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What do aircraft accident investigators do and what makes them good at it? Developing a competency framework for investigators using grounded theory

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ABSTRACT

We present a new analysis of the tasks carried out by air accident investigators and propose a new competency framework which captures the competencies demanded of an effective investigator. Using a subject-matter expert panel, a hierarchical task analysis (HTA) was developed to frame and organise the diverse activities that are required of the air accident investigator. Supported by the HTA, a competency framework was developed using structured interviews based on repertory-grid interview technique. Grounded theory was used to abstract competencies derived from the interviews. The resultant competency framework could be applied to selection and training future investigators in other safety critical domains. More immediately, the framework can deliver insight into what differentiates the good investigator from the excellent investigator.

1. Introduction

In 2004 Ken Smart, former chief inspector of the UK Air Accidents Investigation Branch (AAIB) wrote:

> *"In my experience it is a relatively straightforward process to establish a candidate's professional qualifications and experience. Far more difficult is to get a good assessment of a candidates personal qualities."*
>
> Smart, 2004

We have little doubt that this is a common refrain in all but the most straightforward of roles and their associated selection processes. In this article, we address part of this challenge through the development of a new task analysis and resulting competency framework for air accident investigators. Air accident investigation is a highly specialised and demanding role. In the United Kingdom, the AAIB is the government body responsible for the investigation of air accidents and has been extant since 1915. The AAIB's purpose is "…to improve aviation safety globally by determining the causes of air accidents and serious incidents, and making safety recommendations intended to prevent recurrence. It is not to apportion blame or liability." (AAIB, 2017a). Since 1951, the International Civil Aviation Organisation (ICAO) has published international standards and recommended practices (SARPS) to its member states that air accidents and serious incidents should be investigated in the same way (ICAO, 2016). In Europe, this was mandated by the European Parliament through EU996/2010 (European Union, 2010).

Air accident investigation is a complex task that draws upon a broad range of skills. Although many of the component parts of the task are not inherently difficult, it is the nature of accidents that creates the potential for great complexity (Strauch, 2016). Air accidents are unscheduled, destructive and may lead to loss of life. They are often highly visible, shocking and can become politically sensitive. Investigators must react swiftly in order to preserve evidence which may be perishable or vulnerable. Investigators will likely work in a multinational, multidisciplinary team, formed at short notice and often working away from their main base. An investigation may continue for many years following a large or complex accident, yet the pressure to reassure the travelling public, as well as the operators of aircraft is immediate. Investigators need to be led by evidence, some of which may have been damaged or destroyed by the accident or which witnesses may be unwilling to share because of the fear of negative consequence.

Air accident investigators are characterised by a high level of technical skill and knowledge in the aviation domain. We suggest that this is given; technical skill alone cannot differentiate excellence in this complex role. In this article we develop a competency framework that can be used to progress and develop high work performance of the investigator. The idea of competencies has been progressed in the human resources and personnel literature and is related but distinct from merely a descriptor of *what* an employee does in a given role (Shippmann et al., 2000). In eliciting descriptions of competencies

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Shippmann et al. found a plurality of understanding including the related concepts of skills, abilities, performance, knowledge and behaviours. Of particular interest in the current article is the idea that competencies can differentiate the higher performer: the superior from the mediocre (Campion and Odman, 2011; Olesen et al., 2007; Parry, 1996). Of more practical value to the employee is the application of competency frameworks to coach average performers to superior performance (Shippmann et al., 2000). Shippmann et al. propose that whereas job-analysis is focussed on the *what* competency analysis is focused on the *how*. That is the difference between *what* tasks are done by the employee and *how* those tasks are done by the employee. Competencies are performance shaping factors of a job or role, modifying performance on a task. Sanchez and Levine (2009) develop the definition of a competency further. They propose that competency modelling is a higher level description of a role which is aligned with an organisational strategy and purpose. They argue that the strong acceptance of competency modelling by senior management is a result of the strategic and direct language used when writing competencies. This is in stark contrast to the sometimes opaque psychological vocabulary associated with descriptions of jobs or the personal attributes required to do them.

With reference to the literature, a core, generic set of competencies that could be applied to a broad groups of jobs, for example leadership or technical roles is proposed. Notably the so-called 'great eight' (Bartram, 2005) which include competencies relating to decision making, leading and communicating. Generic professional competence standards are also proposed by Lester to include ethics and professionalism and profession specific problem solving and evaluation (Lester, 2014). These generic frameworks provide an effective frame of reference to understand content and construct validity. In other words what is the kind of material that is found in a competency framework and is this material synonymous with the understanding of a competency? In addition the meta-analysis proposed by Bartrum includes reference to selection tests which could differentiate these competencies. Despite the availability of these generic frameworks, progression and development of a bespoke framework for air accident investigation remains a valuable line of inquiry. The task is specialised and we view it as important for the practical application of the framework for it to be specified in the language of the sector and its stakeholders. This is identified as a key user acceptance factor for the deployment of such frameworks within organisations (Cummings and Worley, 2008).

Air accident investigation is a complex role. We show that the good investigator must have a diversity of competencies in addition to excellent technical knowledge of aviation systems and processes to achieve success in the role. One hazard in assembling a classic job analysis is that the role itself may be reduced to a number of independent activities. While this is an important element of the process, the focus could then be shifted towards generating lists of required technical knowledge omitting the performance shaping factors that could make the good investigator a great investigator.

The research presented in this article is informed by two aims. Firstly to understand what tasks accident investigators do. Secondly, to understand what competencies make investigators good at these tasks. These aims have been met firstly through the development of a hierarchical task analysis (HTA) in conjunction with a subject-matter expert (SME) panel. Secondly, competency data was elicited using individual, structured-interviews with the SMEs informed by the HTA. We have developed an interview structure using repertory-grid interview techniques. Finally the results of the structured interview are analysed using a grounded theory approach, the output of which informs the generation of competencies. The resulting competency framework contains a rich hierarchy of competencies and sub-competencies which are then finally placed into context using narratives.

2. Method

2.1. Participants

The research conducted was approved by the University ethics committee prior to starting the interviews. All participants gave written informed consent before participating in the study. An SME panel was assembled to represent UK accident investigator roles in the research.

Participants were sampled purposively. Participants were drawn from accident investigators having had experience in the civil or military accident investigation domain. Six investigators participated in the SME panel as a group to validate the HTA, and individually to elicit the competencies. Participants had a cumulative experience of 82 years, representing a high level of expertise and wide ranging experience in the accident investigation process including military, civil fixed-wing, rotary-wing, and engineering and flight operations. The mean level of participant experience is 13.6 years (SD = 5.6). Sample size in qualitative research has generated much discussion and debate (for example see Crouch and McKenzie, 2006; Morse, 2000). In quantitative research arguments to support selection of sample size can be framed in terms of the confidence of an inference from sample to population or the power of a study to find a given effect size avoiding a Type II error. It is not germane to frame selection of sample size in qualitative research in these terms. For the research presented in this article a smaller, expert sample was used to generate in-depth insights into the accident investigator role. The six investigators purposively sampled bring a depth of experience over 82 years. The modest sample size is warranted by the highly specialised nature of the industry which in the UK, has a population of fewer than twenty-five full-time investigators (AAIB, 2017b). As such the panel represents appropriate reliability which will be demonstrated empirically through category saturation in the interview data when new codes are not forthcoming (Guest et al., 2006).

2.2. Design and procedure

Two designs are employed to generate data to support construction of the HTA and secondly to elicit attributes which differentiate high performance investigators. These attributes will form the competency framework.

2.2.1. Generation of the HTA

The generation of the initial HTA was led by the first author (JN) in conjunction with an independent SME, not represented on the wider SME panel employed in the research. The independent SME has 10 years of experience as a Royal Navy air accident investigator. Following creation of the initial HTA, a facilitated workshop was held with the SME panel Participants were briefed on the purpose of the session and gave informed consent to participate in the research. Investigators were given 15 min to familiarise themselves with the HTA. A facilitated discussion was then conducted to establish any tasks that had been omitted from the HTA and the order of tasks presented. The specific wording of tasks was also addressed during the interview. All changes and alterations were recorded on front of participants and discussion progressed until all workshop participants agreed on the changes made to task wordings and order. One investigator who was not able to join the workshop gave comments and changes prior to the workshop and these comments and changes were incorporated into the main workshop discussion. During this workshop, a final version of the HTA was agreed by the panel.

2.2.2. Generation of competencies

Structured interviews were conducted by the first author (JN) with participants to elicit the qualities of stronger and weaker accident investigators. Participants were interviewed individually and briefed on the purpose of the session and gave written informed consent to participate in the research. Participants were informed that the interview

should not last longer than two hours. Interviews were based on repertory-grid interview techniques (Fransella et al., 2004). The completed HTA was made available in the structured interviews to calibrate understanding of the tasks under consideration. Participants were required to think of individuals they had worked with who they would classify as stronger, middling or weaker. Similarities and differences between pairs of individuals in these categories were then elicited by the interviewer. Participants were asked to think of three air accident investigators they had worked with who represented stronger, middling and weaker ability in their view. Participants were then asked to give an informal name to these three individuals to allow for anonymous discussion during the interview. Participants then selected pairs at random, for example stronger *vs.* weaker, weaker *vs.* middling, *etc.* For each pair selected, participants were asked to describe how the investigators were different and how they were similar. Responses were recorded verbatim in full view of the participant as written sentences that could be transferred directly into the analysis. Participants were asked to form comparisons using 'what-else' style questioning until they explicitly stated 'nothing-else'. The interview was structured around the comparisons but led by the participant. When all comparisons were exhausted, participants were asked what they wished to add to the analysis. The interviewer then reflected back all comments made to the participant to check accuracy of recording and to calibrate understanding. When the participant explicitly stated that they could make no more comparisons the data collected was summarised by the interviewer to the participant and the interview was closed. Participants were thanked and debriefed at the end of the interview.

3. Results

3.1. Task Analysis

The top levels of the HTA are shown in Fig. 1. Further levels keyed by the black shapes in Fig. 1 are shown in Figs. 2–5. We give detailed narratives for the tasks elicited in the HTA and these narratives were used in the subsequent interviews to frame the elicitation of the competencies. Overall, participants were in agreement with the content of the HTA at the lower levels of analysis. The major parts of the discussion focused in the top level order of the activities. The SME panel pointed out each reported safety occurrence requires a decision as to whether the accident is formally investigated by the statutory nobody or referred to the manufacturer or another agency. The diversity of information coming into the statutory agencies was surprising. In addition, the task analysis had to accommodate scale: from a small incident to a large scale accident involving fatalities.

Safety occurrences (Level 0) are classified as incidents, serious incidents or accidents based on severity of damage and/or injury (European Union, 2010; ICAO, 2016). Certain events must be investigated either to meet the standards laid out by the International

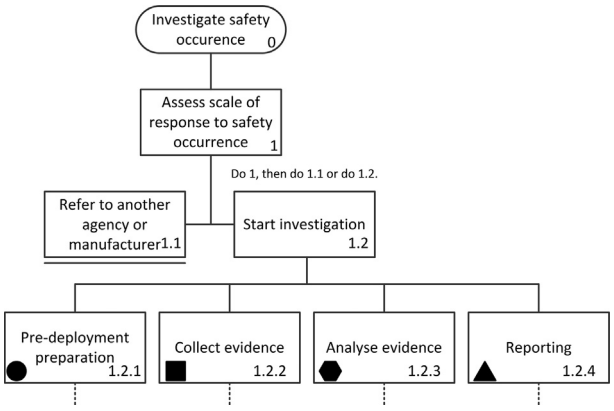


Fig. 1. Top level HTA of accident investigation process.

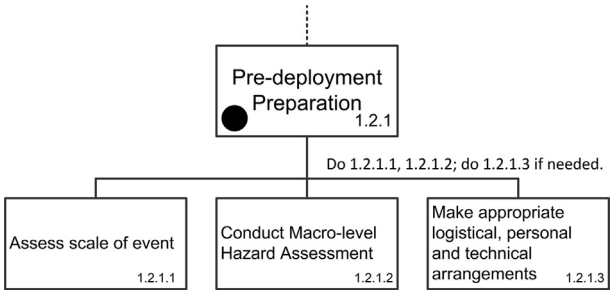


Fig. 2. Pre-deployment preparation HTA detail (Level 1.2.1).

Civil Aviation Organisation (ICAO) for member states or within the EU, to comply with EU Regulation EU996/2010. However, other incidents not mandated for investigation may still offer substantial learning value based on the risk potential and as such, an investigation agency may choose to initiate an investigation. In practice, the decision to investigate is more complex as initial information about an occurrence is likely to be inaccurate or incomplete, especially if it occurs in a remote location.

A delay in responding to an accident may be costly for the investigation, for example in the potential loss of perishable or vulnerable evidence; logistical challenges in deploying to a site where there may be increasing travel disruption, limited accessibility and competing interests; and in terms of reputational damage if the investigation agency is noticeably absent. Too rapid a response may lead to over-committing or misallocating resource which may be expensive.

Assessing the learning value of an occurrence prior to deployment or evidence collection is difficult. Some investigation agencies have taken the decision not to investigate particular event types. For example, the Australian Transport Safety Bureau (ATSB) does not investigate all small air accidents even if there was a fatality involved due to the large territory (Australian Transport Safety Bureau, 2017). Other investigation agencies accept that field deployment provides opportunity for maintaining currency, even if no significant safety -lessons are anticipated or reported. Where a national investigation agency makes a decision not to investigate, it is likely that other stakeholders: the aircraft operator, airport, manufacturer or insurer will conduct their own.

Pre-deployment preparation (Fig. 2, Level 1.2.1) is a critical task which ensures the safety and efficiency of the subsequent investigation. Firstly, the appropriate knowledge and skills in the types of hardware or accident type most be deployed to the investigation. Secondly, an initial assessment should be formed from the occurrence report to determine the scale of deployment required, composition of the team, participant organisations and how long the deployment is likely to last. The size and scale of the event is likely to dictate how many investigators are required and from which specialisms, but also how complex logistics are likely to be on site. For example a large, multiple fatality accident is likely to involve media presence who will compete for hotel rooms, hire cars, *etc*. International obligations dictate who has the 'right to participate' in an investigation. Depending on the location of the accident, the operator, engine manufacturer, aircraft manufacturer, law enforcement agencies may be mandated to participate. The lead investigator may also choose to appoint technical advisors but can only do so through the relevant investigation agency for that state.

On site, an accident investigation is secondary to the emergency service response and. In certain jurisdictions, law enforcement agencies have primacy. This may mean that evidence collection in support of the accident investigation is delayed. Evidence may be lost: physical evidence is moved during rescue operations or witness memories become tainted or fade (Baddeley et al., 2015; Strauch, 2002). Evidence may also be degraded the longer the time between the occurrence and the preservation and recording of the evidence. For less severe incidents, where physical evidence is often limited or absent, notifications are often delayed which may further compromise an investigation.

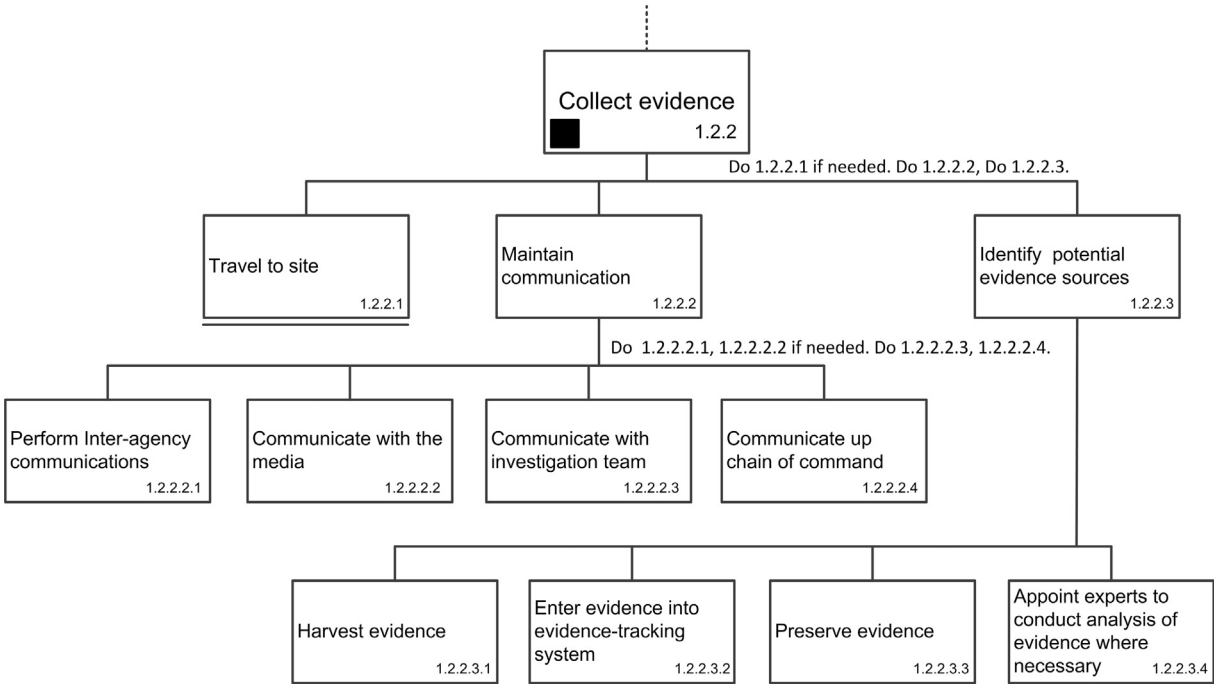


Fig. 3. Collect evidence HTA detail (Level 1.2.2).

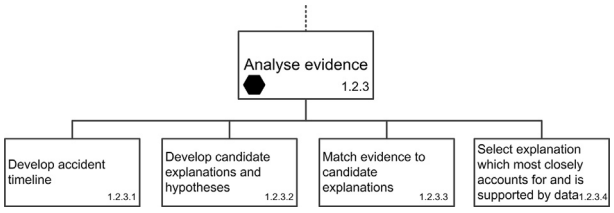


Fig. 4. Analyse evidence HTA detail (Level 1.2.3).

Evidence collection (Fig. 3, 1.2.2) is central to effective accident investigation. Evidence can take many forms including physical, documentary or people. Evidence may be located at an accident site, distributed along a flight path or be remote, such as in a hangar, corporate headquarters. Evidence can also reside in witness memory such as passengers who can quickly scatter across the world. Evidence can be perishable or vulnerable: changing or degrading over time or be damaged deliberately or accidentally. For example, physical evidence may change if aircraft wreckage is moved during rescue operations or in order to re-open an airport. Witness memory may be affected by interviewing technique or exposure to media reports (Baddeley et al., 2015; Strauch, 2002).

Air accident investigators need to be methodical in their approach to identifying and capturing evidence which means conducting a level of analysis on site to prioritise their efforts. This requires a disciplined balance of hypothesis forming / testing and the recognition of investigative bias. Recording of evidence is also important, both to the integrity of the accident investigation, but also in case a criminal act is subsequently discovered. In a large investigation, this may mean a large volume of evidence to be catalogued. For example, the wreckage trail of the Pan Am Boeing 747 that exploded over the town of Lockerbie in 1988 was 130 km long (AAIB, 1990). Each piece of wreckage had to be catalogued and its location documented.

Certain evidence will need to be analysed by technical specialists. Technical expertise may reside within an accident investigation agency itself. For example at the AAIB, flight data and cockpit voice recorder (FDR, CVR) specialists must legally reside within the investigation team to be able to access the data. Technical expertise can also be brought into the team. For example, aircraft manufacturers or operators or a specialist research organisations in support of specific questions relating to the investigation. All technical experts need to be supervised to ensure continuity of evidence and to defend any suggestion of interference or lack of independence.

The analysis phase of an accident investigation (Fig. 4, Level 1.2.3) may be lengthy and complex, but is essentially devoted to establishing what happened, why it happened and what action should be taken to

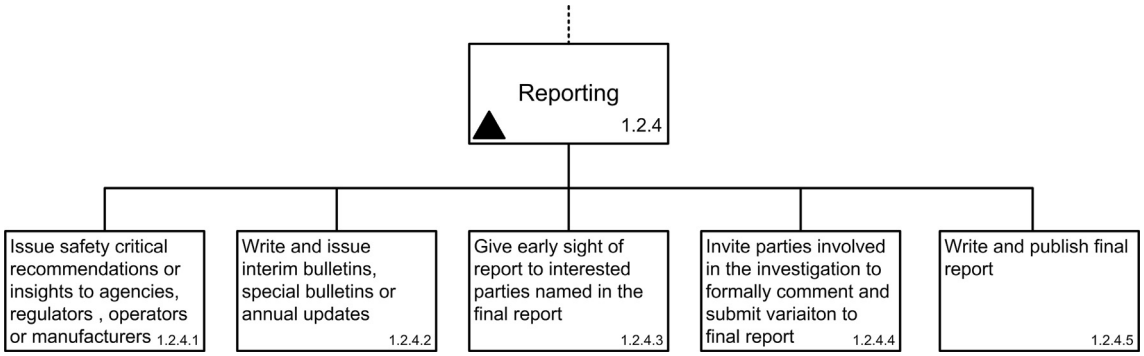


Fig. 5. Reporting HTA detail (Level 1.2.4).

prevent recurrence. We repeat Walker and Bills (2008) cautionary note in respect to analysis: “Despite its importance, complexity, and reliance on investigators’ judgements, analysis has been a neglected area in terms of standards, guidance and training of investigators in most organisations that conduct safety investigations.”.

Analysis is a process that, especially for a large investigation, involves a multidisciplinary and multinational team meaning the challenges are not just of logic, but also of interpretation. In accident investigation, ‘piecing together the jigsaw’ is not just a matter of assembling the facts, but also requires assessment of evidence which may prove to be erroneous, contradictory, inaccurate or incomplete. Accidents are in effect, experiments that have already run without control of the variables and as such, can prove especially difficult to reverse-engineer.

Investigator power is projected through a written report which sets out through the presentation and analysis of evidence that there is a particular safety issue to be addressed and in some cases, a way in which the issue is to be addressed (Fig. 5). We cannot improve upon Wood and Sweginnis (2006) comment on the importance of reporting: “A superbly written report cannot do much to overcome a bad investigation, but a poor report can definitely ruin a good investigation”. The process of reporting is necessarily complex; there are certain obligations upon the authoring body and there are multiple audiences.

An accident investigation body often has statutory obligations for publication which may be in conflict with the time it may take to complete an investigation. For example, EU996/2010 demands that EU Member States publish the investigation into an air accidents in the shortest time possible or within twelve months (European Union, 2010). If no report is forthcoming interim reports must be delivered at regular intervals. Investigations can take many years to complete. For example, the Canadian investigation into Swissair flight 111 which crashed in 1998 took 5 years to publication (Transportation Safety Board of Canada, 2003) and the French investigation in the loss of Air France flight 447 which crashed in 2009 took 3 years to publication (Bureau d’Enquêtes et d’Analyses, 2012). Conversely, industry may wish for a much shorter timescale, especially if investigation findings may impact upon their current operations. Investigators must decide at what point to release interim findings to alert industry to an imminent concern while balancing the need to deliver an early warning against the need for thorough and complete investigation.

Prior to publishing a report, investigators, again, need to execute their statutory obligations which means consulting both technical stakeholders and those who may be personally affected such as family of the deceased. EU 996/2010 states “Before publication of the final report, the safety investigation authority shall solicit comments from the authorities concerned, including EASA, and, through them the certificate holder for the design, the manufacturer and the operator concerned, who shall be bound by applicable rules of professional secrecy with regard to the contents of the consultation.”. In addition, family members often benefit from a briefing about the content of an accident report prior to its official release, especially if they may be negatively affected by the content. This process is important to ensuring the accuracy of a report and may be an emotive one. However, it is not necessarily about achieving a consensus view, an investigator must retain the independence to make difficult recommendations.

As the audience of accident reports ranges from the naïve to technical. From those who may be affected by human tragedy through to those who may be responsible for design, operational or regulatory changes. As such, the style and the level at which a report is pitched is of great importance. Investigators are obliged to ensure that they do not imply blame or liability, must present a clear and transparent exposition of evidence its analysis, and ultimately present conclusions and any applicable safety recommendations. These recommendations may require changes that could cost the industry many millions of pounds and hence must be compelling, logical and evidence-led. Reporting is the essential vehicle for catalysing change. If done well, the report contributes to the overriding aim of accident prevention, in some cases across a broad range of industrial sectors.

3.2. Competencies

Data from the interviews consisted of 175 statements that characterised the differences between stronger, middling and weaker accident investigators. The distribution of the statements was similar across the interviews. Grounded theory was used to analyse and interpret the data and generate the competency framework. Three stages of coding are used: open coding, axial coding and selective coding. In the open coding stage nineteen codes were developed by the first author through consideration of the data. The 175 statements were the coded by the first author using the method of constant comparison where each item is compared to every other item. Once the items were grouped, a name was assigned to the group of statements which characterised a common theme. Although this type of research design is a subjective endeavour, greater reliability can be achieved through the assessment of inter-rater reliability. If two or more raters agree on the allocation of the statements into the codes then this can be used to empirically support the reliability of the judgements.

To establish reliability and to evaluate the effectiveness of the open-

Table 1
Descriptions of the nineteen open codes developed.

	Open Code	Short Description
1	Addressing development needs	Recognises and addresses personal development needs
2	Awareness of bias	Is aware of, and manages bias in the investigation process
3	Character	Elements of character which assist and hinder investigative process and technique
4	Effective presentation skills	Ability to present findings orally
5	Effective writing skills	Ability to present findings in writing
6	Empathy	Ability to be empathetic and to leverage this insight to achieve success in the investigative process
7	Evidence led approach to Investigation	Uses and tests evidence to support findings from the investigation
8	Imagination	Ability to be innovative and to think ‘outside of the box’ when required
9	Leadership skills	Ability to lead and manage people
10	Motivation and commitment	Effective attitude towards role
11	Objectivity of Analysis	Ability to objectively evaluate evidence and data
12	Openness to discussion and challenge	Openness to discussion and challenge during the investigation process
13	Organisational skills	Ability to plan and manage time and resources to achieve objectives
14	Self-insight	Ability to evaluate own weaknesses and strengths in order to be a better investigator
15	Situational communication	Ability to modify communication strategy depending on situation or audience
16	Team working	Ability to operate as part of an inter- or intra-agency team. Ability to engage internationally with different cultures
17	Understanding the social element of interaction	Ability to grasp the social elements of verbal interaction and adapt strategy accordingly
18	Understanding the organisational mandate	Understanding of the role of the organisation and the purpose of the investigation more widely
19	Working to standards	Working to standards laid down by the regulator

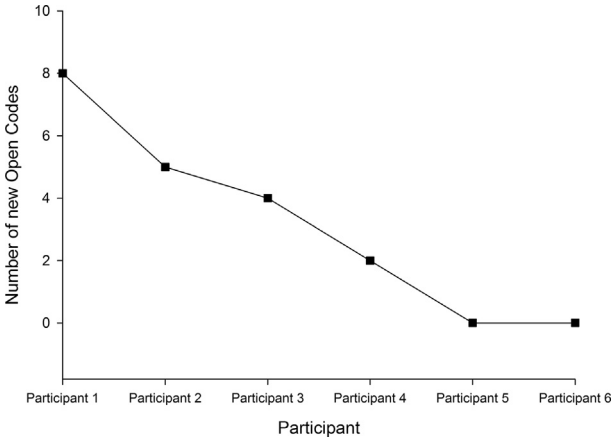


Fig. 6. Number of new codes as SME interviews progress.

codes, the independent reviewer then coded the 175 statements into the nineteen open categories (Table 1). Cohen's kappa (κ) indicated significant agreement between raters ($\kappa = 0.41$, SE ± 0.04, N = 175, $p < .01$). This level of agreement is characterised as fair to moderate being at the lower bound of the moderate agreement category: 0.41–0.60 (Landis and Koch, 1977). Discussion in respect of any disagreement was held and a final set of agreed codes was recorded. In many cases the wording of the codes was improved to ensure that the open codes captured the themes from the interview statements. Fig. 6 shows the number of new codes generated by each participant. The number of new codes fall rapidly to zero after the fourth SME which may reflect the highly specialised nature of the investigator role. We claim acceptable reliability of the study based on the absence of new code generation in the final two interviews (O'Reilly and Parker, 2012; Walker, 2012).

Following the open coding, axial and selective coding were conducted and agreed between the authors. Fig. 7 shows the agreed axial and selective codes and their explicit links to the independently rated open-codes. The selective codes represent the five general competencies that differentiate performance in the air accident investigator role.

4. Contextual narratives

To contextualise each of the top-level competencies, a vignette of why these competencies are important in the accident investigator role is described. In this section, each competency, corresponding to the selective code level, is narrated to calibrate reader understanding of the wider competency framework. In practice, these narratives could be applied to discussions which involve performance assessment, improvement or to simply start discussion as to the nature of the role itself.

4.1. Professional behaviours and characters

Investigators must be able to cope with uncertainty. Accidents are complex and happen without notice. Investigators must re-establish the context of an accident, recognising and managing hindsight bias while remaining curious and evidence-led. Investigators must have appropriate empathy. Investigators may be called upon to interview witnesses who have undergone traumatic experiences or be required to feedback difficult messages to individuals, organisations or regulators. Investigators must also develop resilience to manage the continuing and cumulative effects of fatigue, both emotional and physical.

Investigators must continuously develop and learn. Aircraft and technologies change and so do investigation techniques. For example modern aircraft use new materials such as composites, are increasingly digital and the training of both operators and maintainers continues to evolve. The tools and techniques available to the investigator continue to develop. For example recovery of non-volatile memory from flight data recorders or the use of laser scanning technology to capture accident sites. The need for currency is often dictated by the circumstances of a particular accident and therefore hard to predict and manage proactively; investigators need to identify and react to development needs rapidly and effectively.

4.2. Analytical and investigative approach

Investigators need to establish the 'what, why and what can be done' aspects of an accident in an evidence driven way. This is not just a knowledge based process that can be followed. Investigators should aim to 'break' hypotheses, looking for the anomalies rather than risking bias by collecting only corroborating evidence. Investigators must be open to discussion about potential explanations for accidents and actively solicit peer review. This openness to challenge extends to the ability to work in multidisciplinary international teams and to manage expert opinion. For example, an aircraft manufacturer may have the best knowledge about an aircraft but the independence of the process is paramount so that their input into the investigation must be managed carefully and transparently during the investigation.

4.3. Communication skills

Investigators need to communicate carefully and effectively to a wide range of individuals, organisations and audiences to ensure that their mission is fulfilled. For example, an investigation agency must produce a definitive report which ultimately informs society's view of the organisation's credibility and competence. Such reports are read by a variety of audiences: manufacturers, government agencies, operators, training organisations and other involved parties such as crew or passengers. These different stakeholders will have varying levels of technical skills and interests and formal reports need to take these differences into consideration. Conversely, different forms, styles and expertise are required when interviewing witnesses who may range from willing and able, to unwilling or unable. Accidents routinely have an international dimension. For example an airframe manufacturer powerplant manufacturer and operator who comprise a single flight may be from different countries. All of these stakeholders have the right to be involved in an investigation potentially bringing a variety of cultural influences to bear on the types and styles of communication demanded of the investigator.

4.4. Team working

Team working presents unique challenges to the accident investigation process. Teams are multidisciplinary, often multinational, convened at short notice. A large accident will require a large team, under pressure to understand and report initial findings. In addition to the complex team dynamics generated by the factors above, the investigative skills required demand the creation of opportunity for challenge and peer review often over a prolonged period of time.

4.5. Organisational focus and management skills

The credibility of an investigation agency is determined by appropriate organisational focus. The organisation must have an effective relationship with stakeholders to ensure messages are heard and change can happen. The organisation must be assured of a consistent approach to unique events. In other words being confident that regardless of which investigators of the team investigated the incident, they would find *the* answer as opposed to explanations bias towards experience or knowledge base. The application of standards and focus on the goals of the organisation must be matched with management skills at many levels. Investigators can have simultaneous responsibility for multiple,

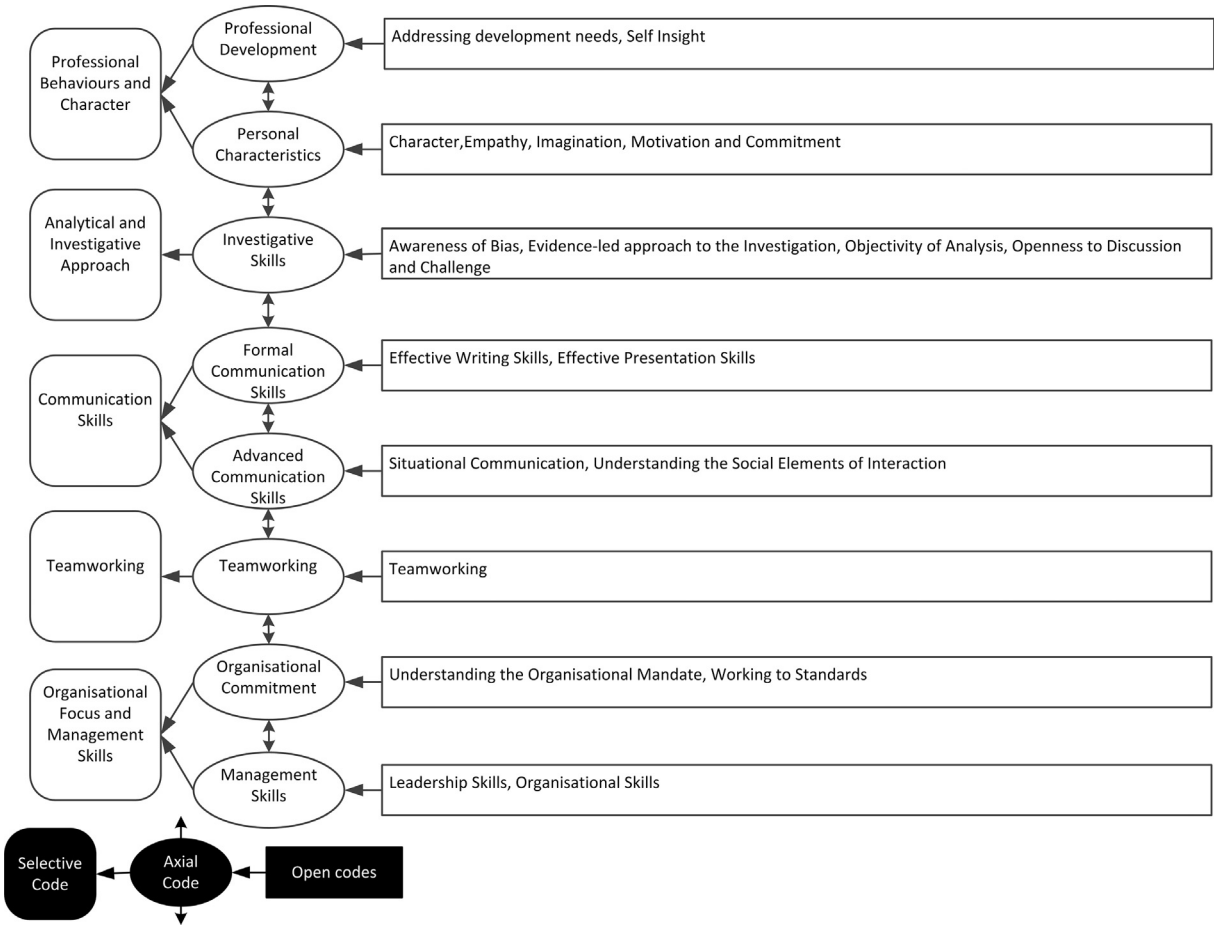


Fig. 7. Axial and selective codes derived from competency open codes.

dispersed sites maintenance hangers, ATC centres accident sites. Responsibility for the preservation of evidence and clearance of the site to allow businesses to continue also falls to the investigation agency. At a different level of management, stakeholders, relatives, witnesses, experts require effective management throughout the process which may include experienced participants to those who had no expectations that they would ever be involved such is the multifaceted and multi-disciplinary nature of the investigator role.

5. Discussion

In this article we have used structured methods to develop a detailed task analysis and a new competency framework for air accident investigators. Structured interviews with SMEs together with a grounded theory approach has generated the hierarchical competency framework. This framework can be interpreted and implemented at any of the constituent levels, depending on the requirements of the organisation.

We make tentative claims for construct validity of the competency framework proposed. The top-level competencies align well with the Great Eight which include leading, analysing and interpreting. This would be expected since the Great Eight are relevant to management and leadership roles more generally. Air accident investigation is a role with high autonomy and management demand. In addition the problem solving and evaluative demands placed on professionals described by Lester (2014) are also reflected in broader consideration of the competencies across the framework. Where the high level competencies differ is the greater focus on investigation and approaches to communication specific to the role. Given the high involvement of SMEs and the structured and exhaustive way in which the interview data has been collected, we claim content validity of the competencies identified. Braithwaite (2004) asked groups of trainee accident investigators what qualities were desirable in an investigator. These lists of words reported are again in broad agreement with our analysis: each word could be located in one or more of the competencies identified. Since these words and the qualities they described are from groups of accident investigators, this may evidence a degree of face validity in the elements of the framework proposed in this article. High face validity is an important component of user acceptance which is, in turn, an important element of transitioning a competency framework to the wider organisation (Campion and Odman, 2011).

When competencies are defined and narrated, this permits decisions to be made as to how best to measure the competencies. Measurement can be conducted for a number of reasons. Firstly, to select investigators for employment by an investigation agency. Bartram (2005) proposes a number of dimensions of the Big Five personality dimensions which load onto the Great Eight competency framework. For example, conscientiousness is associated with the Great Eight competency 'Organising and Executing'. The competency descriptor for organising and executing contains words which align with The high level competency 'Organisational Focus and Management skills ' and its subordinate descriptors in the framework presented here. The relationships between valid measures of personality and ability and competencies proposed by Bartrum could be formally evaluated and used to understand individual differences in the competencies described or to measure any improvement found in the competencies following training activities.

More challenging is the assurance of predictive validity based on the competency framework. Assuming reliable and valid measurement is possible, an individual with higher ratings on the competencies identified would be expected to be a better investigator. This is a very

demanding relationship to demonstrate empirically. Notwithstanding the challenges of measurement the definition of 'success' is multi-factorial. Not all accidents are treated in the same way as is demonstrated by the HTA analysis developed here. As we have reported in this article some occurrences demand the full suite of skills and others may focus on a smaller selection.

Campion and Odman (2011) in their detailed review suggest that competency frameworks can be employed to deliver a wide range of organisational activities and goals. These activities and goals include selection, evaluation, training, promotion, development, compensation, retention, support and the management of employee information. Certainly, our own key exploitation route for the framework identified is the specification and development of education for professional accident investigators. Since 2003 the second author (GRB) has led the training and development of air, marine and rail accident investigators from all over the world. In addition to the practical skills and knowledge required of the investigator, the development of the competencies described in this article can effect transition from the good to the great investigator.

Catano et al. (2007) describes ways in which a competency framework can be exploited to inform promotion and performance appraisal. In a case study, Cantano et al. describe a promotion process in the Royal Canadian Mounted Police (RCMP) whereby candidates evidence competencies through examples drawn from their own professional practice. In addition, the authors describe an SME led process where behavioural anchors are specified and agreed against the competencies. These anchors which are directly related to the competency framework, can then be rated by peers or supervisors to discriminate performance.

The use of grounded theory has been most helpful in the generation of a working competency framework. The coding technique used in grounded theory creates explicit and traceable links between the raw interview data and the subsequent interpretation and analysis in the model, preserving the transparency of the analysis. The exhaustive interview technique applied from repertory grid interview technique has generated reliable data that is amenable to the structured layers of codes demanded by the grounded theory technique. This structured approach has produced an elegant hierarchy which can be employed at any of the levels. For example, if specifying behaviours, the open codes level would be most appropriate to use given the higher level of detail and the lower level of abstraction. Alternatively, the higher levels could be employed as an effective lexicon to describe the role and inform discussion at a strategic or organisational level.

A key limitation of this work is the sole employment of UK based investigators as SMEs. While acknowledging that ICAO sets international standards, the focus on UK investigators must be considered if generalising the research. The narratives relating to the competencies have been developed by the authors who may consequently bring a Western European perspective to the research. Application, measurement and the definition of success may change in different cultural contexts, albeit under an overarching international standard for air accident investigation.

Although we have focused our analysis on air accident investigators, many safety critical industries formally employ investigators who work to resolve the causes of accidents and occurrences. Examples include the marine, rail and most recently in the UK, the healthcare sector. We suggest that the competencies that we have proposed are common to accident investigation regardless of the domain of investigation. For example, the investigation agencies of the sectors described are all mandated to improve safety through understanding the causes of accidents. All agencies demand interaction between the public, families, authorities and regulators. All agencies demand effective and impartial investigation to improve safety. All agencies demand written reports.

Further work in which we are currently engaged is to develop ways in which the competencies identified can be better developed and measured during investigator training. In this way, we are convinced that better accident investigators can be trained, educated and developed who will have a continuing positive impact upon the already excellent safety record in aviation (International Air Transport Association, 2016). We hope that the development of this competency framework and the associated task analysis can at least structure renewed efforts to respond to Ken Smart's original challenge on the assessment of an investigators personal qualities and continue to improve safety in the aviation domain and beyond.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ssci.2017.11.017.

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