation reduces validity of the finding in qualitative research (Ritchie, 2003; Denscombe, 2003). For example, although largely in support of triangulation as an approach, Denscombe (2003) also warns against taking the analogy of triangulation too far, and to avoid assuming that triangulation 'proves' that the analysis is absolutely correct. Similarly, Silverman (2006) believes that triangulation has only limited use as a method of validation in qualitative research because it ignores the consequences of individual contexts. However, in the same text Silverman does acknowledge that triangulation is a valuable means to add a rigour and richness to research, a view also shared by Denzin and Lincoln (2000).

Other possible limitations of triangulation include the increase in time needed to undertake two or more studies and the risk of the researcher not being proficient in both types of method (qualitative and quantitative) and therefore jeopardizing the whole research quality (Thurmond, 2001). Regarding methodological triangulation, as used in this research, it is important to note that the strengths of one method may not compensate for the weaknesses of the other (Fielding and Fielding, 1986).

To summarise, triangulation can provide security to the researcher by extending the understanding, and adding greater depth to the analysis. It can also give a broader picture of what is being researched (Ritchie, 2003) by investigating the convergence and divergence of findings, although for Flick (2004) it should be used more to elucidate divergence than trying to obtain confirmation (convergence) of previous findings.

Considering the worldview within which this research is conducted and its mixed-methods approach, a validation triangulation is the strategy employed in this study. Its purpose is to reduce the researcher's bias when analysing the transcripts from the semi-structured interviews and obtain more in-depth findings regarding the issues being addressed, which are human factors training provision and involvement of human factors expertise.

With this in mind, both qualitative and quantitative methods were used sequentially in this thesis (Robson, 2002; Neuman, 2006). This way, the triangulation will enable the enhancement of the findings from the interviews with the human factors experts. The findings from the questionnaire presented in Chapter VII will therefore be quantitative evidence to support and/or clarify the findings from chapter VI in order to limit subjectivity.

VI- 3 Method for conducting the interviews

VI- 3- 1 Semi structured, face-to-face and one-to-one interviews

The process of interviewing was chosen because it would provide the researcher with greater in-depth insight into the topics of human factors training and investigation than a questionnaire alone (Denscombe, 2003). One advantage of interviewing as a qualitative research tool is that it requires relatively few technical skills on the part of the researcher, although it is essential that they are a good listener, sensitive to respondents and have the ability to use probes, prompts and tolerate silences (Denscombe, 2003). This is not to say that interviewing is an easy task, but it predominantly involves the researcher aiming to understand and record the interviewee's experiences (Silverman, 2006). Moreover, according to Rowley (2012), interviews are useful when trying to understand experiences and opinions, which suit the purpose of this study well.

Interviews were ultimately selected over competing approaches, such as observation, because the issues approached during this study are not amenable to observation (Bryman, 2012). Indeed, for the researcher to observe human factors investigation, training and expertise would be highly impractical, if not impossible. It would also likely be extremely time-consuming and potentially invasive for the investigators. Moreover, observation does not give access to previous experience and is also limited by the variety of persons that can be approached within one organisation.

Three types of interviews exist: Structured, Semi-structured and Unstructured. Each have their specific attributes and advantages as detailed in table 5.

	Structured interview	Semi-structured interview	Unstructured interview
Interviewer and questions	Predicted questions, no prompting, no probing	Clear list of issues and questions to be answered: interview guide, some probing	Aide memoire, single question to start the interview. Active listening
Interviewee and answers	Close ended answers, more like a questionnaire	Open ended, develop ideas and speak widely on topics approached	Open ended, interviewee develop their own thoughts
Advantages	Standardisation, pre-coded answers, easy analysis	Flexible in terms of questions order	Flexible process
Disadvantages	No flexibility	Time consuming, can be expensive	Time consuming, can be expensive

Table 5: Types of interviews (Adapted from Denscombe, 2003; Silverman, 2006; Bryman, 2012)

Structured interviews, as their name suggests, follow a rigid framework and can produce quantitative data in a similar fashion to a questionnaire. The researcher conducting a structured interview has a list of pre-determined questions and pre-coded answers and needs to follow the same order from one interviewee to another. This can be useful when the same interview must be replicated a number of times (for example, when there are a number of different researchers conducting the interview) in order to aid comparison between different respondents, or when the topic is very clearly defined and only a few questions are of interest to the researcher.

Alternatively, there are also semi-structured interviews and unstructured interviews. They are often referred to as 'in-depth interviews' or 'qualitative interviews' (Denscombe, 2003; Bryman, 2012). Both of these methods are more flexible than the structured type in terms of questioning and answering. In the semi-structured format, the researcher has a clear and defined idea of the topics he/she wants to approach whereas in the unstructured type, the researcher has more of a general notion of wanting to research a topic. The main benefits of a semi-structured approach is that it essentially represents a compromise between the rigour and replicability of the structured approach, but also allows the flexibility to ask follow up questions, probe and explore other topics if necessary. Here, the researcher started this study with a relatively clear focus on the topics to be approached during the interviews, so the semi-structured format was the most appropriate, compared with the unstructured format.

To structure the interviews, the researcher developed an interview guide, listing the topics to be approached during the interview (Kvale and Brinkmann, 2009; Bryman, 2012), but with no specific order or detailed questions. The interview guide was used as an aide memoire to guide the topic areas to be covered during each interview. The wording of the questions was similar from interviewee to interviewee, but questions not originally in the interview guide were also sometimes asked after the researcher picked up on certain things said by the interviewee (Bryman, 2012). It was considered important for the interviewer to listen to the interviewee and ask questions depending on the participants' answers to previous questions so that the interview was more in the form of a conversation (Kvale and Brinkmann, 2009). This helps to put the interviewee at ease and build rapport, which are other benefits of the semi-structured approach. A semi-structured interview such as this enables the researcher to access attitudes and values that cannot be observed with a questionnaire or a structured interview (Silverman, 2006). Finally, semi-structured interview provides leeway to the interviewee in the way he/she answers the questions which helps them feel more comfortable and reduce the interviewer's bias.

There are three ways that interviews can be conducted: over the phone, face-to-face and a much newer method using internet media such as Skype or Facetime. Table 6 compares these three formats.

	Phone interview	Face-to-face interview	Skype interviews
Advantages	Low/moderate cost Quick to administer Perception of anonymity for interviewees	High response rate Longer interviews Interviewer can observe reactions and surroundings Rapport development possible Written consent	Low cost, worldwide access Visual (non verbal) cues available
Disadvantages	Small number of questions More difficult to address sensitive topics	High cost Interviewer's bias	Participants may feel embarrassed being filmed (and recorded) Can be difficult to avoid any external distraction (at work or at home) Time lag

Table 6: Advantages and disadvantages of interview formats (adapted from Sturges and Hanrahan, 2004; Neuman, 2006; Bryman, 2012; Deakin and Wakefield, 2014)

All the interviews conducted for this study were face-to-face. This format was chosen over phone interviews because the latter, although much cheaper, are generally considered to be more appropriate for structured interviews or questionnaires (Fontana and Frey, 1994; Neuman, 2006; Bryman, 2012). In fact, relatively few modern qualitative research studies employ phone interviewing (Sturges and Hanrahan, 2004). One of the major limitations of a telephone interview is that the researcher will inevitably not be able to assess potentially important visual cues or other factors such as participants' body language.

Although Holt (2010) believes that telephone interviews should be preferred for some interviews, depending on the groups of participants, face-to-face interviews are often considered as the 'Gold standard' of interviewing (McCoyd and Kerson, 2006). However, online interviews are acknowledged as an alternative approach when it is not feasible to interview the participant in person (Deakin and Wakefield, 2014). The literature provides different views on the use of videoconference tools, such as Skype, as substitutes for face-to-face interviews. For example, Weinmann et al (2012) state that telephone interviewing remains a better approach than Skype because the former generally produces a higher response rate. On the contrary, Deakin and Wakefield (2014) found that participants who claimed not to have time for face-to-face interviews were often more willing to participate when offered the opportunity to use Skype. Hanna (2012) claims that Skype interviews are a good compromise between phone interviews and face-to-face interviews because they retain the important visual element while still respecting the private space of both the interviewer and the participant.

While face-to-face interviews are not always the most appropriate method for a study and do not necessarily always produce the best data (Sturges and Hanrahan, 2004; Novick, 2008), they were preferred for this study for a number of methodological and logistical reasons. Aside from not wanting to miss any important visual cues during the interviews (as previously discussed), during the initial process of contacting potential interview participants it was apparent that in some cases it was going to be beneficial to share relevant documentation, such as training plans or investigation tools to help illustrate points or particular questions. This would have been impossible to conduct over the phone and impractical during a Skype conversation.

Furthermore, for the majority of the interviews the researcher organised a visit to the organisation on a specific day and interviewed all the human factors experts present who were available and willing to be interviewed. This approach proved to be extremely time and resource efficient in terms of conducting the required number of interviews. An additional benefit of this approach that had not been anticipated by the researcher was the increased flexibility it afforded. While the organisation of Skype interviews required strict prior organisation of a time and date to conduct the interview with each participant, by being available 'all day' at the interviewees' place of business, each participant could conduct their interview as and when they were available, and to some extent allowed the participants to organise this schedule amongst themselves. Given the unpredictable nature of the participant's work, this increased flexibility on the part of the researcher is thought to have resulted in more positive responses from participants than if a Skype interview had been proposed.

Most of the experts were interviewed on a one-to-one basis. However, two participants requested that they were interviewed together because they believed they shared similar experiences and opinions on the topics approached during the interviews.

The one-to-one format was also chosen over focus group because it presents numerous advantages. As a researcher, one-to-one interviews are generally easier to organise and control than focus groups as the researcher only has one person at a time to meet with, interview, and listen to (Denscombe, 2003). Given that some issues raised in the interviews may have been of a potentially sensitive nature (for example, their organisation's current practices) it was felt that interviewees may have been more willing to 'open up' than in a group environment.

During the interview each interview was recorded on a voice recorder, after the participant had given their permission to do so. The researcher took notes throughout the interview in order to record what was said but also to note down important issues that needed to be developed further by, for example, using probing questions. Notes were also taken to log non-verbal cues such as looks or when the interviewee used sarcasm or deliberately ironic tones (Denscombe, 2003).

All but one interview was fully transcribed after the interview process was complete. This was due to the poor sound quality of one specific recording. Each interviewee was given an interviewee guide (see Appendix C) providing a short summary of the research and the topics approached during the interview, the researcher's contact details, information on the complete anonymity of the interview and the fact that it was recorded for analysis purposes, and a right of withdrawal. They were asked to give written consent to conduct the interview by signing two identical consent forms, one of which was kept by the researcher while the other was kept by the participant. When required by the organisation the researcher sent the interviewee guide in advance. This happened on two occasions.

VI- 3- 2 Interview sample

A total of eighteen interviews were conducted with nineteen human factors experts involved in accident investigation in November 2014 (see table 7). Prior to that, a pilot interview was conducted to test the interview schedule (see VI- 3-3), but it does not appear on table 7 because it was not analysed.

While a total of eighteen interviews were conducted, only seventeen interviews were analysed as one of them could not be transcribed due to the poor quality of the sound recording (as mentioned previously).

Of the remaining participants, two were from the UK and the rest were from Australia. Australia was targeted because of its strong human factors culture, its renowned human factors course and methodology for accident investigators and for the HF team present within the ATSB. It would enable the researcher to obtain several interviews in a shorter amount of time. The AAIB, for example, does not have such a team. The two experts from the UK were contacted due to their strong involvement with the military accident investigation organisation.

Interview Number	Type organisation	Participant's role	Involvement as IIC	Country
1	Airline	HF expert - investigation support	No	Australia
2 – 3 - 4	Airlines	HF investigators	No	Australia
5 – 6 - 7	National Investigation Agency	HF investigators – management position	Yes	Australia
8 – 9 – 10 – 11	National Investigation Agency	HF investigators	Yes	Australia
12	Air Traffic Control	HF investigator	No	Australia
13	Civil Aviation organisation	HF expert – investigation support	No	Australia
14 - 15 (2 participants)	Consultancy	HF investigation support	No	Australia
16	Military organisation	HF investigator	No	Australia
17 – 18	Military organisation	HF investigators	No	UK

Table 7: Human Factors experts interviewed

All the HF investigators interviewed from the ATSB are involved in investigation as IIC whereas it was not the case for all the other experts. Of the seven participants from the ATSB, three of them were holding management position as well as being involved in investigations.

Fourteen interviews were conducted in the participants' workplace, after agreeing on a convenient date and place. Three interviews were conducted in an improvised area during a conference and one at the interviewee's home.

Given the desire to conduct the interviews face-to-face rather than by Skype, it was necessary to travel to Australia to facilitate this. This was arranged by making contact with potential participants (most of whom worked for the ATSB) by e-mail. Seven interviews were subsequently held in the Canberra and Brisbane offices of the ATSB in November 2014. Some interviewees also suggested contacting additional participants based at other institutions. Subsequently, ten further interviews were arranged with participants from Sydney, Brisbane, Canberra and Melbourne.

VI- 3- 3 Interview schedule and conducting the interviews

An interview schedule is a list of questions or topics that are to be approached during each interview. In the case of semi-structured interviews, following this schedule can be done in a flexible way. Here, the interview schedule was based on topics from findings from previously conducted research (presented in Chapter I), the challenges and issues identified in the literature review (Chapter

II) and the reports analysis (Chapter IV) as well as the findings from the questionnaire in Chapter V. The purpose of these interviews was to obtain a greater insight on human factors investigation, the human factors knowledge and training of investigators and understand the experts' role during an investigation, thus fulfilling, in part, the fourth research objective.

Before conducting the interviews, a practice or 'pilot' interview was conducted with an HF consultant based at a well-known multi-national consulting firm. The purpose of this was so that the interview could be tested 'in the field' in order to practice the order and wording of the questions as well as logistical issues such as using the audio recorder and keeping the interview to time. Following the pilot interview, a number of small adjustments to the interview schedule were made. These minor changes included shortening the wording of some questions so that they were more succinct and sounded less formal when they were delivered. From a technical standpoint, it was found that the recording was clearer when the sensitivity on the audio recorder was increased.

To start the interview, the researcher introduced herself, asked the participant whether the interviews could be recorded for analysis purposes and gave the interview guide to the participant. The first question in each interview was an introductory question, requesting information on the participant's background:

'*Could you tell me about your background and how you arrived in your position?*'

The purpose of this question was to make the participant and the interviewer comfortable and at ease, because it is easy to answer and covers familiar territory, whilst also providing valuable information for the researcher (Denscombe, 2003). This type of non-threatening question is commonly used in qualitative interviewing as a 'warm-up' question (Robson, 2002). The question led to developed and rich answers from the interviewees regarding their experiences in accident investigation but also their academic background.

While some investigators spontaneously elaborated on their role within their organisation, others where specifically asked the following question: '*Can you tell me about your role within your organisation?*'. The objective of this question was to better understand the role of human factors investigators within their organisation, and the process of a human factors investigation generally. The questionnaire in Chapter V highlighted that human factors experts tended not to receive training in areas such as 'management of large site' or 'dealing with inquest, legal skills' so this question also gave relevant information on whether or not they were deployed on site, at what point they were involved in an investigation, and the sort of responsibilities they were given.

From that point, the researcher entered the 'main body of interview' (Robson, 2002, p277). The following question, if not raised naturally by the interviewee, regarded the methodology employed during an investigation. '*Regarding data gathering and analysis, do you use any sort of tool or methodology?*' The literature review (Chapter II) highlighted the importance of accident investigation methodology, whereas the analysis of accident reports (Chapter IV) highlighted that not all investigations involve the use of such methodology, or at least that it is not specified in the reports. The purpose of this question was to understand the benefits and drawbacks of employing methodological tools during an investigation, from a human factors perspective.

Considering the findings from the questionnaire in Chapter V, regarding the human factors training deficiencies for accident investigators, and the different levels of human factors element in accident reports identified in the literature and in the reports analysis, an important question was then '*How is your human factors input received by the other accident investigators?*' This question often naturally led to the interviewees mentioning the training of the investigators. They were then asked to describe the advantages and disadvantages of such training.

Another question was '*Do you think HF consideration in accident investigation could be improved?*' The purpose of this question was to understand what could be done to achieve more thorough the accident investigation process. A common follow up question to this was, for example '*What do you think are the other challenges of human factors investigation?*'

Another topic approached during the interviews was '*understanding and training at management level*'. The purpose of this question was to understand the influence of the management's understanding of human factors on the way human factors is investigated in an organisation.

The following topic approached during the interview was the value of human factors and dedicated human factors expertise. One of the main findings from analysis in Chapter I was the need for a dedicated expert who understands the needs of the organisation. Moreover, the literature (Chapter II) highlighted the necessity to involve a human factors specialist during an investigation. With this in mind, the question '*What do you think is the value of human factors integration in accident investigation?'* was included, followed by '*What do you think makes a good human factors expert?*' The purpose of these questions was to get human factors investigators' point of view on the impact of the involvement of a human factors specialist in an investigation, and to identify the attributes that a '*good*' human factors specialist involved in accident investigation should possess.

Another key challenge identified in Chapter I is the depth of human factors element within the context of a full air accident investigation. Therefore it was a significant topic for this part of the interview. In order to gather the human factors specialists' perspective on such an issue, questions were: '*How deep do you go into human factors?*', '*When do you know when to stop looking?*', and '*How to address the balance between technical and human factors during an investigation?*'. Subsequently, another question for this theme, influenced by the findings from the questionnaire about the deficiencies in training regarding organisational issues investigation was '*How do you address organisational issues*'.

Finally, the interviewees were asked whether they had any other comments on the topics approached during the interview. They were then thanked and the recorder was switched off.

VI- 4 Thematic analysis and coding process

Each interview was audio recorded for analysis purposes. The recordings were fully transcribed by the researcher so as not to lose any information. Analysis was then conducted on the transcripts of these interviews and taking into account the researcher's notes taken during the interviews.

There are various different approaches to qualitative analysis. Robson (2002) lists four of the most commonly used approaches (see table 4 in Chapter IV). The first one, quasi-statistical approaches, relies on the transformation of the data from qualitative format into quantitative format. A typical quasi-statistical approach is content analysis, as is used in Chapter IV. The second approach to qualitative analysis is immersion approaches. These are generally very unstructured and interpretive and emphasize the researcher's observation and judgement. Editing approaches, the third main type of approach, are less interpretive. Grounded theory is commonly considered as a form of an editing approach, and does not involve any form of a priori coding but instead relies on generating codes from the data (Strauss and Corbin, 1990). The fourth main approach to analysing qualitative data is called template approaches. This includes methods such as matrix analysis or thematic analysis. These rely on key codes being determined prior to the conduct of the interviews from previous research or theory (deductively), or after initial reading of the raw data (inductively) (Boyatzis, 1998).

In order to analyse the interviews the researcher conducted a template approach, called thematic analysis, as it is more structured, less interpretive and therefore more objective in nature than editing approaches like grounded theory (Robson, 2002). Having said this, thematic analysis still provides some flexibility in the fact that the template, or themes, can evolve or change as the analysis goes on (Robson, 2002; Braun and Clarke, 2006). The process of thematic analysis involves the identification of themes (the 'code'), or patterns, within the data (interview transcripts), and their analysis (Boyatzis, 1998; Braun and Clarke, 2006).

One of the strengths of thematic analysis is that it can be adapted under any worldview (Boyatzis, 1998; Braun and Clarke, 2006) as long as it is made explicit. This research's paradigm has been developed in Chapter III and it is therefore possible to tackle thematic analysis considering the assumptions made as part of the research design.

In order to conduct thematic analysis, several abilities are required from the analyst (Robson, 2002; Boyatzis, 1998). One essential skill is having relevant knowledge in the area under enquiry in order to be able to identify what is important and give it meaning. This is what Strauss and Corbin (1990, in Boyatzis p8) refer to as 'theoretical sensitivity'. Another important competency necessary to the analysts is the ability to identify themes and patterns (codable moments) and do it reliably (Boyatzis, 1998).

Braun and Clarke (2006) list several decisions that need to be made prior to starting thematic analysis. Amongst those choices is the clarification on what counts as a theme within the data. A theme is an important section of the transcript that addresses the research question. The researcher identified the themes depending on their importance within each individual interview as well as in the whole set of data, that is to say if it was approached by at least half of the participants.

Another important decision that needed to be made, as noted by Braune and Clarke (2006), was whether the analysis was to be inductive or deductive in nature. Here a compromise was agreed upon that included both inductive and deductive elements. The initial codes on which this thematic analysis was based were developed from theories derived from previous research in this thesis and the literature. Here, the thematic analysis can be considered a theoretical thematic analysis (Boyatzis, 1998). However, the researcher kept an open mind about discovering more relevant themes as the analysis progressed. Consistent with the flexible nature of thematic analysis, and considering the mixed-methods research approach of this project, new themes were then created inductively from the data itself during the analysis.

The process followed to conduct the thematic analysis was the six-phase process described by Bran and Clarke (2006), detailed in table 8.

Phase	**Description of the process**
1. Familiarising yourself with the data	Transcribing data, reading and re-reading, noting down initial ideas
2. Generating initial codes	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code
3. Searching for themes	Collating codes into potential themes, gathering all data relevant to each potential theme
4. Reviewing themes	Checking if the themes work in relation to the coded extracts and the entire data set, generating a thematic map of the analysis
5. Defining and naming themes	On going analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme
6. Producing the report	Final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating it to the research question and producing a concluding report

Table 8: Phases of thematic analysis (from Braun and Clarke, 2006, p87)

The initial code (Phase 1, see table 8) consisted of the following themes: human factors training for accident investigators, human factors integration in an investigation (depth of HF element and methodology) and the importance of dedicated human factors expertise. As mentioned, this was generated from the literature review, the findings from the researcher's previous study, the findings from the review of accident reports and the findings from the questionnaire amongst accident investigators. The interview transcripts were then coded using these themes (phases 2 and 3, see table 8). In practice, this meant that each section of the text that was considered to be relevant was 'labelled' with the appropriate theme. This sort of coding is also called 'topic coding' (Richards, 2009).

After going through each interview, the initial coding frame evolved into a more developed, accurate and meaningful set of themes (Phase 4 and 5). This latter stage of the coding exercise, also called 'analytical coding' (Richards, 2006), is commonly used where the true value of the analysis is realised. It involves the reflection on the meanings of what the interviewees are saying and explains why a specific section of the text, or theme, is interesting and relevant to the research.

VI- 5 Interview Findings

The analysis of the interviews, using thematic analysis, resulted in the identification of eleven themes overall, which were arranged as seven main themes and four subthemes. Based on interpretation of the findings from the interviews, they were related in the following way: see figure 28

The main themes are credibility, managerial culture, HF training, team dynamics, HF integration, accident report and HF expert attributes. They were classified as main themes because investigators mentioned them on several occasions, elaborating and going into great detail by providing examples. It was interpreted that these main themes were also the participants' main challenges and therefore were of high importance concerning the research objective. The subthemes identified in the interviews were investigators acceptance (of HF), HF input (evidence based), the scope of the HF investigation, and the necessity of a thorough analysis. These subthemes, although important, were only approached by the participants and were not always developed further. They were nevertheless identified as key elements to this analysis because of their impact and influence on the main theme. They are required in the process of a thorough human factors investigation. It was decided to represent this process and influences by arrows (see figure 28) because in some cases, themes were equally affecting each other. For example, the managerial culture (or management) has influence on the recruitment process of the HF specialist. In turn, if the expert contributing to an investigation produces high quality and evidence-based reports, the management is more likely to acknowledge the value of HF.

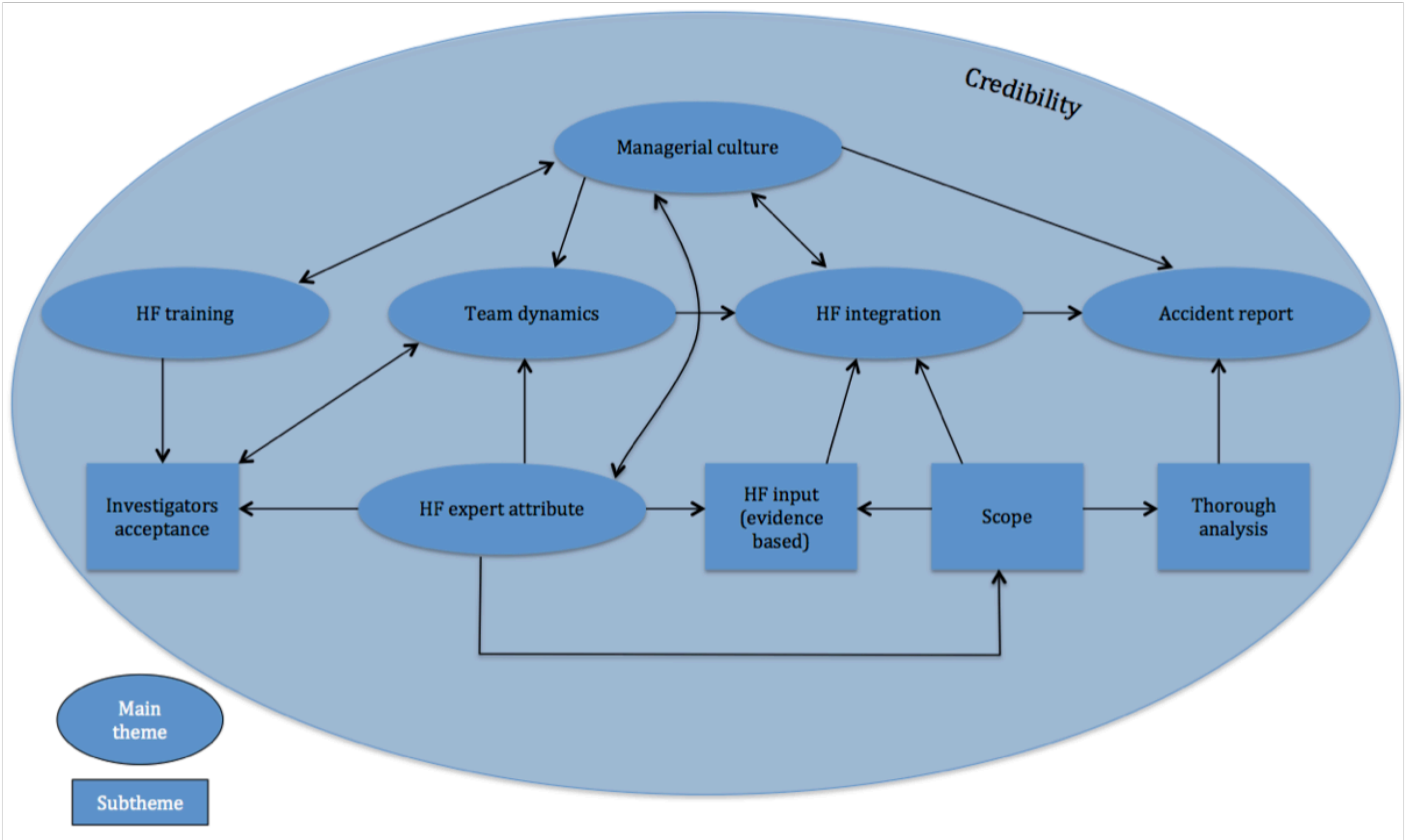

Figure 28: Coding result (themes and subthemes)

The first theme that encompasses everything is *credibility*. This theme, recurrent in all the interviews was seen as 'the biggest challenge' for human factors investigators as well as for the whole organisation. One investigator for example insisted "*In this job, credibility is everything. If we don't get it right (the report) that credibility goes. And this place is built on credibility*" The credibility of an organisation or department running investigations relies highly on the production of thorough, valid and evidence based reports, integrating human factors. Credibility was also one of the main themes discovered after analysis of interviews within an organisation without human factors specialists (see chapter I). Credibility is therefore of primary importance, hence the necessity to base report findings and conclusions only on evidence and not the other way around, which is trying to fit the evidence to match speculations. Credibility was determined as being essential to the other themes, and particularly for the management, and therefore the managerial culture, which is responsible for any published report.

Managerial culture was identified as the key factor for human factors integration in accident investigation. If the management does not believe HF to be relevant then it will not be pushed in the accident investigation process, nor will it be a priority topic in the investigators training. Moreover, some HF experts specified the importance of educating the management in order to have a 'top to bottom' effect on the rest of the organisation. For example, one participant said, "*we'll send the lead investigator to advocate and convince the management that that's* [human factors] *worth pursuing*". This identifies the necessity for investigators and management to understand HF. Other HF experts interviewed were themselves in a management position, and felt that educating senior or top level management was necessary, although they acknowledged that this would likely be extremely challenging in reality. The participants who currently worked with 'HF managers' all highlighted the positive impact it had on the integration of human factors in their company. For example, before a report is published, it is proof read and peer reviewed by a manager or team leader to make sure nothing has been missed and each argument is justified with reliable evidence. It was argued that if the person conducting the review does not understand human factors properly then valuable information could be missed during this process. One investigator mentioned a good example of the change brought by a HF manager: "*I think it changed with my previous boss. She came in and said 'That's not good enough; you are not qualified to assess if there's human factors or not.'*" This also illustrates the necessity for qualified HF expertise.

Experts from the airlines particularly emphasized the level of understanding of HF from the management. As in-house specialists they felt that approaching organisational issues was only possible with a receptive and HF-educated managerial culture.

Thus, managerial culture has an impact on the HF training delivered in the organisation, the team dynamics, the way HF is integrated and the quality of the accident reports. It also has an influence on the quality of the HF specialists because management inevitably has decision-making power over the recruitment process.

The next main theme that came from the interviews is *HF training*. It was found that not only is it necessary for accident investigators to get human factors training, but that they should also regularly undertake targeted and relevant refresher training, according to the HF specialists interviewed in this study. The HF experts interviewed all felt the positive impact of the training provided to investigators. The investigators were described as being more receptive and respectful of the specialist's input. The participants also emphasized that after receiving such training, the investigators were more likely to consult with them when a human factors issue arose. This is how HF training directly influences the investigators HF acceptance, which is one of the subthemes.

Training was also addressed when the participants were answering the questions '*What are the challenges for HF accident investigation?*' Answers varied, but all the interviewees mentioned '*education*' as one solution. From there, some HF experts differentiated between investigators who received human factors training from the beginning of their career and/or training as an investigator (i.e. the '*new generation'*), with investigators who only received HF training later in their career as investigators, sometimes referred to as '*the old school investigators'*. This suggests it may be beneficial to integrate human factors as early as possible in the accident investigators' training.

While the interviewees did not detail the specific content of refresher training, they did mention the issues that they believed should be addressed more in such training, or where understanding was lacking. For example, one HF expert in an airline said: "*I need them to know when to involve human factors*" and "*If it's a case of refreshing the basic modules each year I don't think they'd really need it because they are doing it every day. But if it's a case of here is new incidents and things and concepts that have come up, that I think would be actually relevant.*"

Most investigators agreed with this view that investigators should receive training to remain aware of the recent trends and research in HF but that the objective of this training should be to enable them to identify the point where an expertise is needed and not to encourage them to do it themselves. It was felt that there was a danger in ‘over training’ the investigators. The HF experts recognised that when investigators were trying to develop the HF element of an investigation it was often too weak and therefore increased the risk of involving expertise too late in the process. A HF investigator from the ATSB said for example:

“*I’m always a little concerned that you know, for me, my personal approach with HF course, when we teach a HF course, it’s to get our investigators to understand that human factors is a real thing and then to understand that not everybody can do it. So give them just enough information to convince them, to realise that it is a specialisation and they need to actually talk to some specialists rather than to do it all themselves.*” This highlights that ‘training’ is not to be considered in isolation and that the balance between being an expert and a person who received training is complex.

Team dynamics, which was already mentioned as being influenced by managerial culture, directly affects the way HF is integrated in the investigation and relies on a qualified HF specialist. Although no question directly approached this issue, it was developed as a main theme because several interviewees believed that being part of the investigation team would benefit the quality of the investigation. The participants however also defined this key point as being one of their main challenges. They felt the need to always have to demonstrate the value of their work and input before being considered as an equal member of the team which, they felt, was not required by more technical investigators because their disciplines are already acknowledged fully. Regarding how an investigator sees the acknowledgement of the HF discipline in her organisation, one interviewee noted:

"*We've always sent HF out in the field, so I've done two IIC jobs in the field, two in nine months. I think this helps as well because when you're deployed with a group and you do get to know them a little better and they feel happy coming to see you, and you're not one of these people that sit in their office… You can be a proper investigator too. That kind of integration helps.*"

Thus it appears that being part of the investigation encourages the acceptance of HF from the other investigators. Extensive discussions, team meeting and brainstorming are involved in investigations, particularly during the analysis phase where any bias should be avoided. It was felt by the interviewees that the integration of a HF expert at every stage, from the evidence gathering to the writing of the report, enables a true integration of HF within the investigation.

One of the interviewees said, "*I don't see why human factors investigator can't be IIC*". With the exception of the ATSB, where some HF investigators currently hold management positions, in the majority of organisations HF investigators were not fulfilling the role of IIC. This was surprising, given that one of the main skills required of an IIC was defined as having good project management skills (i.e. attributes closely associated with HF investigators), in addition to understanding the various disciplines that take part in an investigation. However, as highlighted here, there was a general feeling amongst interviewees that HF investigators could fulfil the role just as well as those from other disciplines.

Moreover, the literature emphasised the need to consider HF as a specialist area and therefore the necessity to involve an expert. This expert could be 'in-house' or external to the organisation, which raised an interesting discussion with the interviewees. Both the pros and the cons of this situation were identified by the interviewees. It was felt that one of the main advantages of the in-house expert is that they are considered part of team, which should lead to better team dynamics, which in turn produces better quality reports. Moreover, an in-house specialist may be able to acquire the background knowledge and understand the needs of the organisation, which was a challenge identified in Chapter I.

The possible disadvantages of an in-house expert, particularly in the industry (as opposed to NIAs) is that they may, to some extent, be biased. This can be less likely when using an external specialist. However, an external expert may not get the whole picture and is often called later, which could compromise valuable evidence such as interviewing.

Overall, it was felt that having an in-house expert present during the interviews was very beneficial as he/she has limited technical bias and can ask the more obvious questions, for example the role of a specific autopilot function or determining whether the pilots understand it correctly. It also removes any hierarchy (military, pilot rank) issues. HF experts permanently part of an organisation can also accomplish other tasks such as safety study, training adapted to the needs of the organisation, or development of analysis tools. While this is not to say that HF experts should undertake the interviews on their own, a technical subject matter expert is also necessary to understand the task in detail, their presence was viewed as a benefit overall. This is another example where good *team dynamics* is essential.

The integration of HF can mean a number of things. For example, investigators can refer to their HF peers whenever they feel the need. It also means considering HF at an early stage, and therefore involving an expert when necessary. Interviewing is a key source of evidence in an investigation, and particularly in HF. HF specialists are often proficient at conducting interviewing due to the very nature of the discipline or even the psychology background of some of the experts interviewed. The interviewees insisted that HF should also be embedded in the analysis phase through the use of a tool or methodology. The analysis of accident reports presented in chapter IV demonstrated that such tools provided structure to a report, but it was not always made explicit whether such tools had been employed.

The introductory question meant that the interviewer was able to gather interesting information on the importance of academic background to human factors investigators. In fact, all the respondents had undertaken an MSc and a majority of them a PhD in psychology or human factors. For six of them, that postgraduate degree was obtained after working for a period of time in the industry, for example as cabin crew, pilots or engineers. It was recognised that the knowledge and skills developed as part of this further academic study (for example, handling of large data sets or writing their thesis) had better prepared them for their role as an investigator than had they not undertaken this qualification. It was felt that this was most evident in terms of their improved analytical and writing skills, which perhaps were not so developed among investigators who do not undertake these qualifications. d

Organisations employing HF-based tools and methodology, particularly for the analysis of the evidence saw the positive impact on the quality of accident reports, according to the interviewees. Such tools enable the natural consideration and therefore integration of HF and above all provides a standardisation among the organisation. This tool, often used as a framework or guidance, also enables other investigators to understand the logical process of the investigation if looking at the report years later, although it was noted that only the ATSB and the UK experts were using such a tool accurately. These organisations were also the ones where the experts seem to get the strongest and most influential involvement, which seems logical since an organisation willing to fund a tool is more likely to be supportive and have an awareness of the value of HF.

The *scope* of the investigation, and more specifically the HF element, was also highlighted as essential to a HF investigation. This scope is the depth into which investigators dig to find answers, the extent of the human factors investigation. This theme was approached by the interviewees when asking the questions regarding the balance between the technical and HF elements in an investigation. These questions received positive interest from the interviewees, who noted that defining the scope of the HF element in an investigation was a perpetual challenge. As one interviewee noted, this particular challenge "*is the million-dollar question*'!

An example of this scoping process is described by one investigator, who noted that "Y*ou only have to go as far as the evidence lets you*". Someone else described a more systemic approach to scoping and making sure they did not go too deeply into human factors: "*We try to focus on the accident. We go back into some of the systemic stuff in the organisation but when it starts getting too far out, away from the actual accident sequence, where it's really difficult to link it back to the accident I think that's where we stop*". Scoping the area of research was the solution provided by the participants to the challenge identified in Chapter I regarding the depth and balance of HF in an investigation. A well-defined scope also enables a thorough evidence-based analysis. It is also the product of effective *team dynamics* as illustrated by another investigator who was describing an example where safety culture was involved: "*at the meeting we talk about what are the human factors involved here and where, how far would we go based on what we know at the moment. And so in this investigation we would be looking at its safety culture and its commitment to safety*".

Another main theme refers to the *accident reports.* The final report has been identified as being a key concern for human factors experts. It needs to be evidence-based and objective, consider all the issues, and not apportion blame, which are the characteristics of a safety investigation(see chapter II). A report is also what puts the organisation's credibility at stake. The management will have a last say on the content of the report and this is why it is essential for them to be educated in HF and acknowledge its importance. The report needs to consider all the disciplines and when the IIC is not an HF expert, he or she needs some understanding of HF to be able to integrate the HF element within the whole investigation and link it with other evidence. Another challenge raised regarding the final report is that it needs to be accessible to the general public, for the NIAs, or at least understandable by the non-experts (higher management or co-investigators) for the other organisations, so they can understand it and take actions if required. The quality of the report relies highly on the quality of the *analysis* (subtheme) and is also a product of *team dynamics: "Always multiple people involved in analysis and so then we have what we call team consensus. When the report has to go through the whole team before it goes up to peer review or management*".

Finally, the other major theme that appeared during these interviews is the attributes of the HF expert involved in the accident investigations. It will impact on the *team dynamics* and the *investigators acceptance* of HF (subtheme), and the HF input, by the nature of their role. This input (subtheme) should be evidence-based, which can sometimes seem difficult, considering the nature of HF (see Chapter II). Additional essential attributes identified were the capacity to stay up to date with the literature, proficiency at interviewing and being able to apply theoretical knowledge to an investigation, as discussed by one interviewee: "*I think you need to have experience, I think the reality is you can get a wonderful education but until you actually start applying it and understanding it… that is actually being part of the investigation team*".

The *HF integration* was also indirectly linked to the *quality of the HF specialist.* A recurrent issue appeared regarding investigators having previous negative experience with HF experts (subjective input) and therefore made them sceptical about the value of the discipline.

One participant said: *"As part of the explaining of what happened, I did the research on that. So looking into all the papers and literature on unintentional blindness, distraction, interaction…"* Another one said "*We do go out* [to the crash site] *but it's our ability to pinpoint the right people to go to, from knowledge that we originally have.*" This emphasises the importance of knowing one's own limitations and requesting help from other experts. This also emphasises the importance of critical thinking in order to know where to look and who to contact in such a situation. One important way that critical thinking can be developed is through research, although it is by no means the only way. The technical knowledge of the investigator was also a source of discussion in the interviews. Especially, opinions of the participants varied as to whether it was essential for the HF person to have some industry experience in aviation or whether this could be acquired 'on-the-job'.

VI- 4 Conclusions

Semi-structured interviews were conducted with HF experts involved in air accident investigations. A thematic analysis was conducted leading to development of themes. The main themes were credibility, managerial culture, human factors training, team dynamics, human factors integration, accident report and human factors experts' attributes. The subthemes identified are the acceptance of human factors by accident investigators, the evidence-based human factors input, the scope of the human factors investigation and the through analysis. Those themes were also found to have an impact and influence on each other.

This chapter partly fulfilled the objective to assess the training needs of air accident investigation. It reports experts' opinion on human factors training provision for accident investigators both in terms of its importance, as well as the benefits of refresher training in order to keep investigators aware of current issues and new developments in the discipline. This supports what was identified in the literature regarding the facts that keeping up to date and quality of investigators are key to the credibility of the investigation. It also emphasised the need for this training to accentuate the fact that HF is a specialist discipline and non-specialists therefore should not try to tackle it themselves. It confirms Baker's view (2010) that the presence of an HF expert enables the elimination of biases or preconceived ideas. These findings therefore confirmed the previous results found in this research and develop them further. They are however the product of human factors experts' opinion so the objectivity on the role and importance of the expertise is to be treated cautiously.

A new key finding resulted from this study is that training the management in HF is a key factor to a better integration of HF in accident reports. This set of interviews also revealed important issues such as the importance of excellent team dynamics to run an effective investigation and for the human factors expert to be integrated within that team.

At this point in the research some initial conclusions can be drawn regarding the aim of this thesis, which is to examine the training needs of air accident investigators in order to develop more thorough integration of human factors in accident investigations. Training investigators in HF is indeed a solution, however not *the* solution. It needs to be supported by the integration of HF at all stages of the investigation and is only possible with the input from actual HF experts, who are capable of applying their knowledge to accident investigation. In order to provide valid recommendations on the content of that training and suggest skills and attributes that such an HF specialist should possess, further investigation is necessary. All the different training topics and expert's attributes mentioned during the interviews, were gathered between the whole set of interviews and will be validated through the use of a questionnaire. This questionnaire was sent to the same sample of specialists, and is presented in the following chapter, Chapter VII.

Chapter VII – Human factors experts consensus

VII- 1 Introduction

Before drawing conclusions on the use of TNA in this research project it was necessary to validate and further investigate the findings from the semi-structured interviews, which were undertaken with human factors experts, as presented in Chapter VI. To this end, the chapter presents the findings from an online questionnaire survey, which was sent to the human factors investigators interviewed in the previous part of the research. Consequently, it represents the second and final phase of the triangulation process detailed in section VI- 2.

The purpose of the survey was to obtain greater detail into the type of training and content that accident investigators and managers should receive.

Moreover, considering previous findings highlighting the importance of the involvement of a human factors specialist during an investigation, the questionnaire also approached the skills and attributes that such an expert should possess. Thus, together with Chapter VI, the chapter fulfils the fourth research objective.

The following section, section VII- 2, covers the questions asked in this online survey and section VII- 3 presents the findings. Finally, a discussion and conclusions will be detailed in the final section.

VII- 2 Method for conducting the survey

In order to remain consistent with the principle of triangulation, the survey was aimed at the 17 interviewees who took part in the semi-structured interviews (see previous chapter). One interviewee, whose semi-structured interview was not analysed due to the poor sound recording, was not sent an invitation to complete the questionnaire.

The survey took the shape of an online questionnaire, since it presents the advantages of being a straightforward and simple approach to studying beliefs (Robson, 2002). This approach also had a number of practical benefits. Namely, that the majority of the participants were based in Australia and it would have been impractical to have spoken to them all again face-to-face. This also allowed the respondents to complete the questionnaire in their own time. Besides, considering that the number of topics to be approached was only small, a self-completion questionnaire was preferred over a further round of interviews.

The building of the questionnaire was inspired from the process of a Delphi study. The purpose of such a study is to reach a consensus between subject matter experts. (Hasson et al, 2000; Keeney et al, 2001; Okoli and Pawlowski, 2004; Hsu and Sandford, 2007). The process involves several iterative 'rounds', the first of which involves sending an open-ended questionnaire. The answers from all the participants are then gathered, analysed and converted into a well-structured questionnaire. The participants are asked to review each response, by filling the second questionnaire. The next rounds are built upon the answers from the previous round. The ultimate goal is to obtain an agreement, or consensus, between the experts, on what is being researched.

As with the first questionnaire in this thesis, the questionnaire was administered using the Software 'Qualtrics', and SPSS was employed to analyse the survey findings. Invitations were also sent from a cranfield.ac.uk email address limiting the risk of it being taken for junk mail. As a pilot study, the questionnaire was sent to three investigators who have strong interest in Human Factors in order to identify any flaws in question wording, survey structure and check whether the answers were going to be relevant to the research. Following several minor adjustments, the survey was then made live and the link was accessible for a total of six weeks, between March and April 2016. One reminder e-mail was sent to respondents after the first two weeks to the participants who had yet to complete the questionnaire. 13 completed questionnaires were received back after the six-week period.

VII- 2- 1 Survey structure

The first two questions of the survey were: "*What type of accident investigator are you?*" and "*What mode of transportation are you the most involved in?*". They served as filter questions to make sure the respondents were who they were supposed to be (providing that they responded truthfully) (Oppenheim, 1992).

The remainder of the survey was split in three main sections, and mainly featured closed-ended questions (following the Delphi process). In total, the survey included 26 questions (see Appendix D). The choice of closed-ended questions was used to increase the comparability between answers and respondents and to make it easier to record and process the survey findings (Bryman, 2012).

The first section of the questionnaire focused on '*human factors awareness training*', that is to say the initial training received by investigators and/or management, making them aware of the value of human factors. The purpose of this section was to obtain expert opinions on the training that investigators and managers should receive, in terms of its length, format and content. Questions included, for example: '*Ideally, how long do you think this awareness training should last?*' and '*To what extent do you agree or disagree that the following should be included in that awareness training?*' The last two questions of the first section were "*Do accident investigators receive HF training in your organisation?*" and "*Do managers receive HF training in your organisation?*" In each case, respondents were then asked follow up questions relating to the value, or expected value, of this training.

The second section of the questionnaire was related to recurrent HF training for accident investigators and managers, and sought to identify the ideal content, frequency and format of human factors training according to HF experts involved in investigations. Example questions in this part of the survey included '*What do you think should be approached during this refresher training?*' and '*How often do* *you think the following persons should ideally undertake refresher/recurrent training?*'.

Both in the set of interviews mentioned in Chapter I and the one of Chapter VI, investigators mentioned resources (time and budget) as limitation to more human factors training. Therefore, the following question was also included, '*Considering workload and budget, how often do you think the following persons should realistically undertake refresher/recurrent training?'* The purpose of these two questions was to identify whether there would be a difference between what the HF experts thought would be the ideal frequency of refresher training for investigators and managers, and what is actually realistic considering the context. An open-ended question concluded this section, '*Please add any comments regarding HF training for accident investigators and/or managers that you believe is relevant*'.

The third and final section of the survey was focused on the dedicated experts involved in accident investigations. As highlighted in Chapter VI, HF specialists who are involved in accident investigation need to have specific skills and attributes in order to be a full member of the team and add value to an investigation. The purpose of this final part of the questionnaire was therefore to explore these challenges in greater depth. Questions in this section included those asking whether having an academic background was important for HF specialist to be involved in investigation, with a follow up question asking for justification for their response. Respondents were also asked if it was important to have knowledge of the mode of transportation under investigation.

Respondents were then asked their opinions regarding the best way to gain this knowledge.

A key question in this section asked respondents to list the importance of different skills and attributes to human factors investigators. Examples of attributes listed were '*Leadershi*p', '*Assertiveness*' and '*Analytical*'. To conclude, respondents were asked to list any additional skills or attributes that they thought were important but had not been included.

VII- 2- 2 Respondents

A total of 13 questionnaires were completed and collected. This represented nearly three quarters (72%) of the sample of human factors experts involved in air accident investigation who were interviewed as part of the study presented previously. All 13 of the respondents were HF investigators or HF specialists involved in accident investigation. In terms of their area of specialisation, 12 respondents stated that they were mainly involved in aviation, while one respondent was involved predominantly in rail investigations. However, this respondent noted that they still had a strong aviation background and were regularly involved in air accident investigations. While some respondents inevitably originated from the same organisation, it was still considered important to examine whether investigators and managers received HF training within these organisations. Findings from the surveys are presented in the following section.

VII- 3 Findings

As discussed previously, it was necessary to establish initially the extent to which non-HF investigators and managers receive human factors training in their organisation.

As shown in figure 29, for the vast majority of respondents (respectively 12 and 10 out of 13), non-HF investigators and managers receive some form of HF training in their organisation. The findings will be presented in three sections relating to the respective section in the questionnaire; awareness of HF training, refresher/recurrent training and human factors experts in accident investigation.

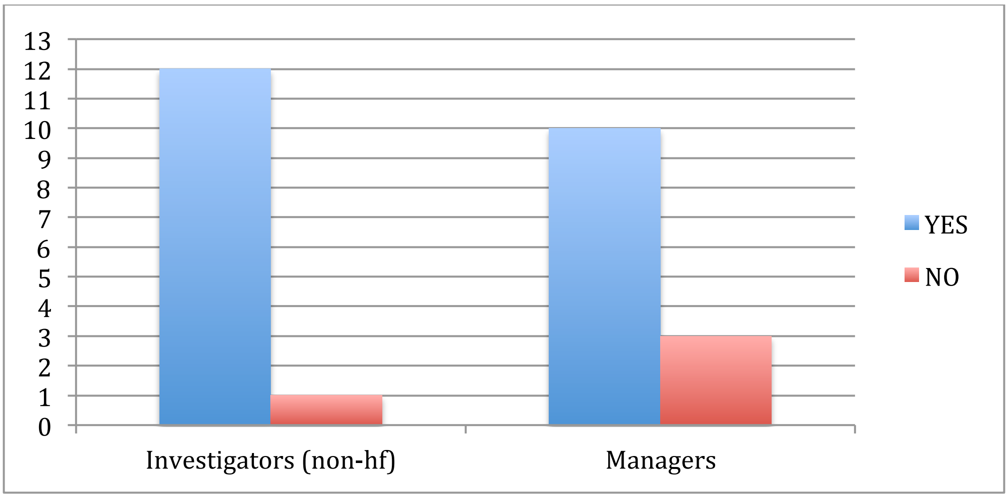

Figure 29: Number of respondents whom organisations require non-HF investigators and managers to receive HF training

VII- 3- 1 Awareness HF training

The first part of the questionnaire focused on 'awareness HF training'. The first questions was: "*How important do you think it is for the following persons to receive initial awareness human factors training?*" (very important to not at all important). The sample all agreed that such training was 'very important' or 'moderately important' for both categories of persons, i.e. the non-HF investigators and the managers. The majority of the sample (9 out of 13) also felt that training should be both general to all investigators and specific to their role (see figure 30). No members of the sample felt that this training should only be specific to the investigators' role. This means that for the HF experts, the ideal awareness training would need to have a part that should be general to all the investigators and a part that should be more specific to the investigators or manager's role.

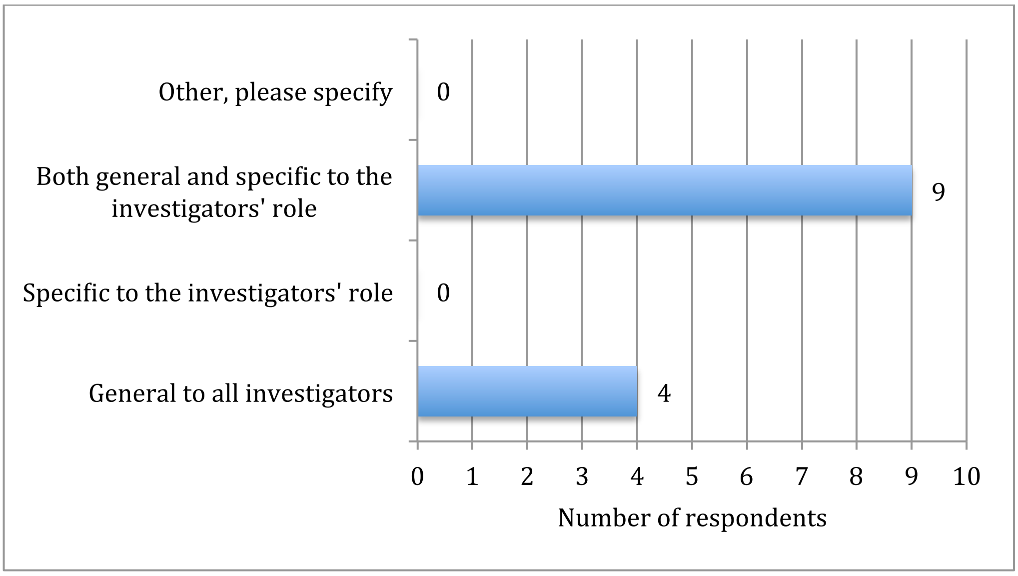

Figure 30: Preferred type of awareness training content

The following questions asked respondents to provide more specific opinions regarding their preferred design of the awareness training in terms of its ideal format, length and content.

The latter characteristic was approached in the form of a likert question, as to whether or not the topics listed should be included in the awareness training. The results show the majority of respondents 'strongly agreed' or 'somewhat agreed' that each topic listed in the questionnaire should be included in the awareness training (see figure 31). While it was expected to some extent that respondents would favour the inclusion of the majority of these topics, it was necessary to identify which topics were considered to be the most important. For example, all respondents 'strongly agreed' that the topic '*Importance of HF investigation*' should be in the awareness training. The topics '*sources of evidence*', '*value of HF investigation*', '*importance of HF expertise involvement*', '*errors/error mechanism*', '*decision making*' and '*situation awareness*' were also ‘strongly agreed’ or ‘somewhat agreed’ by all of the respondents. ‘*Methods and tools available*’, ‘*attention*’, ‘*workload*’, ‘*stress*’ and ‘*biases*’ were HF topics that 12 out of 13 respondents ‘strongly agreed’ or ‘somewhat agreed’ they should be taught during the awareness course. Only 1 participant ticked ‘Neutral’ for these categories. Similarly, ‘*interview techniques*’ received 12 ‘strongly agree’ or ‘somewhat agree’ and 1 ‘neutral’.

The topic ‘*Cue recognition*’ received more ‘neutral’ responses than the other topics (2), although the vast majority of respondents (11) still ‘strongly agreed’ or ‘somewhat agreed’ with the inclusion of the aspect. The only training area that received ‘somewhat disagree’ responses (2) and a split opinion between ‘strongly agree’ or ‘somewhat agree’ and neutral, with 7 and 4 out of 13 respectively was ‘*How to use/apply those methods*’. Both ‘*Methods and tools*’ and ‘*How to use these methods*’ were the topics that received the less ‘strongly agree’ (only 3).

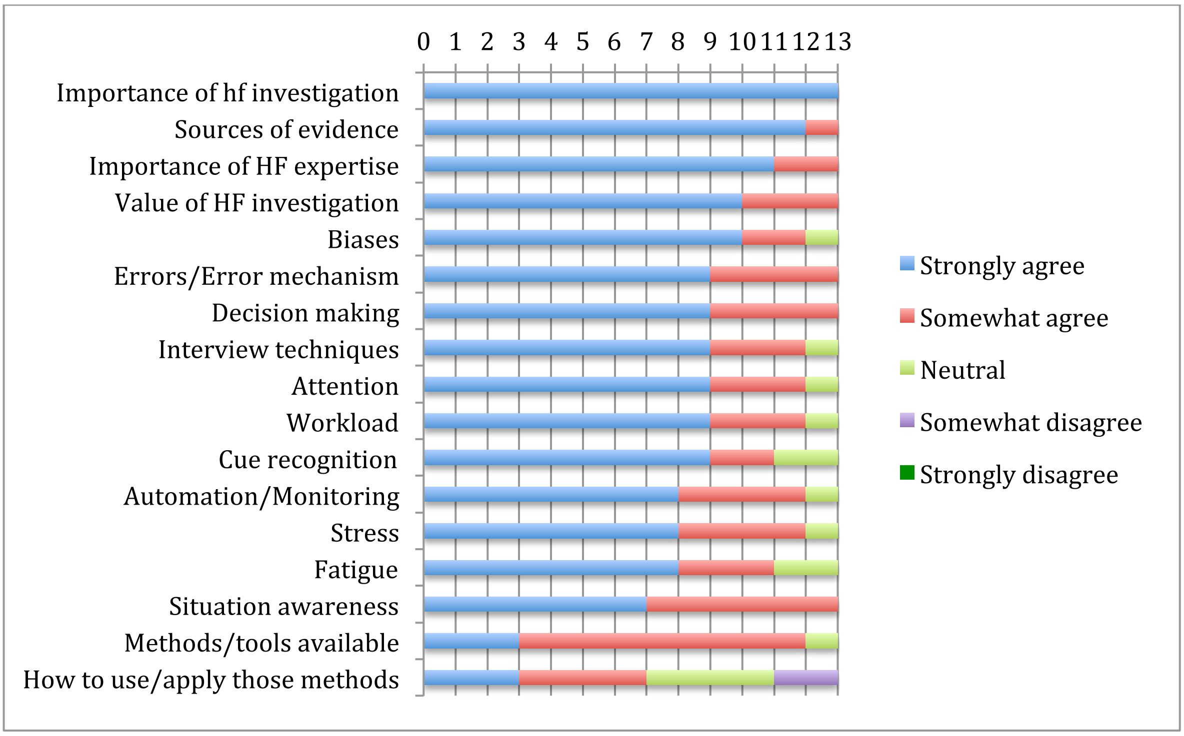

Figure 31: Agreement on different topics to be covered during awareness training

Overall, findings from the survey indicated a strong level of agreement amongst respondents that each of the topics listed should be included as part of the awareness of the training process. While the strength of preference for the inclusion of two topics appeared marginally less strong, namely the '*Methods/Tools available*' and '*How to use/apply those methods*' topics, in both cases the 'strongly agree' or 'somewhat agree' responses still collectively accounted for over half of the respondents surveyed.

Eight participants also listed additional topics that they thought should be covered during the initial awareness HF training. These additional areas included '*communication*', which includes team resource management, and '*culture*', including safety culture and just culture. Three investigators added this particular topic area. Two respondents mentioned '*organisational influences*', '*non-compliance / violation*' and '*investigating SMS*'. The latter could be associated with investigating safety culture, as mentioned previously. Other suggested topic areas also included '*Physiology, e.g. somatogravic illusion*', '*Team resource management*', which could be related to SMS, '*ergonomics / anthropometrics / design*', '*information processing*', '*performance in abnormal situation*' and finally '*medical / pathology*'.

Regarding the length and the most appropriate form of teaching for this awareness training, participants predominantly (7 of them) believed that 5 days (equivalent to a working week) would be the ideal length for such a course (see figure 32). 3 participants thought that the course should be longer than 5 days.

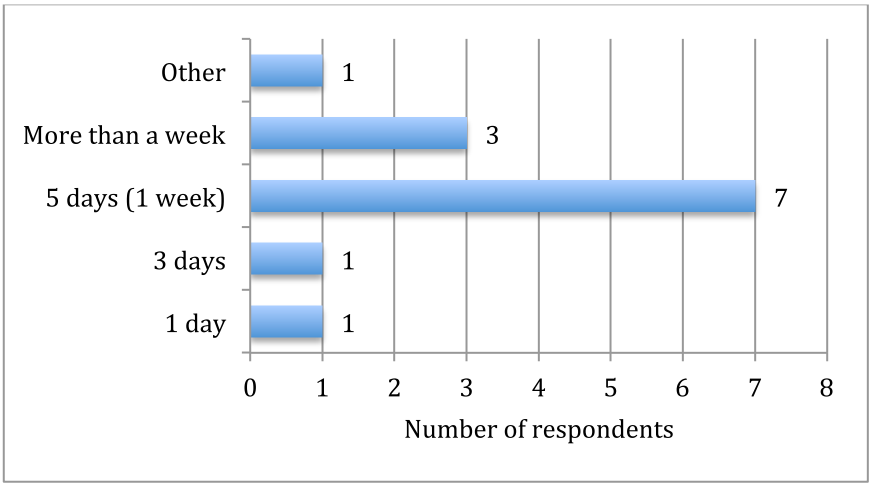

Figure 32: Ideal length of the awareness training

Regarding the way the awareness course should be delivered (see figure 33), opinions also appeared to be divided. However, most HF specialists (8 out of 13) believed that a mix of the methods listed (lecture room, online courses and workshop) would be the best way to teach the course. The next preference goes to the more traditional 'lecture room', with 3 of them preferring this method to the other ones. It is interesting to note here that the respondents thought that solely online courses were not appropriate, with no respondents selecting this as their preferred option.

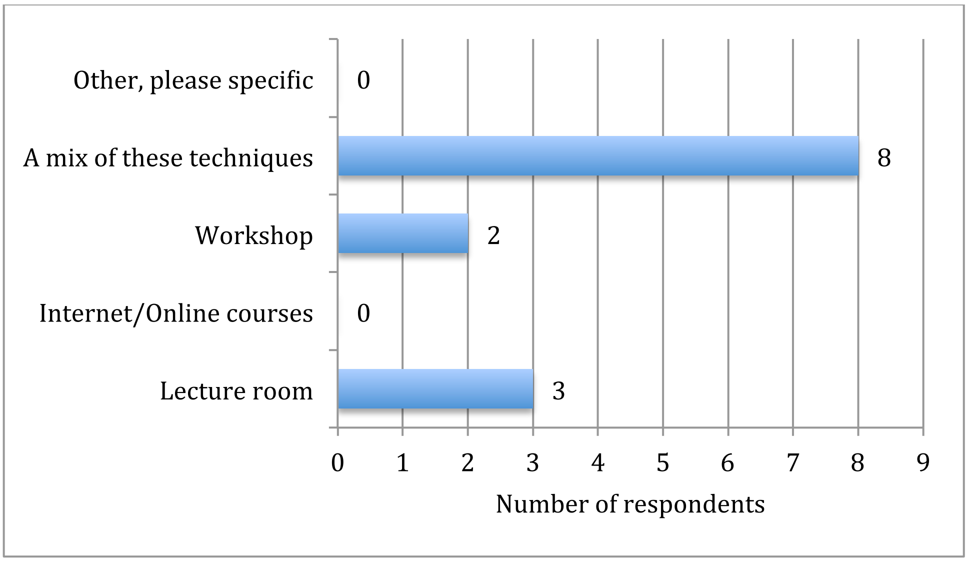

Figure 33: Preferred teaching methods for the awareness course

As shown in figure 29, for the vast majority of the respondents, non-HF investigators and managers received HF training in their organisation. The HF specialists whose organisation trained investigators in HF described the impact of such training as mainly positive, enabling the investigators to acknowledge and identify HF issues, and communicate better with added expertise. For example, one respondent noted that the training "*supplies an understanding amongst non-HF investigators that there is more to accidents than purely technical explanations*". Another respondent made particular reference to how it helps improve communication, noting that the training made for "*easier communication with other HF investigators"* and that there was "*more awareness of the data that needed to be collected, and also more realisation of when they need to get HF expertise involved*."

An interesting counter argument to this was put forward by two respondents, who cautioned that increased training could have negative effects in that it may cause investigators to feel that they can investigate HF on their own without the need to call on HF specialists. The answers, "*Good awareness but can lead some investigators to think they can do complex HF analysis without the help of HF specialists*" and "*The positive is that they understand there can be more to it than a broken component and realise that humans and organisational factors can play a part in the accident sequence. Negatives can be they think they can do HF on their own without specialist HF input. That's never ended well*" illustrate this point of view well. Where the latter comment perhaps also exposes a misconception that engineering investigators don't know how to do systemic investigations, this was not the overall opinion of the panel of experts.

Figure 29 also showed that for 10 of the participants, the managers in their organisation were receiving HF training. For these respondents, the impact of human factors training was universally seen as being beneficial and "*imperative*" to the organisation and to the investigations it conducted. Various examples of benefits were given, including "*understanding short falls of investigation reports during review*", and "*It* [the training] *is crucial for them* [the managers] *to understand the principles of our investigation work* [i.e. an HF approach] *so that they can ensure those principles apply to everything we do*". Specific reference was also made to the way training can help improve the safety culture of the organisation; "*Managers with human factors training are more likely to embrace just culture principles when understanding behaviours and managing employees* *post event. They are also better able to identify when an HF specialist should be involved and are less likely to accept an investigation that has not had sufficient HF consideration or specialist involvement.*" Of the remaining respondents, they all felt that the impact of training managers would be positive, and would encourage managers to actually question HF and push the investigators to acknowledge it and integrate it within their investigations.

VII- 3- 2 Refresher/recurrent training

Regarding refresher/recurrent training, the majority of respondents (11 out of 13) believed that it should be undertaken (see figure 34) by both non-HF investigators and managers. Although it is still a vast majority it is less than for the awareness course (for which all the participants thought non-HF investigators and managers should undertake it) Regarding the design of such training, the participants who believed that they should undertake it, the majority felt that it should contain both general information and more targeted content depending on the investigators' role (see figure 35). The same was found for the awareness training.

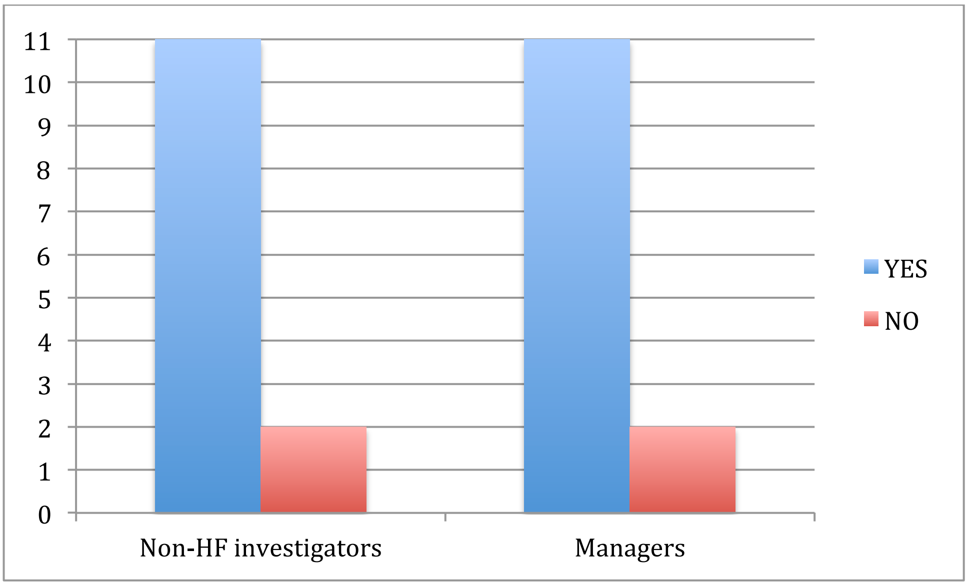

Figure 34: People who should receive HF refresher training, according to the participants

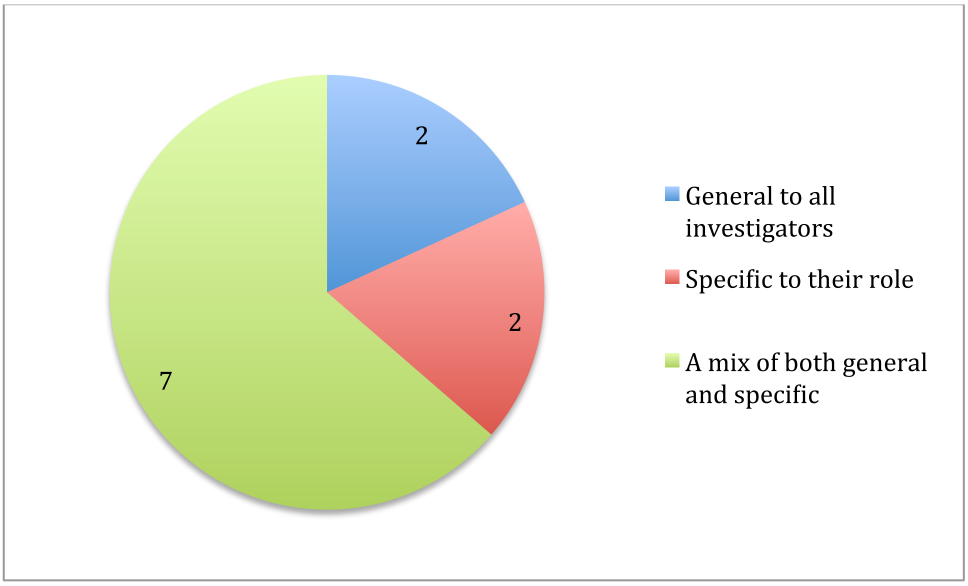

Figure 35: Preferred training content for the refresher/recurrent training

In terms of the specific content of the training (see figure 36), 7 (out of 11) of the same respondents believed that that "*value of previous HF investigations*" should be taught, 6 of them for "*Trends highlighted*", 9 for "*New issues published in the literature*" and only 4 thought that both "*the same issues as the ones approached in initial training*" and "*use of analysis methodology*" should be approached. For the 2 who ticked "*Other*", one respondent specified that such training should be focused on the application of knowledge rather than be limited to theory. This shows that predominantly, the refresher training should focus on actual trends, the value of previous HF investigation within the organisation and the new issues published in the literature. In other words, it should enable the managers and non-HF investigators to stay up-to-date with the current issues and not just re-learn what they were already taught.

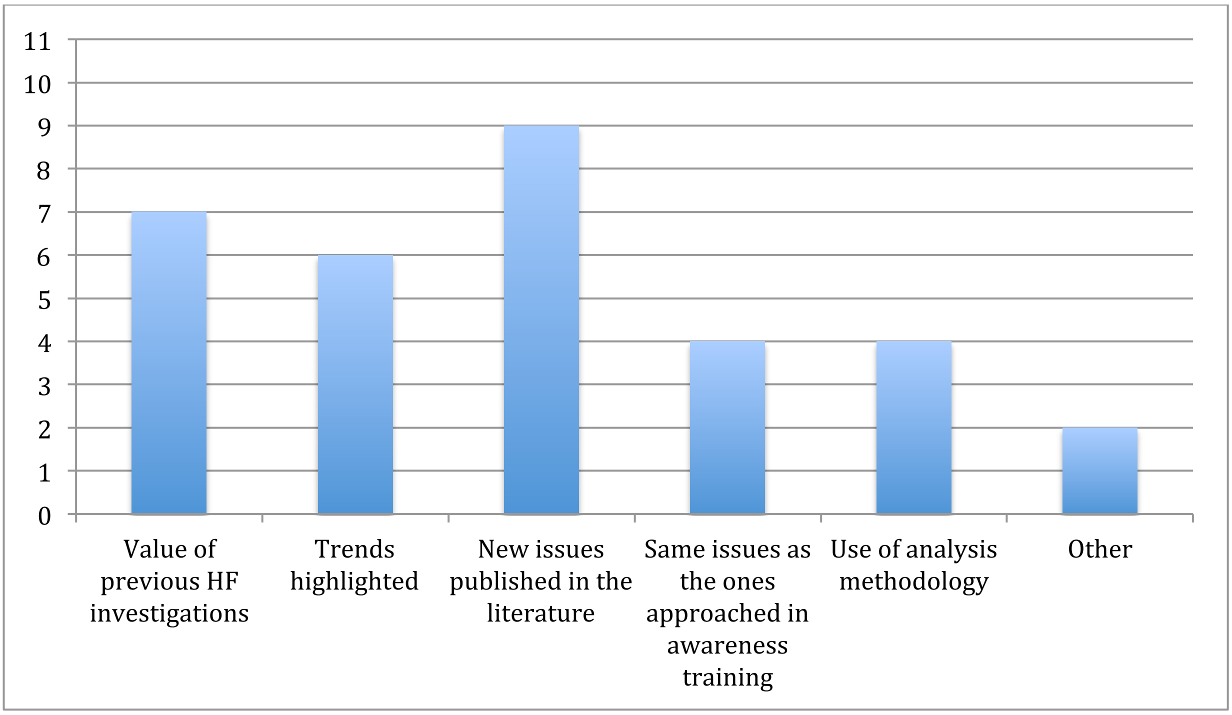

Figure 36: Content of refresher/recurrent training according to the participants

With regards to the frequency with which such training should be conducted, the respondents had different opinions (see figure 37). Amongst those who think investigators should receive refresher training, the ideal frequency of such training was considered to be '*every 2 years*' for the majority of them (8 out of 11). However, considering workload and budget, a more realistic frequency was thought to be '*every 2 years*' for 4 of them and '*every 3 years*' for the same number of participants.

Amongst the investigators who thought managers should receive recurrent training, opinion also appeared to be split. While 5 of them thought training should occur '*every 2 years*', 4 people thought that this should be '*every 3 years*'. When considering workload and budget, 4 respondents thought that managers should receive recurrent training '*every 4 years*', 3 believed it should occur '*every 2 years*', and 3 of them replied '*every 3 years*'.

Findings indicate that, according to the participants, workload and budget would have an impact on the frequency of the refresher training. This confirms the findings from the preliminary study presented in chapter I, showing that where regular refresher training may contribute to better HF integration, it would have to be realistic in terms of its frequency considering their availability constraints. .

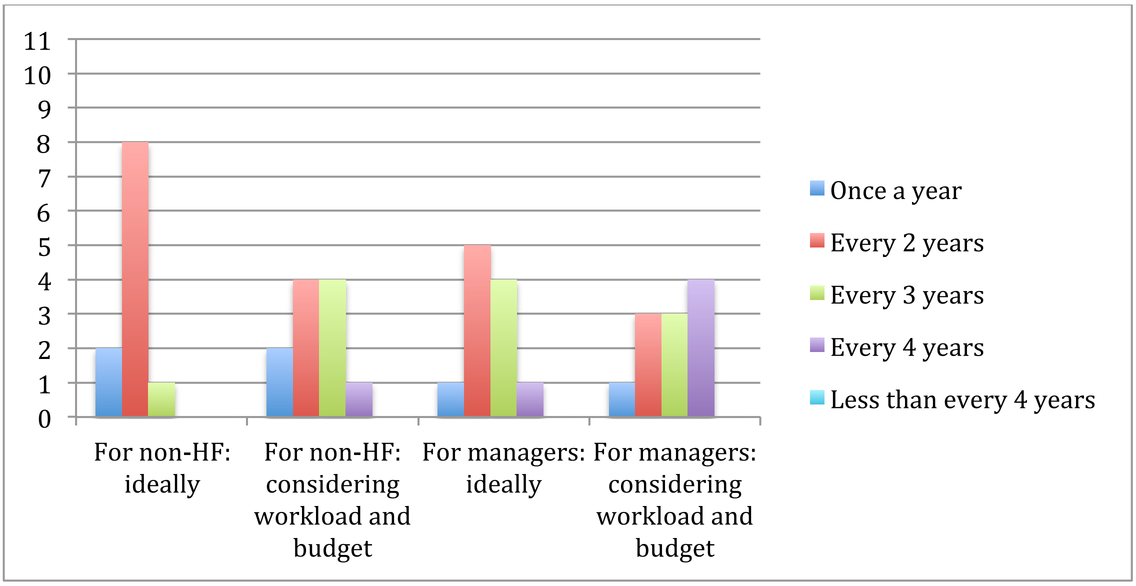

Figure 37: Preferred frequency of refresher/recurrent training

When asked to comment generally about HF training, both for awareness training and recurrent training, a number of participants expressed very strong convictions on the fact that it should be mandatory and maintained regularly, for the benefits of the organisation and the quality of the investigations. For example one respondent commented, "*It should be non-negotiable. It's astounding that people believe it's not necessary*". Another respondent commented that HF training was "*absolutely fundamental to the work of investigators and managers*" and one participant added "*Ideally the organisation would have a general level of training for all and deeper expertise within organisation plus external support*". Finally, one participant commented on the importance of refreshing the knowledge, "*This is a perishable skill and I think it is important not to have a long interval between refresher training so that the skills stay sharp.*"

This section highlighted the need for managers and non-HF investigators to remain up to date in HF and therefore regularly undertake HF refresher training. And although workload and financial resources might come as a limitation, a frequency of every 2 or 3 years for non-HF investigators and every 3-4 years for the managers would seem realistic.

VII- 3- 3 Human Factors experts in accident investigation

The final part of the questionnaire was focused on the dedicated HF expertise involved in investigation. As expected, all the respondents believed that it is either 'extremely important' or 'important' for those experts to have an academic background (MSc, PhD). It is worth noting here that all the specialists interviewed in Chapter VI (and therefore also those who undertook this questionnaire) were awarded such degree in their career. The reasons that were given for this included the depth of knowledge such degrees bring in terms of methods, literature and research skills, as well as broader skills like the logical mind it builds through the application of methods to analyse data.

Regarding knowledge/context knowledge, such as having a good aviation operations understanding, 11 of them thought that is it 'extremely important' or 'important' to develop such knowledge. The 2 remaining participants stayed 'neutral' on the matter (see figure 38).

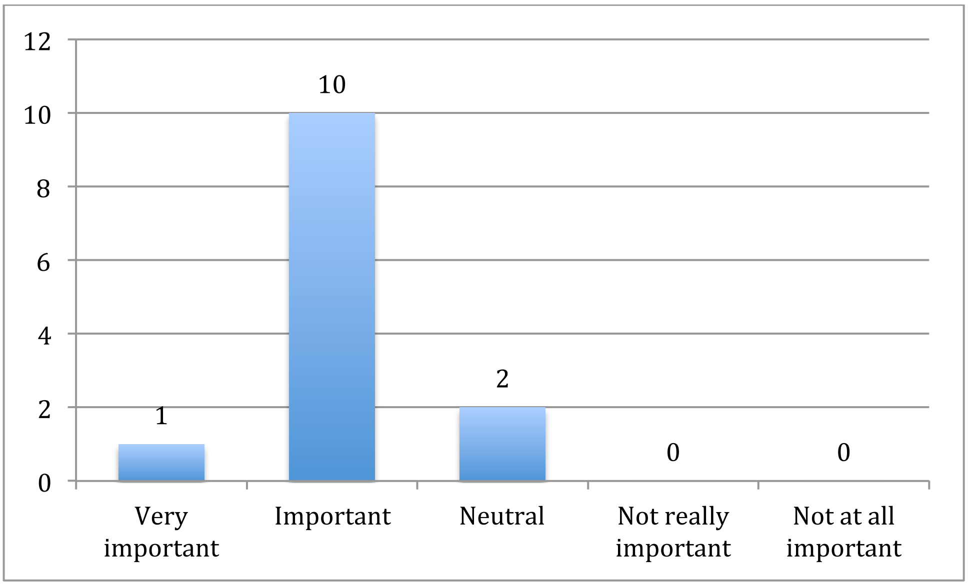

Figure 38: Importance of having context/background knowledge

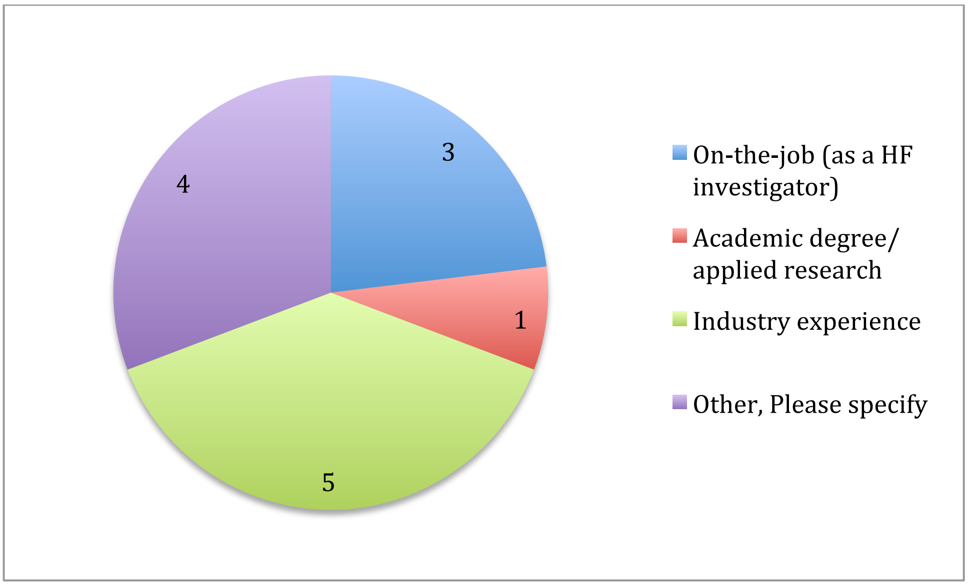

Figure 39: Ways of gaining that context/background knowledge for HF investigators

The respondents' opinions on the way such knowledge should be acquired is illustrated on figure 39. It can be seen that '*industry experience*' is the way preferred by a majority of participants (5 out of 13). The category '*other*' was selected by 5 respondents whereas '*on-the-job*' knowledge acquisition was only preferred by around a quarter of participants. The specialists who selected '*other*' specified that the best way to achieve this was through a mix of methods, i.e. some industrial experience or applied research, associated with on-the-job experience.

Based on the information collected in the interview transcripts the next question asked how important it was for human factors investigators to have certain skills and attributes. These attributes were writing communication, oral communication, analytical skills, being logical, leadership, assertiveness, being a team player, having a network of other experts and good interviewing skills.

Most of sample of specialists who took the questionnaire agreed that all the qualities listed were 'very important', or 'important' for an HF expert involved in accident investigations (see figure 40).

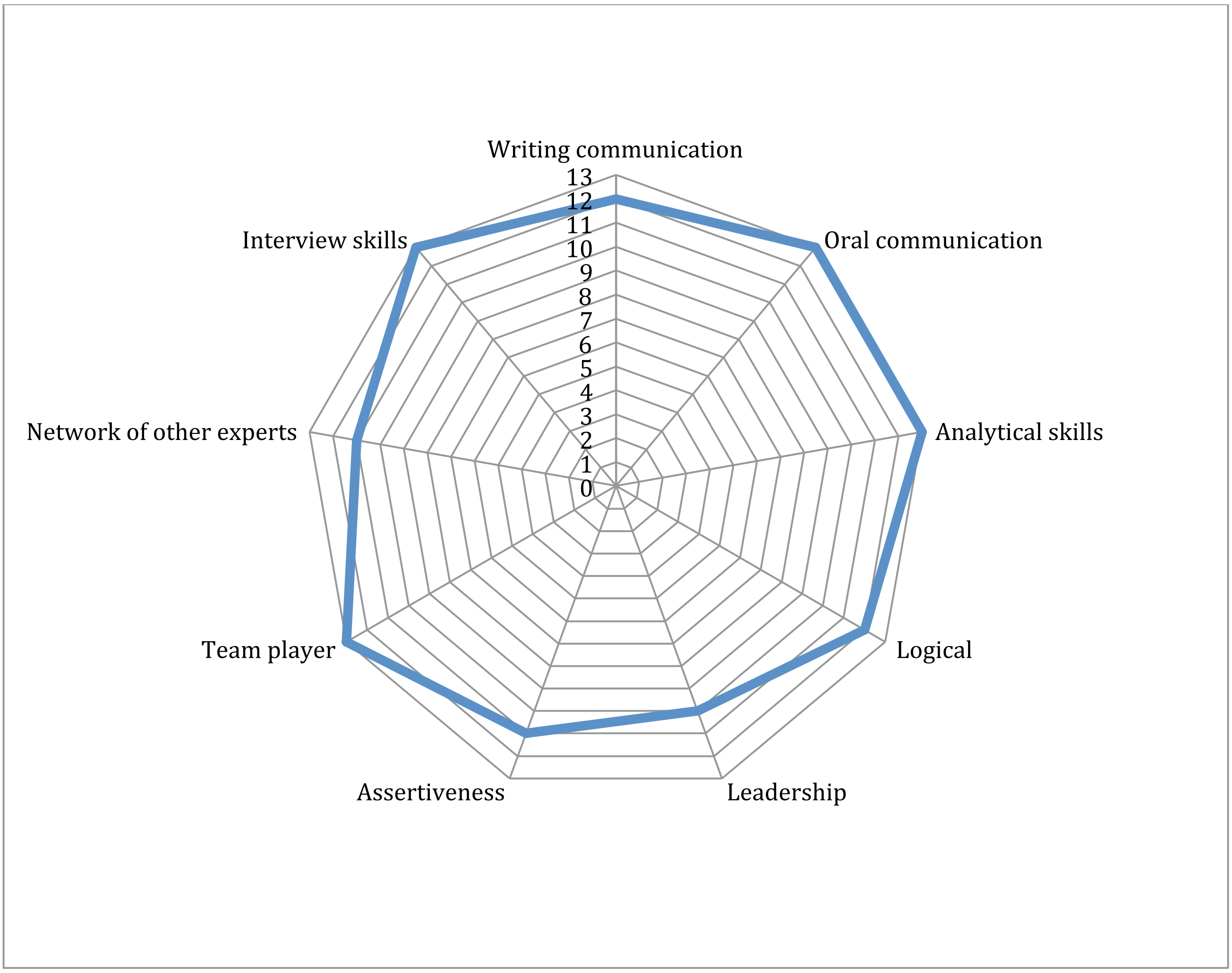

Figure 40: Skills and attributes that are very important and important for HF investigators

Of all these topics, '*oral communication*', '*analytical skills*', '*team player*' and '*interview skills*' were all judged very important or important by all the respondents. 12 of them ticked very important or important for '*writing communication*' and '*logical mind*'.

Of all the attributes, only '*Leadership*' was considered to be 'not really important', and this was only the case for one respondent. It did not appear to be a view shared by other respondents in the survey, as 10 of them believed that leadership was 'important' or 'very important'. As well as for '*assertiveness*' and '*network of other experts*', 2 stayed 'neutral'. 1 participant also remained neutral on the importance of '*writing communication*' and being '*logical*'.

Respondents were also given the opportunity to provide additional skills and attributes that they believed were necessary for HF investigators. Examples of these included both technical skills, such as '*research skills*' and '*being able to apply investigation methodologies*', as well personal qualities such as '*passion about HF*', '*attention to details*', and '*resilience*'.

The next section will discuss the findings from the survey while also taking into account the previous findings from the interviews in Chapter VI

VII- 5 Discussion

While acknowledging that the findings were drawn from a relatively small sample, the questionnaire provided a valuable opportunity to further investigate HF training for non-HF investigators and managers and the skills and attributes of HF specialists involved in air accident investigations. Moreover, considering that this questionnaire was designed as the second and final part of a validation triangulation, the size of the sample is satisfactory (13 out of 18 interviewees undertook the survey).

As suggested in the interviews and illustrated in this questionnaire, it would seem extremely beneficial (if not essential) that both managers and non-HF investigators receive HF training, as well as refresher training. It is likely that this would benefit both the quality of the investigation and the whole organisation, as well as having indirect benefits to the safety of aviation operations. As HF is investigated in greater depth over time, it is likely that continual improvements will be made to practice, theory and application, and ultimately aviation will become safer as a result.

Providing non-HF investigators with a robust awareness of HF training would likely enable them to identify HF issues as well as know when they should contact an expert. It would also enable them to discuss HF issues with the specialists in order to integrate it within the report, thus increasing teamwork. This would seem to be qualities that lead to improved accident investigations. Team work being such an important factor in an investigation, as demonstrated in the previous chapter.

The questionnaire also confirmed how important it is HF training at a management level. For non-independent organisations, for example airlines or manufacturers, having HF-trained managers may result in a wide range of benefits, including the increased likelihood of operating a just culture. Managers who acknowledge HF and understand its value should in turn also be more receptive to its wider integration in the investigation process at all levels, from the operator level to the organisational levels.

The awareness and refresher training should contain both a general element for all participants and a more specific element tailored to the role of the investigators or managers in question. For example, it might be more appropriate to give investigators focus on operational issues to increase their knowledge in areas such as pilot behaviour, pilot fatigue or non-compliance. Alternatively, engineers may focus on improving maintenance-related human factors issues, whereas managers training could emphasise the value of investigating organisational issues and the fact that humans error is often the symptom of a system, as identified in the literature (Chapter II).

The ideal length for the initial awareness training was believed to be around a working week (5 days), with refresher training to happen every 2 to 3 years for the investigators and every 3 to 4 years for managers.

Regarding the content of the training, there was broad agreement that the topics listed should be taught on the proposed training courses, as well as other relevant HF areas such as communication and SMS. However, topics around HF methods received a less strong response than others. Indeed, this was the only topic to receive any 'somewhat disagree' responses in relation to its inclusion in the training programme.

Interestingly, while one might expect that the inclusion of a greater number of topic areas would continually benefit investigations, a small number of investigators cautioned that this might actually have a negative effect. Namely, that the increased training in HF may cause investigators to feel that they could 'do it alone', and that they no longer needed to ever engage with human factors experts in the future. While it is impossible to predict whether this would in fact be the case or not, it highlights the importance of trying to anticipate unintended negative consequences from any changes that are made. As a minimum, it would seem important to emphasise during any course the fact that undertaking HF and refresher training will not alone make them experts in this area.

Moreover, according to the sample, it is important to adapt the refresher training so it remains up to date with current best practices as opposed to just being a reminder of what has already been taught in previous years. New discoveries from the literature, current trends in the industry, avoiding common pitfalls, and the proven value of HF to the organisation are all topics that refresher training could approach in order to remain fresh and relevant. By its very nature, it is important that refresher training occurs at relatively frequent intervals and that the content of these sessions evolves in response to the needs of the investigators and the industry as whole.

There were also mixed views in the sample about how best to deliver HF courses. Although more than half of respondents thought a mix of methods was the most appropriate, a significant minority still claimed that they would prefer the classic 'lecture' method. Lecture rooms do enable discussion and debate, questions as well as the application of knowledge through exercises or workshops. However, as highlighted previously, team work is essential to accident investigation therefore HF courses in lecture room or workshop would facilitate this sort of interaction.

While there were no participants who favoured a purely online format for their training, it is possible that online elements could still be used successfully to complement other approaches (for example, as part of a mixed methods approach also involving a mix of lectures and workshops). This could provide the possibility of refreshing and updating theoretical knowledge online and then applying it in face-to-face workshops. Online components may also be better suited to certain topic areas than more traditional approaches. For example, looking at the current issues in the literature might be better suited to an online environment than a classroom. Ultimately, the choice of method should be driven by the needs of the topic area and that of the audience.

The second key point emphasised in chapter VI and VII is the necessity for the organisation undertaking investigation to consider the use of an HF specialist. Whether in-house or external, such an expert may be able to reduce biases that former pilots or engineers might have regarding the behaviour of operators, as well as bringing their expertise to investigate the relevant issues.

The negative reputation that HF can sometimes have is that it is not evidence based and ‘fuzzy’. A good expert should be able to prove otherwise, basing statements and analysis on the literature or previous research as identified by the content analysis of the reports in chapter IV and through the interviews. According to respondents in the sample, these experts should have an academic background for the logical and analytical mind it develops. Other benefits of this include a greater depth of knowledge, which would be harder to acquire otherwise.

It is also important for the expert involved in the investigation to understand the context he or she is investigating (i.e. in this case, aviation). For example, for an aviation accident the HF specialist should be able to understand the task of flying an aircraft and how the aviation industry works in order to work effectively as a team with the other investigators. This idea was illustrated by the response of one of the questionnaire participants who noted:

"*I think it is equally important to have general investigators with high level of HF knowledge and specialists with an academic background in particular disciplines of HF. This is the ideal scenario in my view, providing investigative context and flexible specialism tailored to the needs of a particular investigation.*"

Other key attributes for HF specialists involved in investigation were good communication, being a team player, and having a good network of contacts. This network is believed to be important when reaching the limits of one's knowledge. As mentioned in the interviews, an expert needs to know the limit of their expertise and seek advice from relevant people when required. A good HF expert knows where to look for this, whether it is in the literature or amongst their peers.

VII- 4 Conclusions

An online survey was designed as the second part of a triangulation methodology. The first part of this was the semi-structured interviews presented in Chapter VI. The survey presented in this chapter was then sent to the same participants as the interviews, and was subsequently completed by 13 respondents.

The results from the questionnaire confirmed and validated the importance of training managers and non-HF investigators in order to obtain better HF investigation. Thus, together with chapter VI, it fulfils the fourth objective of this thesis. It also confirmed the need to involve an expert when HF issues are present in an investigation, which according to the literature, should be for the majority of the accidents or incidents. The questionnaire also investigated the format and content of the training investigators should undertake, as well as giving more specific information on what makes a 'good' and reliable HF investigator. Consistently with the findings from Chapter VI, teamwork was also emphasised as being a key factor in accident investigation.

The findings from the triangulation process need to be added and discussed together with the findings from the different studies developed in this thesis. This will enable the researcher to draw conclusions on the process of TNA and provide recommendations on the issues approached in this research. The next chapter, chapter VIII, will develop these conclusions and recommendations and will be the final chapter of this thesis.

Chapter VIII – Discussion and conclusion

VIII- 1 Introduction

This research has used the principle of TNA to examine the training needs for air accident investigators in order to develop more thorough integration of human factors in accident investigations to help improve safety. This process involved gathering data from a variety of different sources to help establish the extent to which the current state of HF integration in accident investigation was due to the lack of training or the influence of other factors.

Analysis was conducted in four stages: a literature review, analysis of accident reports, an online questionnaire of practitioners, semi-structured interviews with HF specialists involved in investigation and triangulation questionnaire. From this emerged a number of key points and important issues that require further discussion. Based on this, a number of recommendations for investigation organisations are made. These are covered in the following section. Following this, the key findings from the research are summarised, followed by a section highlighting the potential research limitations. The fourth and last section of the chapter provides guidance on possible further research that could be conducted in light of the research.

VIII- 2 Discussion and recommendations

Through the process of conducting the research, a range of important issues emerged. In some cases these were interrelated and/or complex in nature, with a degree of specificity to certain regions or investigation organisations. However, several key issues were also identified that were much broader in their application, both in terms of their relevance to different organisations and their implications for policy and practice. These warrant further discussion in order to understand their possible implications.

In the preliminary research, it was found that some investigators from the organisation in question felt they were lacking HF training. In particular, adapted and practical training was identified as one area that could be improved. As acknowledged in the literature (for example (Marinho de Bastos, 2004)), training is a vital part of an investigators' career, and their capacity to remain up-to-date with current best practice determines not only their own individual capabilities as an investigator, but by association the credibility of their organisation.

It was therefore surprising that the training for accident investigators, in terms of human factors, did not appear to adequately reflect the importance of these issues. Indeed, the findings from the questionnaire highlighted the lack of consistency and standardisation in terms of HF training amongst the investigator community. While it could be argued that aviation safety as a whole has benefitted significantly from much greater degrees of standardisation and consistency in terms of safety standards and protocols in recent times, this does not appear to necessarily always be the case with regards to the training provision for air accident investigators.

Perhaps as a result of this, there also did not appear to be any real adapted and specific training on offer to investigators. A general lack of HF refresher training was also emphasized. This situation did not appear to be the result of a lack of recognition or motivation on the part of the investigators since the vast majority of them acknowledged and valued the importance of HF training. Instead it is likely attributed to other factors. These factors, as suggested by the findings of this research, appear to be a lack of accurate and detailed guidance on the matter of training provision, the lack of specific requirements and the lack of accredited training or official qualification processes. In this sense, findings from the research support the literature review (for example, see Braithwaite, 2002).

While recognising that there is considerable diversity existing between different investigation organisations in terms of their structure, it makes intuitive sense that across member states they should adopt a more concerted, systematic approach to enrolling their investigators in mandatory HF training programs. As part of this, it is important, indeed vital, that these programs include appropriately-timed refresher programs to ensure that the investigators' skills remain up-to-date. This, in turn, could also help develop greater levels of consistency and standardisation in terms of the type/quantity of training provided to investigators and as a result increase collaboration between investigators and specialists and likely improve the quality of the reports.

Although it will most likely remain up to the organisation in question as to the length and timing of such training, the opinion of HF investigators, perhaps unsurprisingly, lends support to the importance of HF. Indeed, when asked their preference in terms of the desired length and duration of any possible future training schemes, the majority of specialists favoured a five-day programme refreshed every two to three years. Even if the realisation of such a program is not feasible in reality, it nonetheless demonstrates the importance with which they view the provision of HF training for accident investigators. Furthermore, the questionnaire sent to the large sample of investigators highlighted their desire to receive more HF training.

As with any training, it is important that the content is targeted and relevant to those undertaking it. This would certainly appear to be relevant in an HF context. While it remains important that general 'core' issues such as 'importance and value of HF investigation', 'importance of HF expertise', 'fatigue', 'stress' and 'cognitive biases' (amongst others), should be included in the training of all investigators, findings from the research suggest that there may be considerable benefits from offering some more specific topics depending on the role of the investigator. For example, 'HF in aviation maintenance' could be included as a more targeted element for engineering investigators. Such an approach would hopefully mean that investigators would receive both general training on key concepts, but also more targeted training relevant for their particular role.

In terms of the content of the refresher training perhaps a slightly different approach could be adopted. Rather than simply covering key concepts (which the investigator should theoretically have already covered), its focus could be on more practical, applied aspects of HF, as well as any key trends or current issues that may be relevant for their role, and thus would aim to keep them up to date. Furthermore, both initial training and recurrent training should approach human factors issues related to human performance, but also touch topics such as 'organisational issues' and 'investigating SMS'.

It is also apparent that there is not always a clear overlap between the academic side of the discipline and the applied 'day-to-day' nature of conducting an accident investigation, particularly regarding the use of accident analysis methodology. This is to say that the training received by investigators did not always reflect current understanding or best practice identified in the academic research. Equally, it would appear likely that the same can be said of academic research in that it does not always accurately reflect the realities of an investigation. While this is not a problem confined solely to human factors and air accident investigation, it would seem likely that closer collaboration could benefit both parties in the longer term. The regular use of refresher training, for example approaching new issues developed in the literature, would seem to represent a valuable opportunity to develop this collaboration.

In terms of the format of future HF training, it is recommended that a mix of methods could be implemented. While the benefits of a quintessential 'classroom' experience are not disputed, it can be resource intensive to implement and not always best suited to the required topics. Therefore, while it is recommended that initial awareness training, workshops and case studies be conducted on a face-to-face basis wherever possible, for aspects such as identifying new issues from the literature, the possibility of providing online training components could be explored. Whether conducted face-to-face or online, it would be essential to that a specialist was available should the trainees have any questions or raise any issues for discussion.

The preliminary research and interviews also suggested that newer generations of investigators were more open to greater integration of HF. This is perhaps understandable given that HF is now an integral part of pilots and engineers training, so new investigators are perhaps more likely to acknowledge and embrace HF within the context of their role. Thus, it is suggested that the earlier HF is implemented in the investigators training, the more impact it will have on the individual and the organisation as a whole. As well as involving investigators in dedicated HF programs it is recommended that a stronger HF element is included in the initial training program so that investigators consider it as a core element of an investigation. Additionally, future training should help investigators in identifying different HF issues so that they can refer to other specialists when necessary, and enable them to integrate the specialist's findings into the final report. It should also be emphasised that undertaking the training should not encourage them to tackle an HF element of an investigation which exceeds their level of skill.

Beyond the training needs of investigators, there is also a compelling case for recommending HF training for managers too. Such an approach would likely not only benefit the HF understanding of the managers but would lead to significant benefits in terms of the wider integration of HF in the culture and mindset of the investigation organisation and therefore have a positive impact on the quality of the accident reports. This supports Dul and Neumann (2005), who believe that if HF were to contribute to the organisation's strategy, and be phrased in the 'language' of the organisation, managers would be more likely to accept it and it would therefore be better embedded within the organisation.

Moving away from the issue of training, analysis of the accident investigation reports highlighted the disparity existing between different organisations in terms of how HF issues were treated. While in some cases HF issues were investigated very thoroughly, including both dedicated expertise and using clear literature references, this was by no means always the case. Generally speaking, and perhaps unsurprisingly, organisations with in-house HF specialist tended to be those that investigated and integrated the HF element more consistently and thoroughly than organisations without a dedicated HF expertise.

While this seems self-evident, it raises an important question. Namely, what are the reasons for organisations choosing *not* to operate an in-house HF specialist, given that HF is widely viewed as a valuable component of an investigation and a number of organisations already have them? If these are predominantly structural barriers, such as insufficient funding, insufficiently skilled candidates available, or problems with recruiting investigators, then it could be suggested that the problem could be addressed by changes at high level (governmental or regulatory for example). However, if as the literature suggests (Baker, 2010), there remains scepticism on the part of some investigation organisations regarding the value and credibility of HF, then it would seem that these problems are more inherent and more difficult to address.

The findings from this research, however, would suggest that providing training to managers and investigators would increase their awareness and acknowledgement and therefore 'convince' them of the value of HF. This could potentially resolve the scepticism issue regarding the 'usefulness' of HF, which was one of the reasons why HF failed to be implemented in the industry, as noted by Helander (2000).

For example, when an accident report lists several human factors issues as causal and/or contributory factors, as did a number of the accident reports that were analysed, it might be expected that these issues were developed thoroughly in the report and that relevant expertise would be consulted. However, as the analysis has shown, this was not always the case. Indeed, it was surprising that a number of reports did not investigate HF in any great depth and failed to refer to HF expertise. This situation would appear to be inconsistent with the importance and value of HF emphasized by the findings from this research. Further, this also appears to go against much of the related literature, which similarly supports the importance of HF. Nevertheless, it provides an illustration and justification of the investigators' doubts regarding the way HF is investigated in their organisation (see chapter V).

Whether conducted by a dedicated 'in-house' expert or external party, the issue of who (if anyone) is best to involve in an investigation remains a key challenge.

Indeed, this was highlighted by the organisation interviewed in the preliminary research (which do not currently have dedicated in-house expertise) as one of their key challenges. In some cases, investigators were unconvinced that there was sufficient need or workload to justify employing a full-time HF specialist. While this view was unexpected, given the significant role of HF issues and the extent to which they are involved in air accidents (Shappell and Wiegmann, 1997), and the fact that HF experts could also play the role of IIC, it also possibly highlights a wider issue. Namely, that there might be a need for greater efforts in communicating the value and importance of HF within investigation organisations, especially to those that currently lack a culture and history of engaging with HF or those that do not systematically involve HF specialists in investigations, even where HF issues appear to be heavily involved. In this case, the importance of training managers so that they can influence the organisation in integrating HF more thoroughly would appear to have significant benefits.

There is also a need for HF experts and practitioners to more clearly define what HF can, and cannot, offer an investigation, as well as its benefits and potential limitations. This should in turn help to eliminate criticisms of HF, such as it being a 'fuzzy' discipline that does not lend itself to quantifiable 'facts', and that it can be hard to remain objective and know when to 'stop digging'. In some cases, HF specialists' testimonies clarified that the negative view of HF was often the result of 'bad experiences' with HF, where an HF 'expert' had not based their work on evidence and had not made it accessible to non-experts. The task of a specialist is therefore not limited to investigating the HF element but also making sure his or her fellow investigators understand the value of it and how it fits in the investigation. Equally, according to Peterson et al's (2011) work in the maritime industry, the HF specialist should also understand the inquiring character of the engineering discipline. This again emphasises the importance of context knowledge and understanding for HF investigators in order to facilitate HF integration. In this sense, wider communication and dissemination of the importance of their skills and expertise should therefore represent an important role for the wider HF community.

Of course, in order to build greater confidence and credibility in HF it is crucial that HF experts possess the necessary skills and attributes to conduct robust and valid investigations. While industry experience, like almost any other profession, is likely to help develop the necessary skills to become a better HF investigator over time, the responses from the interviews imply that a solid research background, likely brought by a specialist degree such as an MSc or a PhD, is also valuable. This suggests that while knowledge of the context can be developed through experience and on-the-job experience, fundamental qualities such as a logical, analytical mind, assertiveness, interpersonal and team working skills, as well as good oral and written communication can also be brought by a solid research and academic background.

Conducting research in academia can be similar to an investigation in that data is gathered, analysed using only the evidence available and conclusions are drawn from what is available. A research or academic background can be valuable in this sense precisely because it develops the necessary skills early in one's career, rather than having to build them 'on the job' later on. Indeed, this was a view widely shared by the interviewees in the sample. Furthermore, while in some cases respondents felt that having a 'title', such as MSc or Dr., could potentially increase one's recognition and credibility (for example during an inquest), ultimately it is the rigour and integrity of the HF investigator himself that lends credibility and recognition, not their title.

Ultimately, there should be little reason preventing a HF specialist being the IIC of an investigation. In the same way that an academic background may develop key skills and personal attributes for an investigator, it may also help develop essential project management skills that would be required for leading an investigation. The benefits of the addition of a qualified HF specialist within an organisation would not be at the expense of other disciplines or expertise (such as operation or engineering). Instead, it would seek to complement and add to existing skill sets to obtain a wider range of expertise in the investigation team. Together with the subject matter expert, the information gathered, and the report as a whole, would likely benefit as a result. Moreover, the presence of a specialist within an organisation could potentially address the 'academy-industry collaboration' issue. Whether 'in-house' or external, the expertise would likely need to be available from the very early stages of the investigation and consistently along the process in order to potentially facilitate the communication between investigators and specialist and as a result improve the quality of the HF element in accident reports.

The need for greater clarity and consistency emerged as a common theme from the analysis, and the same can be said of the need for a common approach.

Despite the fact that analysis methods are widely spread in the literature, the use of a specific tool or methodology to run the analysis of an investigation is limited. While it was not the goal of this research to compare the merits of different tools and methodologies, the benefits arising from using a common approach (whatever that may be) are potentially significant. Such a tool or method could bring a common standardisation within an organisation, allowing for easier data classification and comparison through time. For example, if for any reason it were necessary to examine an older report or one conducted by a different organisation, an approved methodology would allow for easier interpretation of the findings and comprehension of the process.

In summary, recommendations from the research revolve around three key interrelated aspects; training provision, the involvement (or not) of HF specialists, and the adoption of an approved approach or methodology. While progress in either one of these areas may be beneficial, it seems likely that the most significant benefits would be felt when all these aspects were addressed simultaneously. Indeed, in such a scenario it could be envisaged that the progress in one area could lead to benefits in other areas and vice versa.

Clearly this is no simple task, and while the scale of the challenge should not be underestimated, it is by no means insurmountable either. Certainly, a coordinated approach from all related parties is important, and it is believed that organisations such as ICAO and regulators have an important part to play here in providing more accurate and up-to-date guidance and/or requirements with regards to HF integration in HF investigation.

As identified in the literature, integrating human factors is a challenge shared by other industries, particularly the challenge of improving HF acceptance by managers (Perrow, 1983; Dul and Neumann, 2005, 2009). In the rail industry, steps towards training managers have already been taken (Rose, 2009) and Wilson et al (2007) report the increased use of human factors integration plans both in the rail and defence industry. This would suggest that progress can be made in terms of human factors integration within organisations and that NIAs could potentially learn from these other industries.

Ultimately, it is not the objective of human factors investigation to remove human error, and this is the message that needs to be spread. Humans will continue to make mistakes, but by being proactive and understanding these mistakes, why they occur, and then put effective mitigation measures in place to minimise negative consequences, further accidents can be avoided. Through this, the prospect of shifting from a culture of reactive safety to a more proactive safety may be viewed as an achievable target, rather than just an ambition to aspire to.

VIII- 3 Summary of research findings

The aim of the research was to examine the training needs of air accident investigators in order to develop more thorough integration of human factors in accident investigations. In order to do so, an adaptation of a Training Needs Analysis was conducted and five objectives were fulfilled.

The first objective was to identify the current role of, and key human factors challenges for air accident investigators. The literature review presented in chapter II fulfilled this objective by emphasising the importance of human factors investigation in aviation safety, demonstrating the evolution of HF and highlighting the fact that despite some efforts from organisations more thorough HF investigation is necessary. It also pointed out the fact that no real detailed guidance is provided on how to enable NIAs to conduct relevant HF investigations.

The second objective, fulfilled by the review of accident reports using content analysis, was to analyse human factors integration in accident investigation reports. It was found that investigations that referred to a specialist produced more thorough and robust HF investigations. This was particularly the case for organisations with existing in house dedicated HF expertise, where the greatest consistency in terms of the quality of the reports was observed. On the contrary, it was also found that some reports still did not investigate HF issues deeply enough to understand the so-called '*why*' questions associated with an accident.

Here, the use of a specific methodology was believed to provide good standardisation between the different reports of an organisation.

The third objective was to evaluate the relevance and efficiency of human factors training provision for air accident investigators. This was fulfilled by analysing the results of an online questionnaire of 89 air accident investigators from around the world. It was found that while it is widely acknowledged that HF is an important component of an investigation, current training lacks consistency, depth and standardisation. Moreover, the results suggested that in many cases little or no HF refresher training was provided. Additionally, the analysis emphasised the fact that the training did not seem adapted to the investigators' needs.

The fourth objective was to assess the training needs of air accident investigators. This was fulfilled by analysis of a series of semi-structured interviews conducted with HF experts involved in air accident investigation, and a subsequent follow up questionnaire. This part of the research provided detailed insight into what the training and refresher content and format should be for accident investigators, as well as a highlighting the fact that managers should also receive training and regular recurrent training. A key finding here related to the need for training programs to enable investigators and managers to accurately identify HF issues in order for them to contact an expert when necessary, and not simply try to tackle the issue on their own.

Findings also focussed on the skills and attributes required of HF experts. It was suggested that academic and research background paired with a deep understanding of the aviation context would be a starting point for a good HF investigator. The presence of a HF specialist in an organisation was also identified as being beneficial for the integration of HF, with the possibility of having HF experts in a management or IIC position as well as helping further develop training and methodology.

The fifth and final objective was to provide recommendations for developing human factors integration in accident investigations. While the conduct of the TNA concluded that more adapted training was necessary, it was also recommended to investigation organisations and other departments conducting investigations to consider the involvement of a HF specialist.

Additionally, it was recommended that organisations develop or use an approved tool or methodology to conduct and report the analysis of the investigations. It was felt that this would help increase the awareness of HF, bring standardisation within the organisation and bring wider credibility to the HF element of an investigation.

VIII- 4 Research limitations

While every effort was made to ensure that the design and execution of the research was robust and valid, there are inevitably some possible limitations that need to be acknowledged.

As specified in the analysis in chapter IV, a total of 15 accident investigation reports were analysed. While it is recognised that this represents only a relatively small proportion of the total number of accident reports available, given the necessary time constraints associated with analysing lengthy documents in considerable detail, it was believed best to sacrifice a much larger sample in favour of a smaller, but more in-depth, analysis of a smaller number of up to date reports. Moreover, the sample of the accident reports was selected as objectively as possible, as detailed in chapter IV.

Another limitation was that the researcher was the only person coding both the reports and the interview transcripts. Ideally a number of researchers would have analysed the documents and transcripts in order to establish an agreed coding scheme. However, the use of predetermined coding and triangulation methodology enabled the researcher to compensate for these flaws and minimise researcher bias or interpretation in these steps of the project.

As with any questionnaire survey, achieving a suitable sample size was extremely important. Indeed, where quantitative analysis of survey findings is concerned, generally speaking, the larger the survey sample, the better. In this sense, 89 completed questionnaires (as was the case here) does not appear to be a particularly large sample. However, while perhaps modest in terms of total number, given the highly specialised nature of the target population (i.e. current air accident investigators) and the geographic spread of respondents, it could at least be considered as representative. In fact, to the best of the researcher's knowledge, no other published studies examining the views of investigators have achieved a larger sample size (of air accident investigators). Similarly, while 13 semi-structured interviews does not in itself represent a large interview sample, this represented around three quarter of the targeted sample. The response rate was therefore considered as high and sufficient to run descriptive statistics.

Finally, the period during which this research was conducted did not enable the researcher to develop and conduct training, allowing feedback and adjustment, which would have closed the systemic cycle of training.

As with any research of this nature, the findings of the research to some extent represent a snapshot in time. The aviation industry, and indeed the world in which we currently inhabit, is subject to almost constant flux and on going change. This is to say that while the findings of the research presented here are valid and appropriate for the present context, it would be naive to assume that this would always remain the case regardless of external factors affecting the industry in the future.

VIII- 5 Further research

In light of the research findings and potential limitations, a number of possible areas for future research can be identified.

VIII- 5- 1 Development and Evaluation of Human Factors Integration for investigator training

It is foreseen that thorough and systematic integration of human factors concepts and key issues into initial training regimes and follow on refresher programmes, targeted specifically for air accident investigators, could yield important benefits for the discipline. Namely, that investigators possessing a firmer grounding and appreciation of human factors issues will ultimately feel more empowered and able to routinely identify human factors issues and be able to communicate effectively with the HF expert, should the situation demand it. Over time it is seen that this would benefit the breadth and depth of accident reports and, ultimately, improve accident safety rates.

For such a scenario to become reality it would inevitably require close collaboration with, and the active involvement of, key regulatory bodies and policy makers throughout the integration of human factors in training programme and the development of an accreditation system to recognise the value of different courses on offer. In other words, without sufficient commitment or 'buy in' from bodies such as ICAO, there is little hope that achieving enhanced integration of human factors in training regimes will occur.

Hence, an important path for further research may focus on examining precisely how, and when, the modification of investigator training programmes should be changed to reflect the greater focus on human factors issues under existing regulatory frameworks.

While it is beyond the scope of the thesis to try and outline precisely what such a scheme might look like in practice, especially given the diverse nature of different investigative organisations and national regulatory bodies worldwide, it would however make sense that such plans would identify strategic tasks and targets for completion, with accompanying milestones for the delivery of these. This type of plan is commonly referred to as 'road-map' or policy 'pathway', and are commonplace in an aviation context. For example, in 2009 ICAO published their roadmap detailing the progressive transition from AIS (Aeronautical Information Service) to AIM (Aeronautical Information Management), which describes the dynamic, integrated management of aeronautical information services (ICAO, 2009). In the roadmap, the implementation of the new operating practices and protocols is detailed, broken down into separate 'phases', as well as outlining the affected stakeholders for each stage and the tools needed for delivery. A similar approach might be taken in this case for the integration of human factors into accident investigation. A possible initial phase would be to determine a way to embed HF in initial training for investigators, via the use of accident simulation involving HF issues for example, and to determine detailed guidelines and requirements on specialist and recurrent HF trainings investigators should undertake, which could be based on this research's findings and recommendations. Following phase could involve the identification of an accreditation system for training organisations or specific HF courses. This would in turn guide investigation organisations to the appropriate courses into which they should enrol their investigators. Parallel regulatory steps could include the development of guidelines on HF expert's involvement and recruitment.

Once in operation, the ability to measure the effect of such training on the subsequent quality of accident reports over longer time scales, and ultimately on the overall safety rate, would provide valuable contributions to this field. However, it is recognised that this would likely represent a considerable challenge and care would need to be taken to ensure that this was implemented appropriately.

VIII- 5- 2 Comparing 'in-house' versus 'external' HF expertise

The differences between in-house and external HF expertise within an investigation organisation was identified as a key finding in the research. Namely, it was seen that differences existed in terms of the depth and consistency of human factors reporting in the accident reports. Subsequently, future research may seek to compare the benefits and limitations of in-house versus external expertise more systematically. This might take the form of longitudinal study comparing different organisations. While this might be challenging from a purely quantitative perspective, given the nature of air accident reporting, a more qualitatively focussed assessment may produce important findings. It is foreseen that such work would help more informed decisions on the part of organisations as to how they should engage with HF experts when conducting investigations.

As demonstrated in the thesis, human factors in accident investigation is a complex issue that has led to considerable academic research and industry development. With global airspace getting busier and busier, and the uncertain influence of factors such as the growth of automation, it can be assumed that the role of human factors in air accident investigation will become even more important in the future. As this research has demonstrated, it is therefore never more important than it is now to ensure that managers and investigators receive the quality and type of training proportionate with the importance of human factors as a discipline.

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APPENDIX A: ICAO HF checklists used for the content analysis of the accident reports (ICAO Digest number 7, 1993, p39-44)

CHECKLIST A

To determine the relevant areas warranting further Human Factors investigation/analysis, rate the importance of each factor by indicating the appropriate weighting value beside each item.

0 = Not contributory
1 = Possibly contributory
2 = Probably contributory
3 = Evidence of hazard

BEHAVIOURAL FACTORS

A. Faulty planning (pre-flight, in-flight) ______
B. Haste (hurried departure, etc.) ______
C. Pressing the weather ______
D. boredom, inattention, distraction ______
E. Personal problems (familial, professional, financial) ______
F. Overconfidence, excessive motivation ("get-home"itis) ______
G. Lack of confidence ______
H. Apprehension/panic ______
I. Violation of flight discipline (risk-taking) ______
J. Error in judgement ______
K. Delay ______
L. Complacency, lack of motivation, etc. ______
M. Interpersonal tension ______
N. Inadequate stress coping ______
O. Drug abuse ______
P. Alcohol/hangover ______
Q. Personality, moods, character ______
R. Memory mindset (expectancy) ______
S. Habit patterns ______
T. Perceptions or illusions ______
U. Bush pilot syndrome ______

MEDICAL FACTORS

A. Physical attributes, conditioning and general health ______
B. Sensory acuity (vision, hearing, smell, etc.) ______
C. Fatigue ______
D. Sleep deprivation ______
E. Circadian disrhythmia (jet lag) ______
F. Nutritional factors (missed meals, food poisoning, etc) ______
G. Medication(s) (self-prescribed) ______
H. Medication(s) (doctor-prescribed) ______
I. Drug/alcohol ingestion ______
J. Altered consciousness ______
K. Reaction time or temporal distortions ______
L. Hypoxia, hyperventilation, etc. ______
M. Disbarisms, trapped gases, etc. ______
N. Decompression ______
O. Motion sickness ______
P. Disorientation, vertigo ______

Q. Visual illusions ______

R. Stress ______

S. Hypothermia/hyperthermia ______

T. Other acute illness(es) ______

U. Pre-existing disease(s) ______

OPERATIONAL FACTORS

A. Personnel selection ______

B. Limited experience ______

C. Inadequate transition training ______

D. Lack of currency/proficiency ______

E. Inadequate knowledge of A/C systems ______

F. Inadequate knowledge of A/C life support systems ______

G. Company policies and procedures ______

H. Supervision ______

I. Command and control relationships ______

J. Company operating pressures ______

K. Crew compatibility ______

L. Crew training (e.g. cockpit resource management) ______

M. Inadequate flight information (A/C manuals, flight planning, etc.) ______

TASK-RELATED FACTORS

A. Tasking information (briefing, etc.) ______

B. Task components (number, duration, etc.) ______

C. Workload tempo ______

D. Workload saturation ______

E. Supervisory surveillance of operation ______

F. Judgement and decision-making ______

G. Situational awareness ______

H. Distractions ______

I. Short-term memory ______

J. False hypotheses (vs. expectancy, habit, etc.) ______

K. Cockpit resource management ______

EQUIPMENT DESIGN FACTORS

A. Design/location of instruments, controls ______

B. Lighting ______

C. Workspace incompatibility ______

D. Anthropometric incompatibility ______

E. Confusion of controls, switches, etc. ______

F. Misread instruments ______

G. Visual restrictions due to structure ______

H. Task oversaturation (complex steps) ______

I. Inadvertent operation ______

J. Cockpit standardization (lack of) ______

K. Personal equipment interference ______

L. In-flight life support equipment ______

M. Effects of automation ______

N. Seat design/configuration ______

O. Aerodrome design and layout ______

P. Conspicuity of other aircraft, vehicles etc. ______

ENVIRONMENTAL FACTORS

A. Weather ______

B. Air turbulence ______

C. Illusions (white-out, black hole, etc.) ______

D. Visibility restriction (glare, etc.) ______

E. Work area lighting ______

F. Noise ______

G. Acceleration/deceleration forces ______

H. Decompression ______

I. Vibration ______

J. Heat/cold ______

K. Windblast ______

L. Motion (dutch roll, snaking, etc.) ______

M. Smoke, fumes in cockpit ______

N. Oxygen contamination ______

O. CO poisoning or other toxic chemicals ______

P. Radiation _____

Q. Electrical shock _____

R. Flicker vertigo _____

S. Air Traffic Control _____

INFORMATION TRANSFER FACTORS

A. Adequacy of written materials (availability, understandability, currency, etc.) _____

B. Misinterpretation of oral communications _____

C. Language barrier _____

D. Noise interference _____

E. Disrupted oral communication _____

F. Intra-crew co-ordination _____

G. Crew/ATS communication _____

H. Timeliness/accuracy of verbal communications _____

I. Cockpit crew non-verbal communications _____

J. Cockpit warnings, horns, chimes, etc. _____

K. Cockpit instrument displays1 _____

L. Airport signals, marking and lighting _____

M. Ground/hand signals _____

OTHER PERSONNEL FACTORS

Air Traffic Control

A. Attention (vigilance, forgetfulness, etc.) _____

B. Fatigue vs workload _____

C. Communications (phraseology, rate of speech, pronunciation etc.) _____

D. Working environment (lighting, noise, visibility, etc.) _____

E. Equipment/display layout and design _____

F. Judgement _____

G. Training and currency _____

H. Co-ordination and back-ups _____

I. Supervisory presence _____

J. ATC policies and operating procedures _____

Vehicle Operators

K. Selection and training _____

L. Working environment (noise, fatigue, visibility, etc.) _____

M. Command and control, supervision _____

Aircraft Line-Servicing Personnel

N. Selection and training _____

O. Availability of relevant information _____

P. Operating pressures _____

Q. Supervision _____

SURVIVABILITY FACTORS

A. Crashworthiness of design _____

B. Post-accident life support equipment (exits, chutes, life vests, ELTs, medical kits, etc.) _____

C. Command and control procedures _____

D. Crew training _____

E. Passenger briefings and demos _____

B. CHECKLIST BASED ON THE SHEL MODEL

FACTORS RELATING TO THE INDIVIDUAL (LIVEWARE)

1. PHYSICAL FACTORS

Physical characteristics

* height, weight, age, sex
* build, sitting height, functional reach, leg length, shoulder width
* strength, coordination

Sensory limitations

Vision

* visual threshold
* visual acuity (seeing details)
* focus time
* light adaptation
* peripheral vision
* speed, depth perception
* empty field myopia
* glasses, contacts

Others

* auditory threshold, understanding
* vestibular (ear senses)
* smell, touch
* kinaesthetic (body feelings)
* g-tolerances

2. PHYSIOLOGICAL FACTORS

Nutritional factors

* food intake 24 hours
* hours since last meal
* dehydration
* on a diet/weight loss

Health

* disease
* fitness
* pain
* dental conditions
* blood donation
* obesity, pregnancy
* stress coping (emotional/ behavioural signs)
* smoker

Lifestyle

* friendships
* relations with others
* change in activities
* life habits

Fatigue

* acute (short term)
* chronic (long term)
* skill (due to task)
* activity level (mental/physical)

Duty

* duration of flight
* duty hours
* leave periods — activities

Sleep

* crew rest, nap duration
* sleep deficit, disruption
* circadian disrythmia (jet lag)

Drugs

* medication over the counter
* medication — prescription
* illicit drugs
* cigarettes, coffee, others

Alcohol

* impairment
* hangover
* addiction

Incapacitation

* carbon monoxide poisoning
* hypoxia/anoxia
* hyperventilation
* loss of consciousness
* motion sickness
* food poisoning
* nauseating fumes
* toxic fumes
* others

Decompression/diving

* decompression
* trapped gas effects
* underwater diving

Illusions

Vestibular

* somatogyral (vertigo)
* somatogravic
* the leans
* coriolis illusion
* elevator illusion
* giant hand

Visual

* black hole
* autokinesis
* horizontal misplacement
* circularvection
* linearvection
* landing illusions
* chain-link fence illusion
* flicker vertigo
* geometric perspective illusion

3. PSYCHOLOGICAL FACTORS

Perceptions

Types

* non perception
* misperception
* delayed perception

Reaction time

* to detect
* to make an appropriate decision
* to take the appropriate action

Disorientation

* situational awareness
* spatial
* visual
* temporal
* geographic (lost)

Attention

* attention span
* inattention (general, selective)
* distraction (internal, external)
* channelized attention
* fascination, fixation
* vigilance, boredom, monotony
* habit pattern interference
* habit pattern substitution
* time distortion

Information Processing

* mental capacity
* decision making (delayed, poor)
* judgment (delayed, poor)
* memory capacity
* forgetting
* co-ordination — timing

Workload

* task saturation
* underload
* prioritization
* task components

Experience/recency
* in position
* in aircraft type, total time
* on instruments
* on route, aerodrome
* night time
* emergency procedures

Knowledge
* competence
* skills/techniques
* airmanship
* procedures

Training
* initial
* on the job
* ground
* flight
* transition, learning transfer
* recurrent
* problem areas
* emergency procedures

Planning
* pre-flight
* in flight

Attitudes/moods
* mood
* motivation
* habituation
* attitude
* boredom
* complacency

Expectations
* mind set/expectancy
* false hypothesis
* "get-home"itis
* risk-taking

Confidence
* in aircraft
* in equipment
* in self
* overconfidence, showing off

Mental/emotional State
* emotional state
* anxiety
* apprehension
* panic
* arousal level/reactions
* self-induced mental pressure/stress

Personality
* withdrawn, grouchy, inflexible
* hostile, sarcastic, negative
* aggressive, assertive, impulsive
* excitable, careless, immature
* risk taker, insecure, follower
* disorganized, late, messy
* anti-authoritative,resigned
* invulnerable, "macho"

4. PSYCHOSOCIAL FACTORS

* mental pressure
* interpersonal conflict
* personal loss
* financial problems
* significant lifestyle changes
* family pressure

FACTORS RELATED TO INDIVIDUALS AND THEIR WORK

1. LIVEWARE-LIVEWARE (HUMAN-HUMAN) INTERFACE

Oral communication
* noise interference
* misinterpretation
* phraseology (operational)
* content, rate of speech
* language barrier
* readback/hearback

Visual signals
* ground/hand signals
* body language

Crew interactions
* supervision
* briefings
* co-ordination
* compatibility/pairing
* resource management
* task assignment
* age, personality, experience

Controllers
* supervision
* briefing
* coordination

Passengers
* behaviour
* briefing
* knowledge of aircraft, procedures

WORKER-MANAGEMENT

Personnel
* recruitment/selection
* staffing requirements
* training
* policies
* remuneration/incentives
* crew pairing, scheduling
* seniority
* resource allocation
* operational support/control
* instructions/directions/orders
* managerial operating pressure

Supervision
* operational supervision
* quality control
* standards

Labour relations
* employee/employee-management
* industrial action
* unions/professional group

Pressures
* mental pressure — operational
* morale
* peer pressure

Regulatory agency
* standards
* regulations
* implementation
* audit
* inspection
* monitoring
* surveillance

2. LIVEWARE-HARDWARE (HUMAN-MACHINE) INTERFACE

Equipment

Switches, controls, displays
* instrument/controls design
* instrument/controls location
* instrument/controls movement
* colours, markings, illumination
* confusion, standardization

Workspace
* workspace layout
* workspace standardization
* communication equipment
* eye reference position
* seat design
* restrictions to movement
* illumination level
* motor workload
* information displays
* visibility restrictions
* alerting and warnings
* personal equipment interference (comfort)
* data link
* operation of instruments (finger trouble)

3. LIVEWARE-SOFTWARE (HUMAN-SYSTEM) INTERFACE

Written information
* manuals
* checklists
* publications
* regulations
* maps and charts
* NOTAMs
* standard operating procedures
* signage
* directives

Computers
* computer software
* user friendliness

Automation
* operator workload
* monitoring task
* task saturation
* situational awareness
* skill maintenance
* utilization

Regulatory requirements
* qualification — in position
* qualification — in management
* certification
* medical certificate
* licence/rating
* non-compliance
* infraction history

4. LIVEWARE-ENVIRONMENT (HUMAN-ENVIRONMENT) INTERFACE

INTERNAL
* heat, cold, humidity
* ambient pressure
* illumination, glare
* acceleration
* noise interference
* vibrations
* air quality, pollution, fumes
* ozone, radiations

EXTERNAL

Weather
* weather briefing, FSS facilities
* weather: actual and forecasts
* weather visibility, ceiling
* turbulence (wind, mechanic)
* whiteout

Other factors
* time of day
* lighting/glare
* other air traffic
* wind blast
* terrain/water features obstacles

Infrastructure

Dispatch facilities
* type of facilities
* use
* quality of service

At the gate
* APU
* towing equipment
* refuelling equipment
* support equipment

Aerodrome
* runway/taxiway characteristics
* markings, lighting, obstructions
* approach aids
* emergency equipment
* radar facilities
* ATC facilities
* FSS, weather facilities
* airfield facilities

Maintenance
* support equipment
* availability of parts
* operational standards, procedures and practices
* quality assurance practices
* servicing and inspection
* training
* documentation requirements

APPENDIX B: Online questionnaire sent to accident investigators

Cranfield UNIVERSITY

Dear Sir, Madam, Thank you for taking the survey.
This will take only 15 minutes of your time.
I am a PhD student at Cranfield University (UK) and I am running a survey on training and human factors training.
I have a degree in engineering and an MSc in Human Factors and Safety Assessment in Aeronautics.
My PhD aims to identify to what extent accident investigators should be human factors specialists.
This first survey is extremely important for my research as its objective is to understand the actual situation regarding training (occurrence, frequency, efficiency).
Do not hesitate to have a look through your training log or documents if you have any doubt.

Do not hesitate to contact me if you have any question about the research or the results :
c.m.burban@cranfield.ac.uk
This survey received epic approval from the Cranfield SEREC (Science and Engineering Research Ethics Committee) and full anonymity is ensured.
Please answer all the questions as you need to answer them all to be able to go to the next page (although the last one is optional).
Please answer openly and truthfully.

The following 6 questions concern your BACKGROUND.

Are you an air accident investigator?

- ◯ Yes
- ◯ No

Did you receive formal training?

- ◯ Yes
- ◯ No

0% [ ] 100%

>>

Where are you located

- North America
- South America
- Europe
- Asia
- Africa
- Oceania

What type of accident investigator are you?

- Operations
- Engineering
- Human factors
- Other, please specify

What type of organisation do you work for?

- National accident investigation agency
- Regulator
- Operator
- Manufacturer
- Other, please specify

How many investigations have you undertaken as an accident investigator?

- 0
- 1 to 5
- 6 to 10
- 11 to 20
- more than 20

0% 100%

<< >>

The following 3 questions cover your INITIAL ACCIDENT INVESTIGATION TRAINING.

How in-depth was the training that you received in the following areas during your initial training?

	No training received	Only brief	Neither brief nor in-depth	In-depth	Extremely In-depth
Administrative arrangements (organizations, legislation, liaison arrangements, investigation procedures, Annex 13, responsibilities of states involved etc)	○	○	○	○	○
Investigation management	○	○	○	○	○
Investigators' equipment	○	○	○	○	○
Accident site safety	○	○	○	○	○
Protection of evidence	○	○	○	○	○
Initial response procedures, accident notification procedures and initial actions at the accident site	○	○	○	○	○
Information gathering techniques	○	○	○	○	○
Communication, recording equipment and processes	○	○	○	○	○
Witness interviewing	○	○	○	○	○
Recorders (CVR, FDR etc)	○	○	○	○	○
Examination of maintenance documentation	○	○	○	○	○
Fires and explosions	○	○	○	○	○
Survival aspects, crashworthiness	○	○	○	○	○
Aircraft systems and structures	○	○	○	○	○
Aerodynamics	○	○	○	○	○
Power plants	○	○	○	○	○
Rotary wing aircraft	○	○	○	○	○
Organisational/management factors	○	○	○	○	○
Human performance	○	○	○	○	○
Analysis techniques	○	○	○	○	○
Report writing and recommendations	○	○	○	○	○
News media and public relations	○	○	○	○	○

How useful do you think the training you received was, considering the accident investigator's task.

	No training received	Of little use	Neither useless nor useful	Useful	Extremely useful
Administrative arrangements (organizations, legislation, liaison arrangements, investigation procedures, Annex 13, responsibilities of states involved etc)	○	○	○	○	○
Investigation management	○	○	○	○	○
Investigators' equipment	○	○	○	○	○
Accident site safety	○	○	○	○	○
Protection of evidence	○	○	○	○	○
Initial response procedures, accident notification procedures and initial actions at the accident site	○	○	○	○	○
Information gathering techniques	○	○	○	○	○
Communication, recording equipment and processes	○	○	○	○	○
Witness interviewing	○	○	○	○	○
Recorders (CVR, FDR etc)	○	○	○	○	○
Examination of maintenance documentation	○	○	○	○	○
Fires and explosions	○	○	○	○	○
Survival aspects, crashworthiness	○	○	○	○	○
Aircraft systems and structures	○	○	○	○	○
Aerodynamics	○	○	○	○	○
Power plants	○	○	○	○	○
Rotary wing aircraft	○	○	○	○	○
Organisational/management factors	○	○	○	○	○
Human performance	○	○	○	○	○
Analysis techniques	○	○	○	○	○
Report writing and recommendations	○	○	○	○	○
News media and public relations	○	○	○	○	○

How important do you think it is for an accident investigator to have knowledge in these areas?

	Not important at all	Unimportant	Neither unimportant nor important	Important	Extremely important
Administrative arrangements (organizations, legislation, liaison arrangements, investigation procedures, Annex 13, responsibilities of states involved etc)					
Investigation management					
Investigators' equipment					
Accident site safety					
Protection of evidence					
Initial response procedures, accident notification procedures and initial actions at the accident site					
Information gathering techniques					
Communication, recording equipment and processes					
Witness interviewing					
Recorders (CVR,FDR, etc)					
Examination of maintenance documentation					
Fires and explosions					
Survival aspects, crashworthiness					
Aircraft systems and structures					
Aerodynamics					
Power plants					
Rotary wing aircraft					
Organisational/management factors					
Human performance					
Analysis techniques					
Report writing and recommendations					
News media and public relations					

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The following 4 questions cover your ADDITIONAL and then REFRESHER TRAINING that you may have received.

What type of course did you undertake? (tick all the relevant boxes)

- ☐ The organization of a major investigation (relations and responsibilities of all the agencies involved)
- ☐ Relations with the media
- ☐ Relations with families
- ☐ Dealing with inquests, legal skills
- ☐ Management of a large site (large number of wreckage parts, security and safety)
- ☐ Investigation of complex systems (fly-by-wire, GPS, EGPWS, glass cockpit etc)
- ☐ Helicopter accident investigation
- ☐ Gas turbine engine accident investigation
- ☐ Survival aspects
- ☐ Fire and explosions
- ☐ Human factor investigation
- ☐ Regulations
- ☐ None
- ☐ Other, please specify

In which of these areas do you receive (regularly or not) refresher training? (tick all the relevant boxes)

- ☐ Initial response (notification, liaison with other agencies etc)
- ☐ Accident site safety
- ☐ Protection and gathering of evidence
- ☐ Analysis of evidence
- ☐ Relations with the media
- ☐ Relations with families, family assistance
- ☐ Report writing and safety recommendations
- ☐ Dealing with an inquest, legal skills
- ☐ Human factors (interview techniques, human factors investigation methods, human performance etc)
- ☐ Aircraft and systems technical knowledge
- ☐ Regulations
- ☐ None
- ☐ Other, please specify the frequency

How regularly do you receive refresher training in these areas?

	Never	Rarely (less than once every five years)	Sometimes (once every five year)	Often (once every two years)	Very often (at least once a year)
Initial response (notification, liaison with other agencies etc)	○	○	○	○	○
Accident site safety	○	○	○	○	○
Protection and gathering of evidence	○	○	○	○	○
Analysis of evidence	○	○	○	○	○
Relation with media	○	○	○	○	○
Relation with families, family assistance	○	○	○	○	○
Report writing and building safety recommendations	○	○	○	○	○
Dealing with an inquest, legal skills	○	○	○	○	○
Human factors (interview techniques, human factors investigation methods human performance etc)	○	○	○	○	○
Aircraft and systems technical knowledge	○	○	○	○	○
Regulations	○	○	○	○	○

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How current/up-to-date do you feel in these areas?

	Not at all	Not very current	Current	Very current
Initial response (notification, liaison with other agencies etc)	○	○	○	○
Accident site safety	○	○	○	○
Protection and gathering of evidence	○	○	○	○
Analysis of evidence	○	○	○	○
Relation with media	○	○	○	○
Relation with families, family assistance	○	○	○	○
Report writing and building safety recommendations	○	○	○	○
Dealing with an inquest, legal skills	○	○	○	○
Human factors (interview techniques, human factors investigation methods human performance etc)	○	○	○	○
Aircraft and systems technical knowledge	○	○	○	○
Regulations	○	○	○	○

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The following 7 questions cover HUMAN FACTORS.

How important do you think it is to investigate human factors?

Not at all Important	Very Unimportant	Neither Important nor Unimportant	Very Important	Extremely Important
○	○	○	○	○

How useful was the human factors training that you received?

N/A	Useless	Neutral	Useful	Very Useful
○	○	○	○	○

What areas did your human factors training cover? (tick all the relevant boxes)

- ☐ Interview techniques
- ☐ What is human factors?
- ☐ Human factors investigation tools and techniques
- ☐ Human factors data that should be collected
- ☐ Use of human factors specialists
- ☐ Human factors in engineering and maintenance
- ☐ Human factors in ATC
- ☐ Human factors in flight operations
- ☐ Human performance and error
- ☐ Cultural/organizational factors
- ☐ Basics in aviation medicine
- ☐ Not applicable

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How confident do you feel in practicing these human factors areas?

	Not confident at all	Not very confident	Neutral	Confident	Very confident
Interview techniques	○	○	○	○	○
Human factor investigation	○	○	○	○	○
Human factors tools and techniques	○	○	○	○	○
Human factors data that should be collected	○	○	○	○	○
Use of human factors specialists	○	○	○	○	○
Human factors in engineering and maintenance	○	○	○	○	○
Human factors in ATC	○	○	○	○	○
Human factors in flight operations	○	○	○	○	○
Human performance and error	○	○	○	○	○
Culture/organizational factors	○	○	○	○	○

How important do you think it is to your role to have knowledge in human factors?

Not at all Important	Very Unimportant	Neither Important nor Unimportant	Very Important	Extremely Important
○	○	○	○	○

Would you like to receive more human factors training?

Yes	No
○	○

Do you think human factors is investigated deeply enough in your organization?

Yes	No	Neutral
○	○	○

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OPTIONAL QUESTION: For the purposes of feedback, please provide an email address (please note that this information will stay confidential and will not be used in the data analysis)

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Thank you very much for taking part in this survey

Your answers are very important for my research and please remember that any personal information will stay confidential.
If you have left you email adress, you will receive feedback from the research as soon as the data are received and analysed.
If you have any questions please do not hesitate to contact me : **c.m.burban@cranfield.ac.uk**

Have a good day

Camille Burban

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APPENDIX C: Interviewee guide

INTERVIEW GUIDE FOR INTERVIEWEES - CONSENT FORM

- About the interviewer:

Camille Burban, PhD student at Cranfield University (UK)
Nationality: French
Background: Mechatronics engineering, MSc in Human Factors and Safety in Aviation

PhD topic: To what extent Air accident investigators should be human factors specialists?
I am looking into the level of HF training that accident investigators should receive. After identifying a lack of confidence and knowledge due to deficiencies in their initial training and lack of recurrent training, I am now looking at designing more adapted training by trying to understand what are their needs and what should their role be in Human Factors investigation.

- About the interview:

Length: approx. 1 hour
Topics approached:
- Your background and motivation
- Recruitment/expectations
- Role and involvement / approach to the investigation / approach within your organisation / task and challenges / balance
- The way HF in considered nowadays in accident investigations
- Relation with accident investigators / teamwork / their understanding
- What you do different/ what makes you an expert
- How they could improve their knowledge / confidence / most important HF topics to cover and develop

I am interested in your opinion about the way Human Factors is approached in accident investigations and the way it could be improved, looking specifically at accident investigators' knowledge and attitude.

It is not the goal of this interview to obtain any confidential information. Each interview will stay anonymous and only be used for the purpose of this research.
Please note that this is not, in any case, an evaluation and you can decide to withdraw your interview from the research one week after it took place.

You can contact me at:
c.m.burban@cranfield.ac.uk
+ 44 7 428 521 737

For analysis purposes this interview will be tape-recorded.
Please sign here if you agree to take part in the survey:

Date: Name and Signature:

APPENDIX D: Online questionnaire sent to HF experts previously interviewed

Cranfield UNIVERSITY

Welcome to the final data gathering of my PhD.

Thank you for agreeing to take part in this questionnaire that aims at reaching a consensus on human factors in accident investigation amongst practitioners.

Having interviewed experts about human factors training and expertise, the final objective in my PhD is to make recommendations on those issues, in order to help accident investigation organisations undertake better human factors investigations. In order to do so, I am running a Delphi study, which seeks to reach a consensus on important matters.

Please remember that I am interested in your own experience, point of view and opinion and that this is not a test. Your participation will remain anonymous and you have the right to withdraw your response within the week following the questionnaire completion.

Please do not hesitate to contact me if you would like any further information or have any concern.

Thank you very much once again, your participation is extremely important to me and my research.

What type of accident investigator are you?

- ◯ Human Factors
- ◯ Operations
- ◯ Engineering
- ◯ General
- ◯ Other, please specify ______

Please specify the mode of transportation in which you have been involved the most?

- ◯ Air
- ◯ Rail
- ◯ Marine
- ◯ Road
- ◯ Other, please specify ______

>>

The following questions will be regarding awareness human factors training.

How important do you think it is for the following persons to receive initial awareness human factors training?

	Very important	Moderately important	Neutral	Not really important	Not at all important
Accident investigators (non-hf)	◯	◯	◯	◯	◯
Managers	◯	◯	◯	◯	◯

Ideally, how do you think the content of the awareness course should be designed?

◯ General to all investigators

◯ Specific to the investigator's role (Engineering, operations, IIC)

◯ A mix of both

◯ Other, please specify

To what extent do you agree or disagree that the following should be included in that awareness training?

	Strongly agree	Somewhat agree	Neutral	Somewhat disagree	Strongly disagree
Importance of hf investigation	◯	◯	◯	◯	◯
Interview techniques	◯	◯	◯	◯	◯
Sources of evidence (hf related)	◯	◯	◯	◯	◯
Value of human factors investigation	◯	◯	◯	◯	◯
Importance of hf expertise involvement	◯	◯	◯	◯	◯
Methods/tools available	◯	◯	◯	◯	◯
How to use/apply those methods	◯	◯	◯	◯	◯
Fatigue	◯	◯	◯	◯	◯
Attention	◯	◯	◯	◯	◯
Workload	◯	◯	◯	◯	◯
Errors/ Error mechanism	◯	◯	◯	◯	◯
Automation/Monitoring	◯	◯	◯	◯	◯
Cue recognition	◯	◯	◯	◯	◯
Stress	◯	◯	◯	◯	◯
Decision making	◯	◯	◯	◯	◯
Biases	◯	◯	◯	◯	◯
Situation awareness	◯	◯	◯	◯	◯

Are there any other additional human factors areas that you believe should be approached during the initial awareness training?

◯ Yes, please specify

◯ No

Ideally, how long do you think this awareness training should last?

- ◯ 1 day
- ◯ 3 days
- ◯ 5 days (1 week)
- ◯ More than a week
- ◯ Other, please specify

What form of teaching method do you think should be employed for this training?

- ◯ Lecture room
- ◯ Internet/Online courses
- ◯ Workshop
- ◯ A mix of these techniques
- ◯ Other, please, specify

Do accident investigators (non-hf) receive human factors training in your organisation?

- ◯ Yes
- ◯ No

>>

Do managers receive training in human factors in your organisation?

- ◯ Yes
- ◯ No

>>

The following questions will be regarding refresher/recurrent training.

Do you think these persons should receive refresher/recurrent human factors training.

	Yes	No
Accident investigators	○	○
Managers	○	○

Do you think refresher training should be...

- ○ General to all investigators
- ○ Specific to their role
- ○ A mix of both
- ○ Other, please specify
- ○ I believe they should not receive refresher training

What do you think should be approached during this refresher training? (tick all the relevant answers)

- ☐ Value of previous human factors investigations run within the organisation
- ☐ Trends highlighted
- ☐ New issues published in the literature
- ☐ Same issues as the ones approached during the initial training
- ☐ Use of analysis methodology
- ☐ Other, please specify
- ☐ Not applicable

How often do you think the following persons should ideally undertake refresher/recurrent training?

	Once a year	Every 2 years	Every 3 years	Every 4 years	Less often	Never / Not applicable
Accident investigators	○	○	○	○	○	○
Managers	○	○	○	○	○	○

Considering workload and budget, how often do you think the following persons should realistically undertake refresher/recurrent training?

	Once a year	Every 2 years	Every 3 years	Every 4 years	Less often	Never / Not applicable
Accident investigators	○	○	○	○	○	○
Managers	○	○	○	○	○	○

Please add any comments regarding human factors training for accident investigators and/or managers that you believe is relevant.

>>

The following questions will be regarding Human Factors expertise in accident investigation

How important do you think it is for a human factors expert involved in accident investigation to have an academic background (MSc, PhD)?

- ◯ Very important
- ◯ Important
- ◯ Neutral
- ◯ Not really important
- ◯ Not at all important

Please specify the reason why:

How important do you think it is for human factors experts involved in accident investigation to have some background/context knowledge (e.g. operations understanding) of the relevant mode of transportation?

- ◯ Very important
- ◯ Important
- ◯ Neutral
- ◯ Not really important
- ◯ Not at all important

How would you say is the best way to gain this knowledge?

- ◯ On-the-job (as an investigator)
- ◯ Academic degree / research applied
- ◯ Industry experience
- ◯ Other, please specify
- ◯ Not applicable

How important do you think these attributes / skills are for human factors investigators?

	Very important	Important	Neutral	Not really important	Not at all important
Writing communication	○	○	○	○	○
Oral communication	○	○	○	○	○
Analytical	○	○	○	○	○
Logical	○	○	○	○	○
Leadership	○	○	○	○	○
Assertiveness	○	○	○	○	○
Team player	○	○	○	○	○
Possessing a network of other experts	○	○	○	○	○
Interview skills	○	○	○	○	○

Please specify any other other attribute / skill that you believe a human factors investigator should have?

>>

Thank you!
You have now completed the questionnaire.
Thank you very much for your answers. They are extremely valuable to my research.
If you have any queries or questions, please contact me on: c.m.burban@cranfield.ac.uk

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