The Role of Communication in Aviation Maintenance and its Relation to Trust

A Thesis submitted by

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ABSTRACT

Aviation researchers have only recently started to study factors not individually, but rather by combining their effects. A gap has been identified following a comprehensive review of the literature on trust and the combined traits of communication and trust in aviation maintenance. This research examines two preconditions of human error in aviation maintenance, communication and trust, and explores the way these are linked. Trust within different aspects of maintenance practice (interpersonal trust, trust towards technology, initial levels of trust) is presented and analysed, as well as examined as a prerequisite of effective communication. The aim of this study is to address the identified gap by investigating the existence of communication and trust in real life aviation maintenance occurrences. A Communication and Trust Question Set, comprising of questionnaires used in other industries, was devised to measure the relationship of communication and trust among aviation maintenance employees belonging to various groups. A thorough content analysis was performed in representative accident and incident investigation reports to identify the co-existence of communication and trust as preconditions in aviation maintenance occurrences. The results indicated that both communication and trust had a contribution to all maintenance occurrences and were prevalent issues in the reports examined. In addition, the content analysis method was applied to the aviation maintenance human factors training curriculum and material (coursebooks) used within the European Aviation Safety Agency regulatory framework. This analysis revealed the indirect existence of trust in the curriculum and the coursebooks, without direct mention to these factors. Based on indications that, in concert with trust, communication can also influence the detection of failures during aviation maintenance practice, an industry survey was conducted. This survey was conducted on 271 aviation maintenance professionals with the use of the Communication and Trust Question Set, intending to explore the association between three factors, communication satisfaction, interpersonal trust and trust towards maintenance software used in aviation maintenance companies. Overall, communication satisfaction was found to have a stronger association with interpersonal trust than with software trust. Thorough explanation and discussion on the significant differences among the different participants' groups is provided. An interesting finding is that aviation maintenance professionals have relatively high levels of trust and communication satisfaction at the start of their current employment. This finding is consistent with the initial trust levels theory, examined in the past for other industries. A novel Conceptual Investigation Process has been developed on the basis of the study's methodology, with the objective to predict possible maintenance practice deviations in a causal relationship with communication and trust. The blending of the Conceptual Investigation Process with the multifunctional Communication and Trust Question Set tool has led to the conception of the Diagnosis of Communication and Trust in Aviation Maintenance (DiCTAM) model. The DiCTAM model is implemented through a hypothetical case study of possible aviation maintenance deviations. These results indicate the capability of the model to predict hypothetical maintenance deviations by using data collected from the target group's perceptions. Moreover, as examined, DiCTAM can be embedded within three out of four components of Safety Management Systems (SMS), safety risk management, safety assurance and safety promotion.

CERTIFICATION OF THESIS

This Thesis is entirely the work of Anna Chatzi except where otherwise acknowledged. The work is original and has not previously been submitted for any other award, except where acknowledged.

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Student and supervisors' signatures of endorsement are held at the University.

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LIST OF ABBREVIATIONS

AAIUI - Air Accident Investigation Unit Ireland

AAIB - Air Accidents Investigation Board (UK)

AD - Airworthiness Directive

ADR - Air Data Reference

ADIRU1 - Air Data Inertia Reference Unit 1

ADIRU2 - Air Data Inertia Reference Unit 2

AIB - Accident Investigation Board

AF - Air Force

AFS - Arline Fleet Support

AFMS - Airplane Flight Manual Supplement

AIATSL - Air India Air Transport Services Limited

AID - Accident Investigation Division (Hong Kong)

AIESL - Air India Engineering Services Limited

AMM - Aircraft Maintenance Manual

ARM - Aviation Resource Management

ASAP - FAA’s Aviation Safety Action Program

ATC - Air Traffic Control

ATM - Air Traffic Management

ATSB - Australian Transport Safety Bureau

ATPL - Airline Transport Pilot License

BEA - Bureau d’Enquêtes et d’Analyses pour la sécurité de l’aviation civile

BITE - Built-in Test Equipment

CAD - Civil Aviation Department, Hong Kong, China

CAP - Hong Kong Civil Aviation (Investigation of Accidents) Regulations

CASA - Civil Aviation Safety Authority

CB - Central Battery

CFDS - Centralised Fault Display System

CIT - Communication Incident Technique

CPA - Pacific Airways Limited

CPL - Commercial Pilot

CTK - Composite Took Kit

DGAC - Direction Générale de l'Aviation Civile

DGCA - Directorate General of Civil Aviation (India)

DFDR - Digital Flight Data Recorder

DP - Dewpoint Temperature

DSB - Dutch Safety Board

EASA - European Aviation Safety Agency

EM - Emission

ETOPS16 - Extended Range twin Engined Operators 16

EU - European Union

FCD - Fan Cowl Doors

FCM - Flight Control Module

FMU - Fuel Metering Unit

GE - General Electric

GPIAAAF - Gabinete de Precenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviarios (Portugal)

HPE - Human Performance Envelope

IDG - Integrated Drive Generator

ICAO - International Civil Aviation Organization

JFK - John Fitzgerald Kennedy

JTSB - Japan Transport Safety Board

KNKT - Komite National Keselamatan Transportasi (Republic of Indonesia)

LAME - Licenced Aircraft Maintenance Engineer

LH - Left hand

FAA - Federal Aviation Administration

FAC - Flight Augmentation Computer

MA - Mishap Aircraft

MC - Mishap Crew

MEL - Minimum Equipment List

MLG - Main Landing Gear

MM1,2,3,4 – Mishap Maintainer 1,2,3,4

MMV - Main Metering Valve

MOSS - Maintenance Operations Safety Survey

NLR - Netherlands Aerospace Centre (Nederlands Lucht- en Ruimtevaartcentrum)

MR1 - Maintenance Report 1

MR2 - Maintenance Report 2

MRM - Maintenance Resource Management

NPRM - Notice for Proposed Rule Making

NTSB - National Transportation Safety Bureau (USA)

OGMA - Indústria Aeronáutica de Portugal S.A.

PFR - Post Flight Report

PIC - Pilot in Charge

QMS - Quality Management System

RH - Right Hand

RPM - Revolutions Per Minute

RTLU - Rudder Travel Limiter Unit

SA - Situational Awareness

SD - Standard Deviation

SARP - Standards and Recommended Practice

SBAR - Situation, Background, Assessment and Recommendation

SMM - Safety Maintenance management

SMS - Safety Management System

SOP - Standard Operating Procedures

TO - Technical Order

TOS - Turbine Overhaul Services

TSM - Trouble Shooting Manual

VMC - Visual Meteorological Conditions

UK - United Kingdom

USA - United States of America

USAFIB - United States Air Force Accident Investigation Board (Military Aviation USA)

WARR - Juanda International Airport, Surabaya, Indonesia

CHAPTER 1 INTRODUCTION

1.1 Introduction

To err is within human nature. However, it is primarily over the last 50 years that human error has become a field of scientific research, as errors have started to have a greater global impact on economies, health, environment and communities. In the US alone, from over $300 billion spent on maintenance and operations every year, 80% was spent repairing damage caused by human error in equipment, systems and dealing with harm caused to people (Dhillon & Liu, 2006; Reason, 1997). In 2014, there were 648 fatalities in 14 accidents caused by human error. This number was 1.5% higher than the previous 10-year average. This increase was the result of larger aeroplanes with higher passenger capacity (European Aviation Safety Agency, 2015), therefore since human error has led to greater human loss, there is a necessity within the aviation community to address this issue.

A better understanding of human factors has become imperative within aviation, and several models and systems have been introduced and implemented in the continuous attempt to predict and reduce human error. In aviation maintenance, there are twelve factors identified as the principal preconditions or conditions, that contribute to human error, widely known as the Dupont's *Dirty Dozen* (Blaise, Levrat, & Iung, 2014; Chang & Wang, 2010; Dupont & G, 1997; Flin, O'Connor, & Mearns, 2002; Marquardt, Gades, & Robelski, 2012; Wise, Hopkin, & Garland, 2010).

These elements (illustrated in Figure 1.1) are dissimilar in nature and appear either on personal, group or organizational performance levels (Reiman, 2011). Communication is among these 12 most frequent causes of human error.

Figure 1.1 Dupont's Dirty Dozen.

Lack of Communication	**Complacency**	**Lack of Knowledge**	**Distractions**
Lack of Teamwork	**Fatigue**	**Lack of Resources**	**Pressure**
Lack of Assertiveness	**Stress**	**Lack of Awareness**	**Norms**

These twelve factors are described briefly below:

1. **Lack of communication:** Lack of communication (due to ineffective communication between aircraft maintenance professionals) can result in maintenance error which can be potentially responsible for an aviation incident or accident.
2. **Complacency:** The calm feeling of being very familiar and possibly false self-confidence with a task, and not needing to double check, question or try one's best over it. An aviation professional might experience complacency during repetitive tasks while having established an overreliance on his/her relative abilities.
3. **Lack of knowledge:** The lack of the required set of information/data for the successful completion of an aviation maintenance task. Updates in technology and procedures require aircraft professionals to keep their knowledge up to date.
4. **Distractions:** Any mental or physical disruptions in the work of an aircraft maintenance professional. These distractions might prevent maintenance professionals from attending accurately to their work, possibly resulting in a maintenance task process error.
5. **Lack of teamwork:** Many maintenance tasks require professionals to work in teams. In the instances that these teams fail to establish mutual understanding and cooperation, there is a significant risk of a maintenance error occurring.

6. **Fatigue:** Fatigue can affect the performance of aviation maintenance professionals. Relevant training is necessary to promptly recognise symptoms of physical tiredness, mental or emotional fatigue in oneself or colleagues.
7. **Lack of resources:** Resources can be accounted as anything required by aircraft maintenance professionals to perform their duties successfully (time, personnel, equipment). Any deviation from the optimal amount might lead to an error-prone situation.
8. **Pressure:** This precondition refers to the management-imposed expectations or self-induced pressure for prompt and flawless employee performance.
9. **Lack of assertiveness:** Assertiveness is the ability to express one's opinion and feelings confidently in a constructive and collaborative way. A lack of this quality may lead to maintenance errors as it can leave maintenance deviations undetected.
10. **Stress:** This precondition has physical and psychological causal conditions and can affect work performance.
11. **Lack of awareness:** The failure to be able to foresee all possible consequences by one's actions.
12. **Norms:** The unwritten rules set and followed by the employees of an organisation. These rules can be either in accordance or not with the organisation's policies and can lead to unsafe practices and procedures.

The *Dirty Dozen* is one of the most used human factors typologies in aviation maintenance, as it is still used in training and accident and human error analysis in aviation worldwide (Blaise et al., 2014; Chang & Wang, 2010; Federal Aviation Administration, U. S. Department of Transportation, & Flight Standards Service 2011; Flin et al., 2002; Marquardt et al., 2012). These 12 factors are of different nature and quantifiability; nevertheless, each one of them represents a causal failure in the user's judgement, and as such, they are treated either individually or in homogeneous groups (Marquardt et al., 2012).

Researchers still investigate the same elements under a new perspective. As a most recent example, the European Union (EU) joint research program 'Future Sky Safety' aims to study the concept of the Human Performance Envelope (HPE) in aviation. This research is investigating the interactions between nine human factors (stress, attention, situation awareness, vigilance, teamwork, workload, communication, trust, fatigue) and the pilot's performance, including how they work individually or in combination, and how they affect or degrade human performance (Silvagni, Napoletano, Graziani, Le Blaye, & Rognin, 2015).

Communication has been indicated by past research to have a strong association with trust (Whitener, Brodt, Korsgaard, & Werner, 1998). Trust is a very important element in human social life and, therefore, has been researched extensively in the past by many different scientific disciplines (Hernandez & Santos, 2010). Numerous researchers agree that trust is a very important element in the employees' relations and it is associated with the quality of their communication (Bachmann, 2003; Carrière & Bourque, 2009; Cascio, 2000; Cho & Park, 2011; Flin, 2007; Muchinsky, 1977; Shapiro, Sheppard, & Cheraskin, 1992; Yeager, 1978). However, trust is an under-investigated trait in aviation (Flin, 2007), as discussed in detail in this study. Moreover, the association of trust with communication is an unexplored area, especially in the aviation maintenance research and practice field.

1.2 Aim of the Study

The aim of this study is to identify the existence of a relationship between communication and trust in the aviation maintenance environment. There are two types of trust to evaluate: trust towards colleagues (interpersonal trust) and trust towards technology (Jian et al., 1998; Li, Hess, & Valacich, 2008; Ockerman & Pritchett, 2000). To that end, this research explores if and to what extent the aircraft maintenance personnel's interpersonal trust and trust towards their company's software is associated with the quality of their communication in the performance of maintenance tasks. One other aspect, which is very interesting to investigate for the first time, is whether the theory of high initial trust levels is also detectable in the aviation sector. Identifying the unknowns around communication and trust in aviation maintenance practice can be useful in addressing known safety shortfalls attributed directly or indirectly to these factors. This puts into the picture basic aviation maintenance training on communication and trust. Thus, the examination of the regulated curriculum and approved training material has also been targeted by this research. Overall, the concise examination and analysis of all these components is expected to offer findings, conclusions and a systematic approach useful to the human factors scientific community and the aviation industry.

1.3 Research Questions and Hypotheses and the Study's Scope

Two research questions and four research hypotheses have been formed to address the aims set for this study:

Research questions:

- ***Research Question 1:*** Are trust and communication detectable in aviation maintenance?
- ***Research Question 2:*** Are communication and trust covered in aviation maintenance human factors basic training?

Research hypotheses:

- ***Research Hypothesis 1:*** (a) Aviation maintenance employees' levels of interpersonal trust towards their colleagues have a positive association with their communication satisfaction and (b) supervisors/managers' levels of interpersonal trust towards their subordinates have a positive association with their communication satisfaction.
- ***Research Hypothesis 2:*** (a) Employees' trust towards the company's software has a positive association with their communication satisfaction and (b) supervisors/managers' trust towards the company's software has a positive association with their communication satisfaction.
- ***Research Hypothesis 3:*** (a) Subordinates' levels of interpersonal trust has a positive association with their communication satisfaction and (b) subordinates' trust towards the company's software has a positive association with their communication satisfaction.
- ***Research Hypothesis 4:*** High initial trust levels are detectable in (a) interpersonal trust and (b) company's software trust to newly recruited maintenance employees.

1.4 Thesis Structure

Chapter 1 introduces the background, the subject of this research study, including the research questions and hypotheses, and provides an overview of the Thesis.

Chapter 2 provides a comprehensive review of the relevant literature in the aviation maintenance industry. Both communication and trust have been critically and thoroughly investigated in the extended literature that covers both traits. The most critical aspects of both theories have been covered in chapter one, while the focus has been on the review of the research (regarding communication and trust) that has been conducted in the aviation maintenance sector. This critical literature review process has identified the gaps to address next in this study.

In Chapter 3 the study methodology is presented. It presents in depth the worldview that governs this whole research project along with the different methods and techniques used. The method chosen as the most appropriate in this study is a mixed-methods analysis. Both qualitative and quantitative designs have been used to analyse the project’s data. Content analysis of accident and incident investigation reports (using tabulation and descriptive statistics from fifteen reports), content analysis of aviation human factors training curriculum and material (using manual word count technique and descriptive statistics) and a survey method (using correlational research design to treat data out of 271 participants) have been conducted.

In **Chapter 4**, all results from the content analyses (from the accident and incident investigation reports and the aviation maintenance human factors training curriculum and material) and the survey method analysis (of the hypotheses testing and additional observations from the data) are presented in a thorough and comprehensive way. Each subchapter includes discussion on the results found.

In **Chapter 5**, the link among communication, trust and aviation safety is discussed. The recognised importance of the contribution of communication and trust in aviation safety has led to the formation of a novel Conceptual Investigation Process. The Conceptual Investigation Process incorporating the multifunctional tool Communication and Trust Question Set, forms the new Diagnosis of Communication and Trust in Aviation Maintenance (DiCTAM) model. The DiCTAM model is able not only to predict possible maintenance practice deviations in a causal relationship with communication and trust, but also with any other human factors traits under examination. In this view, further qualitative investigation is performed (case study using tabulation, Airbus A320 family Fan Cowl Doors Incidents) of possible aviation maintenance deviations. The methodology of the case study is provided in full detail while a full discussion and conclusion is provided as well. Moreover, the embodiment of the DiCTAM model is examined within Safety Management Systems, towards enhancing safe practice within the aviation maintenance environment.

In **Chapter 6**, a full discussion is provided on the results of the methods and all research questions and hypotheses are answered based on the results.

In **Chapter 7**, the conclusions of the study are presented, with further research suggestions to be addressed by other human factors researchers. Also, the limitations of this study are discussed here.

CHAPTER 2 LITERATURE REVIEW

2.1 Basic Communication Theory

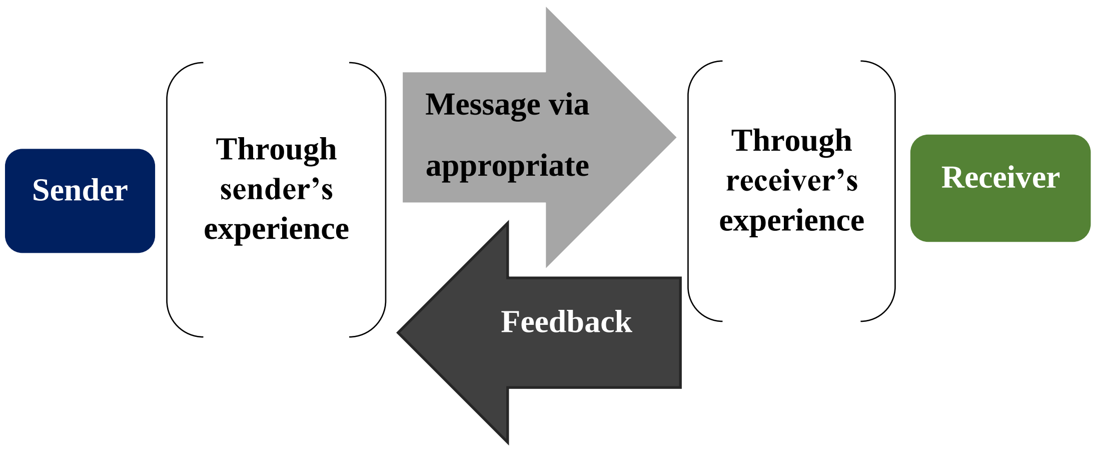
Communication is a field of study that is of interest across many disciplines, including marketing and computer science. Communication is a process that involves everyone in their everyday life. However, defining communication has been challenging. There have been many definitions of communication in textbooks and different approaches through the years, beginning with Shannon and Weaver (1949) as they studied the transmission of messages in communication (Fiske, 1990).

Communication has been frequently defined with different phrases depending on the different approaches and discipline of each researcher. In some definitions there is emphasis on the significance of symbols, as in "the transmission of information, ideas, emotions and skills…by the use of symbols" (Berelson & Steiner, 1964, p.527), while others examine communication as a product e.g. "We use the word 'communication' sometimes to refer to what is transferred, sometimes to the means by which it is transferred, sometimes to the whole process" (Ayer, 1955, p.13).

In the study of communication there are two main streams. One stream considers communication as *the transmission of messages* and the other as *the production and exchange of meaning* (Fiske, 1990). In the *transmission of the message* stream, the member that sends the message is the sender, and the one who accepts it is the receiver. Communication, to be effective, must be an active process where both the sender and the receiver/s assure that the intended objectives are met. To achieve that, both the coding and the decoding process of the message along with the channel and/or medium of communication, are very important to its success. If the result is not the anticipated one, then the communication process is characterised as *failed,* and then the communication steps are investigated to identify the cause of this failure (Fiske, 1990). The second stream, the *production and exchange of meanings* deals with the interaction between any messages and people and the meaning that comes out of this interaction. In this stream, connotation is a term that is usually met. Also, misunderstandings, besides being a result of a failure in communication, may be due to cultural differences between the sender and the receiver (Fiske, 1990).

According to Schramm (1954) very important elements that should be added to the communication process are the sender's and receiver's experiences. The mode of communication chosen should be the appropriate one to meet the circumstances of both the sender and the receiver. The sender proceeds with the message coding based on his/her experience while the receiver understands the message by connecting it to his/her prior knowledge / cognitive level. Then the sender needs to assure that the message has been transmitted correctly by evaluating the receiver's feedback (Schramm, 1954) as shown in Figure 2.1.

Figure 2.1 Schramm's Communication Model with feedback.



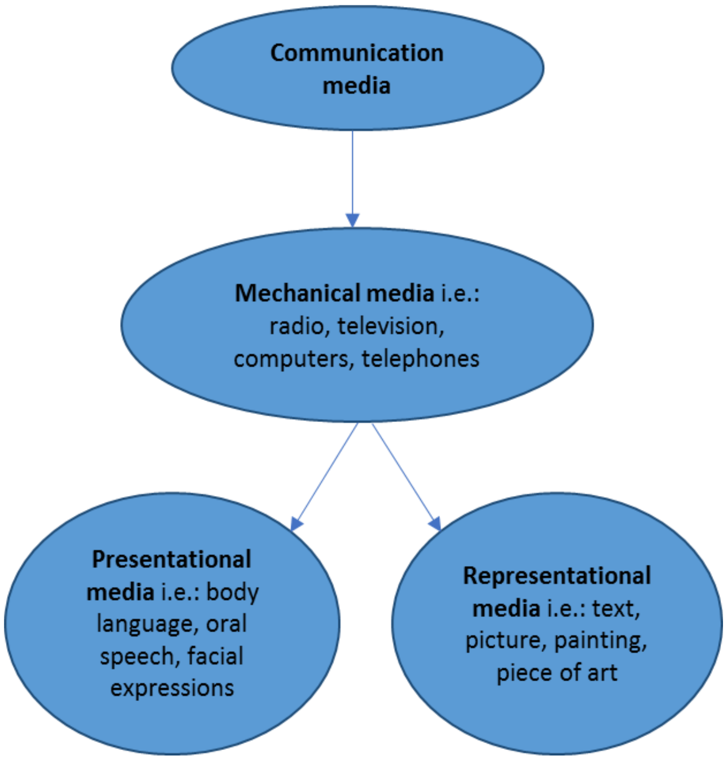
To understand the communication theories fully, the definitions of the terms: channel, code and medium are necessary. Channel is the means through which information flows (Duncan & Moriarty, 1998). Examples of channels are light waves, sound waves and radio waves. Medium is the material or mechanical way of transforming the message into a signal capable of being passed on along the channel. Coding is the sharing of mutual meaning between members of the same culture (Fiske, 1990).

The basic features of the chosen channel determine the nature of the medium that will be selected. Next, this medium will determine the characteristics and the range of the codes that will be used to transmit the message. Fiske (1990) further suggests that media can be divided into three categories, as seen in Figure 2.2:

- The presentational media. The body language, oral speech, the facial expressions are providing communication. This requires the physical presence of the communicator as he/she is the medium and communication happens in real time.

- The representational media. Any medium that represents the above by the production of a text, picture, painting, piece of art. These media do not require the presence of the communicator as they can act independently.
- The mechanical media. These media utilize technologically developed channels; therefore, they are transmitters of the presentation and representation media. Examples are radio, television, computers, telephones.

Figure 2.2 Concept map of communication media.



Given that communication is effective and complete it can a) be beneficial to staff's interpersonal and group relationships; b) guarantee that attitudes and expectations will be clear with no hidden agendas; c) retain focus on the task and situational awareness; and d) act as a managing tool (Kanki, Helmreich, & Anca, 2010).

2.1.1 Miscommunication

To understand and define communication, researchers needed to clarify miscommunication as well. It is difficult to investigate communication and miscommunication separately as they are strongly interrelated. Miscommunication is treated as a kind of communication with its own distinct patterns and characteristics (Anolli, Ciceri, & Riva, 2002). In this context, miscommunication can be defined as ‘the dark side of interpersonal communication (Parret, 1994) not being too far from its standard meaning of missing, flaw and disruption of the rules of communication (Mortensen, 1997).

Furthermore, miscommunication includes ‘mismatching interpretation’ and distortion of the message (Anolli et al., 2002). This definition also includes the potential cultural differences between the sender and the receiver which are responsible for possible alternative interpretative models. Miscommunication, in the condition that it is noticed and attempted to be repaired, has a positive outcome on the communication process as well, as it provides a chance for further interaction between the communicators. Miscommunication has been included in several communication theories, e.g. Shannon & Weaver (1949) through the years as a deviation or a disruption, either important or less important, at any stage of the communication process (Anolli et al., 2002).

In the aircraft maintenance environment, a model of communication fault was developed by Shukri, Millar, Gratton and Garner (2016) that was inspired by Cushing’s (1994) detailed communication between a pilot and an air traffic controller failure overview. In this model there are six message characterisations: “a) A message that is unavailable; b) A message that is available but incomplete; c) A message that is available, complete but incorrect; d) A message that is available, complete, correct but not clear; e) A message that is available, complete, correct, clear but not understood; f) A message that is available, complete, correct, clear, understood but mistakes still happen due to human factors” (Shukri et al., 2016).

From this model, it is evident that even if the message is free from all the failure-prone factors, there is still the possibility of mistakes. Subsequently, all the specialists' efforts lead to the direction of the elimination of the known or predictable factors that can lead to a fault and the constant attempt to identify and eliminate the uncharted ones.

Therefore, in the case that communication for one or more reasons does not result in the correct exchange of the message, the beneficial effects are not fully realised.

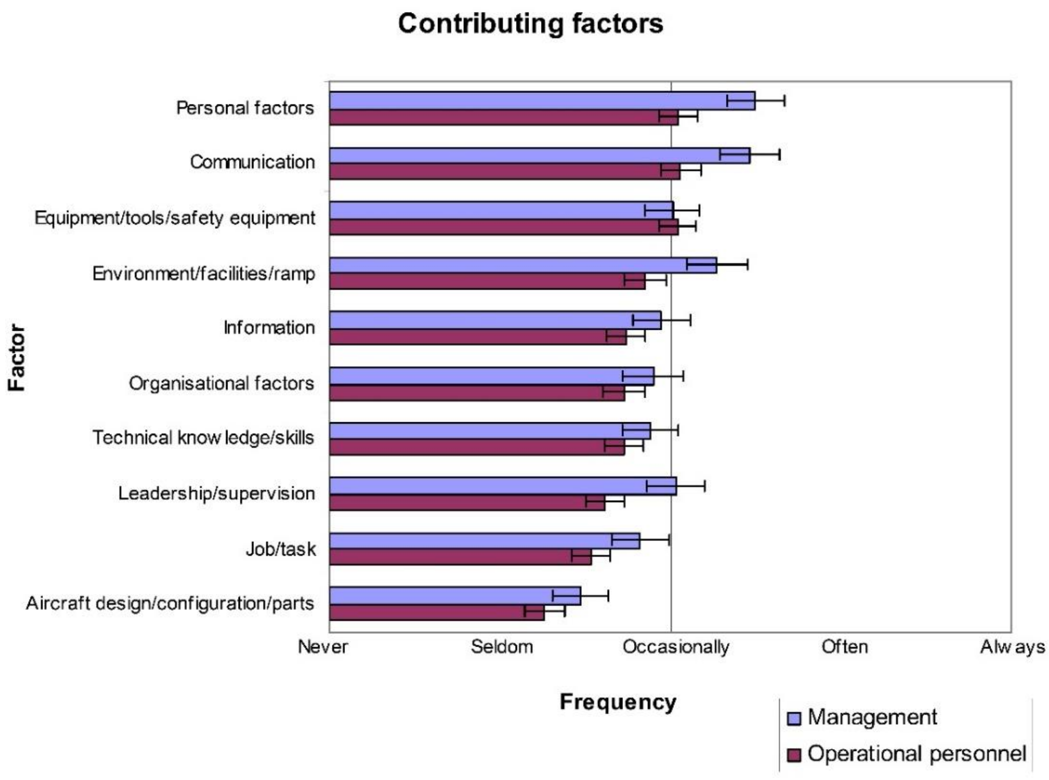
The contribution of communication to the occurrence of human errors stems from various reports. Human error can be tagged as “the human causal factor associated with aviation accidents” (Wiegmann & Shappell, 2003) or “the failure of planned actions to achieve their desired ends—without the intervention of some unforeseeable events” (Reason, 1997). A study commissioned by the Dutch Aerospace Research Centre (NLR), identified various contributory factors to aircraft accidents, incidents and errors. In seven ground service providers in the Netherlands, both management and operational personnel named the ten most frequent factors that are involved in the cause of mistakes on the ramp (see Figure 2.3). Poor communication is the second most prevalent factor on that list (Balk & Bossenbroek, 2010).

Ineffective communication is an important precondition for human error in all highly complex and regulated industries worldwide (Cushing, 1994). Extended research in aviation has shown that human factors cause 70-80% of aviation incidents at the front end, and 15-20% of them occur in maintenance procedures (Drury, 2000; McFadden & Towell, 1999). The aviation sector was the first to identify that the implementation of standardised procedures has contributed to safety and teamwork efficiency (70% of commercial flight accidents were caused due to communication errors between crew members) (Leonard, Graham, & Bonacum, 2004).

Another large study in the aviation industry found that 70% of all accidents were caused due to crew coordination and communication issues (Lautman & Gallimore, 1987). These findings are supported by Wiegmann & Shappell (1999) and Yacavone, (1993) as they have recognised crew coordination to be a major contributing factor in military aviation (as cited by Wiegmann & Shappell, 2012). Failed communication has also been reported to be the second most frequent local factor in airworthiness events (Rail Safety Standards Board, 2003). As a comparison, in railway maintenance, it has been shown that 92% of incidents occurred due to communication failures (Murphy, 2001; Rail Safety Standards Board, 2003). In the healthcare industry communication is among other common elements prone to mistakes as well (Leonard et al., 2004). Subsequently, healthcare had as well the need for standardisation of the communication tools due to its complexity, the limitations of human performance and the different training amongst the medical professionals. For that purpose, tools like SBAR (Situation, Background, Assessment and Recommendation) were introduced for all medical personnel as a means to establish common terminology and methodology to avoid any communication failures (Leonard et al., 2004).

The European Commercial Aviation Safety Team (ECAST) has acknowledged the awareness of the potential risk of ineffective communication as a human factor and that further research is necessary towards that direction (Balk & Bossenbroek, 2010). Of note are the results of a survey conducted by Balk & Bossenbroek (2010) on aviation staff working on the ramp, as illustrated in Figure 2.3. In particular, it was found that management's awareness is at higher levels than the line personnel's, suggesting that the administration has recognised these factors to be the causal preconditions of human errors.

Figure 2.3 Contributing factors for errors, as perceived by aviation staff working on the ramp.



(Balk & Bossenbroek, 2010)

Moreover, various researchers have highlighted the problem of ineffective communication between maintenance staff, cabin crew and flight crew, proposing different ways to mitigate this issue (Caldwell, 2005; Mattson, Petrin, & Young, 2001). It is evident from the above that communication is a very important element within complex industries like aviation.

An example in which maintenance communication was involved in an aircraft accident, is the Atlantic Southeast Airlines flight 529 in August 1995. The accident occurred in Georgia, United States of America (USA), during an emergency landing, after the loss of a propeller blade, resulting in 9 casualties and 20 injuries. The National Transportation Safety Board (NTSB) determined that "the probable cause of this accident was the in-flight fatigue fracture and separation of a propeller blade resulting in distortion of the left engine nacelle, causing excessive drag, loss of wing lift, and reduced directional control of the aeroplane. The fracture was caused by a fatigue crack from multiple corrosion pits that were not discovered by Hamilton Standard because of inadequate and ineffective corporate inspection and repair techniques, training, documentation, and communications." (National Transportation Safety Bureau, 1996). The NTSB in this report highlighted as a contributing factor the internal inadequate communication and documentation systems of the aeroplane’s manufacturer (Hamilton Standard) that led maintenance personnel to confusion and faulty procedures.

Even though aviation was the first industry to regulate and implement human factors policies and guidelines, the need for new research and procedural improvement is continuous and arduous. In the occurrence of any new procedure introduced, new research over the possible reasons for a failure of the new system or its human element towards its failure must be applied. Moreover, the continuous effort to make communication in aviation effective has led to the observation and understanding of all aspects of human expressions. Different modes of expression, such as politeness (Bonnefon, Feeney, & De Neys, 2011), are under review by human factors specialists, in their attempt to promote clarity and minimise miscommunication at all levels.

2.1.2 Aviation Maintenance Areas prone to Communication Failure

In aviation maintenance, one critical aspect is documentation. The most common reason for accidents in aviation is insufficient documentation and procedures (Taylor & Thomas, 2003b; Von Thaden, Wiegmann, & Shappell, 2006; Ward, McDonald, Morrison, Gaynor, & Nugent, 2010). More recent studies indicate that written communication can be more prone to mistakes than oral communication in critical maintenance communication. The reason is that in oral communication, clarification is easier to obtain, so fewer human errors which affect aircraft safety, are detected (Shukri et al., 2016).

The improvement of maintenance documentation can establish communication as an important factor that could have a positive contribution to the execution of maintenance tasks safely (Sogg, 2002; Taylor & Thomas, 2003b). Written procedures govern every action in aircraft maintenance. These are manufacturers' Instructions for Continued Airworthiness (ICA's) and Fault Isolation Manuals and all supporting documentation that are continually updated. Also, as the aircraft design is evolving fast and becoming more sophisticated, they expand in volume. All this immense amount of documentation amendments and novelty must be adopted simultaneously by maintenance personnel around the world, even if their first language is not the one the documentation was produced in (Drury, 2010, 2013), typically English.

Moreover, there is extensive research in the development and improvement of online platforms, that aim to replace workcards, targeting lower cost along with positive impact on the engineers' situational awareness, error probability, job satisfaction, adaptability (Kraus & Gramopadhye, 2001; Liang, Lin, Hwang, Wang, & Patterson, 2010). Another example is that of an FAA 3-phase sponsored study that dealt with an improved design of the manufacturer's maintenance documentation enabling the transfer of information to the maintenance personnel at a satisfactory level (Chaparro & Groff, 2002).

Many researchers have produced instructions and guidelines, following human factors principles, to help maintenance staff avoid mistakes. Their research has been successful in reducing human errors (Chervak, Drury, & Ouellette, 1996; Drury, 2013). However, the people in charge do not always acknowledge this work by implementing it in the field (Karanikas, Soltani, de Boer, & Roelen, 2016). They usually persist in following their own former good experience and the employees' perspective rather than adopt guidelines and instructions that stem from research (Chaparro & Groff, 2002).

Shift turnover is of great significance in highly complex and regulated business environments such as aviation maintenance, the oil industry and medicine. According to Parke and Kanki, from the 8% of aircraft maintenance failures that were due to communication factor, 51% were related to shift turnover while 41% had no relation to it (Parke & Kanki, 2008). The turnover related maintenance occurrences were classified, by the reporting system used for this research, to have more severe and dangerous consequences (Parke & Kanki, 2008). These results indicate that debriefs conducted according to human factors principles, can enhance productivity by 20 – 25% (Tannenbaum & Cerasoli, 2013). While debriefs may appear to be cost-effective and produce quick results in the organisations' improvement of performance, the study of such processes over the years is scattered across different disciplines with no conclusive results (Tannenbaum & Cerasoli, 2013).

The literature above highlights that communication in the aircraft maintenance environment provides several considerations. An element that underlies every phase of the aircraft maintenance process, a primary element of the maintenance process, as it is the framework upon which information transmission takes place, the research community and the industry need to proceed with further investigation on the structure of documentation and shift turnover procedures.

2.1.3 Communication in Aviation Training

The training framework in aviation is designed to enhance communication skills and techniques, promote teamwork, accommodate human performance tools and develop and evolve situational awareness among maintenance personnel. This is an indicator of the way that the aviation industry values communication, acknowledges it as an important contributing factor of human error and takes actions towards its successful application within the various aviation activities. This training is either called Crew Resource Management (CRM) or Maintenance Resource Management (MRM) (Patankar & Taylor, 2008; Salas, Burke, Bowers, & Wilson, 2001; Taylor & Patankar, 2001).

As the literature indicates: a) training is essential in enhancing elements such as successful communication and indeed has good results; b) the design of training, the delivery and its implementation is of great importance in achieving the required results in areas such as communication (Lappas & Kourousis, 2016; Salas, Tannenbaum, Kraiger, & Smith-Jentsch, 2012; Taylor & Thomas, 2003b). To define the success of training in promoting factors such as communication, more 'on the job' observation of the participants is needed, given that most of the research has been conducted in simulation (Karanikas, 2013; Kirkpatrick, 1998; Salas et al., 2001).

In the European Union (EU), there is a 30 million Euro program (Future Sky Safety 2015-2019) that explores all new tools and approaches to aviation safety. This research, among other issues, indicates that a significant gap has been recognised between the quality of the students' oral and written communication skills gained during their studies (especially in the aeronautical area) and the skills required by the aeronautical industry to perform the tasks safely (Ribeiro & Filipe, 2016). Industry and academia do not work together as the communication between them is ineffective and discontinued (Karanikas, 2015; Malagas, Fragoudaki, Kourousis, & Nikitakos, 2017). This indicates that since there is no widespread human factors training within the tertiary education curricula, there is a great need for that for newly recruited personnel.

2.2 Trust

First, trust is the belief of somebody else's benignant intentions. Second, no person can impose these beliefs to come true; in other words trust means to be prepared for the possibility that the anticipated benignant outcome will not happen. Third, the meaning of trust includes a degree of interdependency as somebody's situation is linked to somebody else's actions (Whitener et al., 1998). Based on these three elements, trust is the attitude someone or a party adopts (trustor) towards somebody else or another party (trustee) (Robinson, 1996). This attitude, or even both parties' relationship, is influenced by the trustee's behaviour and it will form the trustor's understanding and receptiveness towards the trustee (Whitener et al., 1998). It is noted in the literature that the competence, benevolence and integrity of the trustee are the characteristics that trustor takes into consideration for the formation of his/her trust (Butler, 1991; Mayer, Davis, & Schoorman, 1995).

Trust, while it has been extensively researched by organisational researchers and more specifically by certain industries (e.g. web commerce), is understudied in high-reliability organisations, such as the aviation industry (Cox, Jones, & Collinson, 2006). Trust usually stands in combination with other human characteristics and is difficult to be isolated and quantified. However, there is growing research indicating that trust and professionalism are fundamental factors in maintaining safety in the aviation industry. On the one hand, professionalism is the basis to exercise all the necessary steps towards safety, but on the other hand, personal trust is essential in the communication that is required (Flin, 2007; Muchinsky, 1977; O'Reilly, 1977; O'Reilly & Roberts, 1977; Yeager, 1978).

Also, personal trust is associated with performance and cooperation (Axelrod, 1984; Ben-Ner & Putterman, 2009; Deutsch, 1962; Earley, 1986), citizenship behaviour (McAllister, 1995), problem-solving (Zand, 1972) and towards the skills and capabilities of aviation experts (trust in competence), to achieve the desired level of safety (Harvey & Stanton, 2014). Maintenance personnel need to trust that their colleagues will act as safely as themselves. This is a process that needs to be inspired and enhanced rather taken for granted (Taylor & Thomas, 2003a).

Trust towards people, and especially towards individuals in the case of a risky situation, where an individual will do anything within his/her power to overcome the risk, aspires to be a solid factor in ensuring safety management (Harvey & Stanton, 2014). However, Harvey & Stanton (2014) and Reason (2016) argue that this statement contradicts the modern systems’ approach to risk and human error, according to human factors principles, as human error has been considered so far to be a systemic rather than an individual consequence (Dekker, 2011; Rasmussen, 1997). Adaptation is inevitable where models include the social system and human error while organisations put pressure on their systems on the benefit of their cost-effectiveness - productivity balance (Leveson, 2004).

Apart from the trust between colleagues, there is the trust between maintenance personnel and management that is rather low and makes staff feel sceptic and pessimistic that positive results in safety cannot be achievable (Taylor & Patankar, 2001). Management is responsible for building, namely establishing/taking the initiative towards the employees, as well as maintaining trust (Whitener et al., 1998).

Beyond interpersonal trust, there is the confidence towards technology and procedures, having in mind that trust is bipolar, lingering between the two extremes of trust and distrust (Jian, Bisantz, & Drury, 1998; Ockerman & Pritchett, 2000).

Procedures are clusters of partial steps that, to be successful, need to meet different criteria and conditions (e.g. environment). Due to different reasons, (e.g. lack of knowledge, norms) maintenance employees might not take these conditions under consideration in the case of failure. Situations like these might lead these professionals to lose trust on procedures, in the case of a failure, or show overreliance in the instance that the procedures were effective even if the right conditions were not met (Ockerman & Pritchett, 2000).

The benefits of trust have been well understood for some decades now since Zand (1972) suggested that employees with higher levels of trust compared to the ones with lower levels: a) make information processing more cost-effective to the company; b) seem to have more contentment among them; and c) show certainty towards other counterparts. Research has also shown that trust towards familiar individuals is far more easily achieved, especially when positive feedback makes this person perceived to be trustworthy. Apparently, the level of trust tends to differ amongst various organisations, depending on their size. In small organisations, the interpersonal trust seems to be at a higher level than in larger organisations, including in the military, but for different reasons (Patankar, 2004).

Technology, on the other hand, is a human construction and, as a product, it lacks human characteristics (McKnight & Thatcher, 2004). To focus on the technology itself, one should isolate it from the human element (users, developers) and examine the technology artefact itself. This approach enables the investigation of trust towards technology without being influenced by the surrounding human structures (McKnight, Carter, Thatcher, & Clay, 2011).

People depend on technological artefacts and rely on their anticipated abilities and capabilities to perform successfully. In this concept, trust means to depend or rely on another (McKnight & Chervany, 1996). Therefore, if someone believes he/she can depend on technology's performance in a time of need, then trust towards technology is the describing term for it (McKnight et al., 2011).

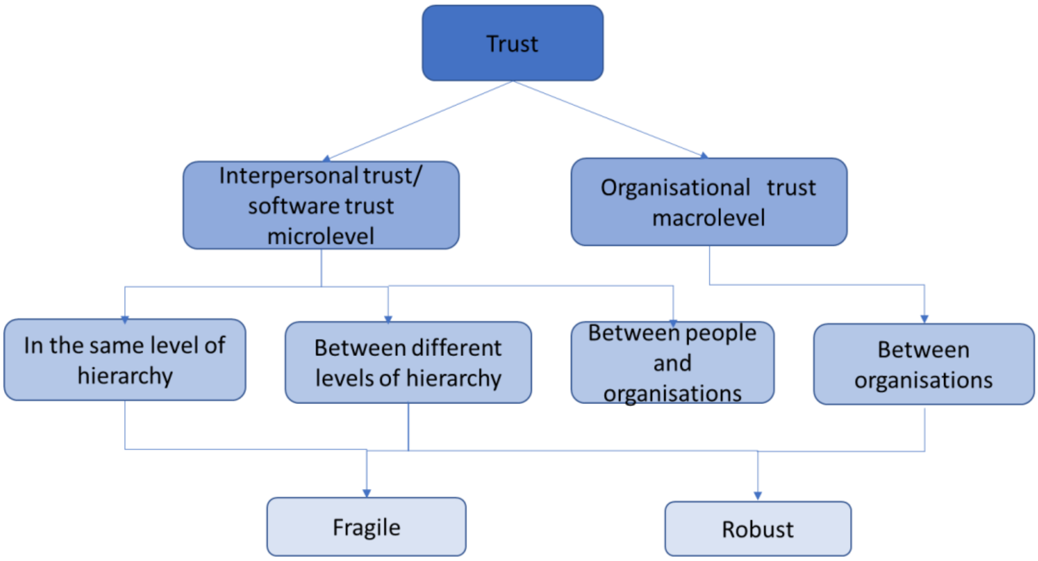
Trust in technology is divided into initial trust and knowledge-based trust (McKnight et al., 2011). Initial trust refers to the expectations and beliefs of the anticipated operations of the technological application chosen by the user. Knowledge-based trust is the result after interaction and familiarisation with a technological system. Trust in technology needs further investigation as not extended research has been conducted in this area (McKnight et al., 2011).

Furthermore, in modern times, more organisations have evolved into sizeable impersonal enterprises, where trust between groups is difficult to achieve (Bachmann, 2003). To overcome this issue, organisations have to agree, adopt and utilise similar social rules to gain familiarity and work together efficiently (Powell & DiMaggio, 1991). Even though these sets of rules seem to prevent distrust among enterprises, some researchers insist that interpersonal relations are the ones that guarantee the formation of trust. This means that specific people need to represent organisations to form the needed familiarity (Giddens, 1990).

Within business relations, trust is a fundamental factor that takes part in the orchestration of their expectations and mode of collaboration (Salam, 2017). It appears to have an assistive role in establishing business relationships, and it is crucial to re-establish the theory behind the organisational influences on business behaviour. This will be of major help in attempts at building trust in inter-organisational interactions (Bachmann, 2003). “The more complex and dynamic social and economic relations and exchange arrangements are today; the more trust is needed as a lubricant to keep the motor running” (Arrow, 1974, p.23).

Overreliance or excessive trust may have negative effects on interpersonal and organisational relations, and there is no current research to describe it adequately (Zaheer & Bachmann, 2006). To unfold the role that trust plays in organisations, one must explore the macrolevel and microlevel of theory and analysis. In the macro level, trust is studied regarding its interaction with the industry structure while in the micro-level trust is examined among people as seen in Figure 2.4 (Kramer & Tyler, 1996).

Figure 2.4 Schematic representation of the concept of trust.



2.2.1 Trust Dynamics in Organisations

When systems in organisations promote open and free communication (knowledge sharing, uninhibited information disclosure) their employees are more likely to develop their trust-building towards the organisation and each other (Butler, 1991; Whitener et al., 1998; Zaheer & Bachmann, 2006). Trust has been linked to safety in the aviation industry and there has been a significant effort through MRM training (5th generation) to implement and enhance safety culture and engage all personnel in that direction.

In the case that an organisation proceeds with implementing all necessary actions to reduce human errors, then learning from their mistakes would be one of them. In this case, it is crucial to the people involved to have a sufficient level of trust that they will not be blamed, if they report the identified mistake and that they can speak openly about it (commonly called a just culture) (Catino, 2008; Dekker, 2009). Although there are mechanisms available to maintenance personnel to avoid or reduce human errors, they must trust their managers mutually to achieve that.

Studies have revealed that a big proportion of engineers do not trust that their managers' actions will be solely aimed at enhancing safety (Goglia, Patankar, & Taylor, 2002). The lack of trust, or distrust, acts as an obstacle to the formation and implementation of programs such as the FAA’s Aviation Safety Action Program (ASAP), that provides maintenance personnel with a system to report failures and thereby contribute to the continuous effort to improve aviation safety.

2.2.2 Characteristics of Trust

Other extended research on trust indicates that trust is at high levels at the beginning of a professional relationship "*high initial trust levels*" (McKnight, Cummings, & Chervany, 1998). New employees begin their employment with an intrinsic level of trust towards their colleagues and their organisations. Thereafter, it is the culture of each organisation that will be responsible for maintaining or altering this level. Trust is also a multidimensional area that is highly influenced by other social features. As proposed in the Model of Trust, Mayer, Davis and Schoorman (1995) suggest trustworthiness is perceived by factors such as ability, benevolence and integrity. In a society that is trained to believe and rely on others, it is most probable that people will trust their organisation initially at a high level (McKnight et al., 1998; Rotter, 1967).

Depending on the circumstances, trust levels can appear to develop as fragile or robust. Fragile is when it is subject to sudden changes during a given period either to a higher level, when the initial level is low or vice versa. Robust, on the other hand, is the opposite of fragile. It is used when the level of trust remains stable over a specified period (McKnight et al., 1998). Since the existence of the “*high initial trust levels*” is identified, it is of primary importance in the aviation industry to maintain it at those levels. It will only be successful by keeping in mind that the elements that make trust robust are:

- Adequate precedent support, that is former good experience which forms a present behaviour in a similar manner;
- Belief-confirming cognitive mechanisms, in which people’s remarks that oppose their beliefs are overlooked; and
- Social mechanisms, the in person socialisation among people enhances the positive attitude between them (McKnight et al., 1998).

Moreover, research has identified legislative procedures, conflicts of power, stress and liability to be factors that reduce trust within organisations (Hovden, Størseth, & Tinmannsvik, 2011; Naevestad, 2008).

Furthermore, research has confirmed the relationship between ASAPs and trust since organisations with ASAPs in place have demonstrated higher scores in trust than other companies in which ASAPs were not in their structure (Patankar & Driscoll, 2005). To evaluate the personal perception of maintenance personnel regarding human factors and safety in the workplace, specific tools had to be introduced. One tool that has been extensively used by the FAA is the Maintenance Resource Management Technical Operations Questionnaire (MRM/TOQ). Among other questions that were used to measure different human factors, the following statements were used to measure the level of trust: “My supervisor can be trusted”, “My safety ideas would be acted on if reported to a supervisor”, “My supervisor protects confidential information.”, “I know proper channels to report safety issues” (Patankar & Driscoll, 2005; Taylor & Thomas, 2003a).

These types of questionnaires are evolving and adapting over time, and new data is accumulating through continuous research. The optimum result would be to obtain a substantial amount of data from the full range of aviation activities, which would enable researchers to analyse results comparatively, inferentially, and longitudinally (Taylor & Thomas, 2003a).

2.3 The Relation between Trust and Communication

Literature has indicated that personal trust is an essential element that is associated with successful communication (Bachmann, 2003; Carrière & Bourque, 2009; Cho & Park, 2011; Flin, 2007; Muchinsky, 1977; O'Reilly, 1977; O'Reilly & Roberts, 1977; Yeager, 1978) this is a non-exhaustive list of references. Experimental research has shown that face to face communication has been highly successful due to, among other reasons, the lifting of anonymity and the trust that the communicators show to each other. Face to face communication enhances verbal communication where trust elements such as commitment and promises are used along with body language, facial expressions and visual cues to a successful outcome (Ben-Ner & Putterman, 2009).

Experimental evidence, regarding the relation between trust and communication, is scarce and more research on that field is needed (Ben-Ner & Putterman, 2009).

When it comes to group communication, the group should establish common ground for the members to agree upon some basic ideas or concepts. This process should go through trust among the members, towards their incentives and attitudes, in order for the group to create a functioning communication (Anolli et al., 2002, as adapted by Bachmann, 2001; Donath, 1999).

At the organisational level, when organisational culture supports open and free communication among all levels of employees, it is expected that they will enhance their trust levels towards each other and towards their organisation (Butler, 1991; Whitener et al., 1998; Zaheer & Bachmann, 2006). Recent research in the aviation maintenance field has indicated that communication and trust are two major factors that both can be used as tools for maintenance failure detection (Langer & Braithwaite, 2016). Also, according to the FAA, trust is an essential element for a successful safety program in the aviation industry. The different safety programs base their effectiveness on the successful communication among the different business partners and mutual trust or distrust can affect this communication.

2.4 The Link of Communication and Trust with Aviation Safety

In the aviation industry, it is well recognised that poor communication is a paramount human factor contributing to errors (Balk & Bossenbroek, 2010; Bureau of Air Safety Investigation, 1997). Some researchers have acknowledged the need for error-free communication within aviation (Caldwell, 2005; Mattson et al., 2001), while others have identified poor communication to be an accident causal factor (Dupont, 1997; Flin et al., 2002; Weick, 1990). Recently, researchers have developed tools to proactively detect maintenance failures, such as the Maintenance Operations Safety Survey (MOSS), in which communication and trust are major factors (Langer & Braithwaite, 2016).

Communication is an important aspect of business as information gathering on different professional matters takes up a large proportion of the employees' time (Mount & Back, 1999). Communication satisfaction is the perception of employees regarding the communication practices followed by their organisation (Carrière &

Bourque, 2009). Communication satisfaction is very important in identifying a healthy and functioning organisation (Downs & Adrian, 2004; Downs & Hazen, 1977). Many researchers believe that satisfactory and effective communication is a sign of an organisation's successful operation, with regards to its productivity, efficiency and its sales and customers approach (Zwijze-Koning & De Menno, 2007).

Communication satisfaction has been associated positively with job satisfaction (Appelbaum et al., 2012; Carrière & Bourque, 2009; Downs & Hazen, 1977; Muchinsky, 1977; Pincus, 1986), employment situation satisfaction (Goris, 2007), organisational commitment (Ng, Butts, Vandenberg, DeJoy, & Wilson, 2006; Varona, 1996), productivity (Hargie, Tourish, & Wilson, 2002), work value, and job performance (Jalalkamali, Ali, Hyun, & Nikbin, 2016). Research on communication satisfaction has been conducted in business areas to date such as: hospitality (Mount & Back, 1999), manufacturing (Downs & Hazen, 1977), private and public sector (Brunetto & Farr-Wharton, 2004), information technology sectors (Appelbaum et al., 2012), nursing (Pincus, 1986), automotive (Jalalkamali et al., 2016), financial services (Clampitt & Downs, 1993) and the ambulance service (Carrière & Bourque, 2009).

In the aviation sector, research to date has shown that effective communication techniques are part of the employees' initial and recurrent training and are linked to their on-job safety-related practices (Karanikas, Melis, & Kourousis, 2017). Also, organisational commitment and employees' level of organisational satisfaction is associated with employees' safety-related practices (Dode, Greig, Zolfaghari, & Neumann, 2016; Evans, Glendon, & Creed, 2007; Glendon & Litherland, 2001; Luria & Yagil, 2010; O'Connor, 2011). Figure 2.5 offers a schematic representation of the summary of the interrelationship between communication and trust and the effect of communication in organisational commitment and safety. It is of note that the literature does not discuss any links between the other four organisational traits and safety, even though these are affected by communication as well. However, the literature review did not reveal any research which was conducted to identify the association between communication satisfaction and trust in aviation maintenance professionals.

Figure 2.5 Interrelationships between communication, trust, safety and other organisational traits.

Whitener et al. (1998) have found that there are three factors in communication which appear to have a strong association with trust: precise information, explanations and justifications of decisions and openness. Trust, as a fundamental trait in human social life, has been the focus of many different disciplines of science, and each one has dealt with it and defined it according to each discipline's scope and interest (Hernandez & Santos, 2010). Trust has not been investigated as a trait in the aviation sector (Flin, 2007). However, it is a very important element of the interrelationships of co-workers in all industries and warrants further research, as it is linked to the quality of communication (Bachmann, 2003; Carrière & Bourque, 2009; Cascio, 2000; Cho & Park, 2011; Flin, 2007; Muchinsky, 1977; Shapiro et al., 1992; Yeager, 1978).

Interpersonal trust is one of the organisational variables that have an interrelationship with communication. While other variables are not the focus of this study, these include performance, citizenship behaviour, problem-solving, cooperation and cooperative relationships. These variables can be defined through three distinct dimensions (Whitener et al., 1998). The first dimension is the confidence of the element of benevolence in the other party's acts. The second dimension is that there is no control over the other party's actions; therefore, there is no warranty in the deliverable outcome, and the third dimension is that the individual's performance has some reliance on the performance of another individual (Whitener et al., 1998). Also, past research has indicated that the character of trust can change, depending on the stage of the relationship between the different parties involved (Hernandez & Santos, 2010). Moreover, the interaction between the two parties, i.e. the knowledge and evaluation of previous successful collaboration, which can lead to successful prediction of potential future collaboration, enhances trust. This is called knowledge-based trust (Hernandez & Santos, 2010).

2.5 Summary of Findings and Research Gaps

This review aimed to include mainly aviation maintenance literature relevant to communication and trust; however, this literature was found to be scarce. Thus, it stems that these factors, examined either independently or in combination, are understudied in aviation maintenance. Communication and trust were, therefore, explored in the broader multidisciplinary literature, subsequently filtered to obtain studies applicable to the aviation maintenance context. The most important findings of this review are presented in a synoptic/summarised form in Table 2.1, acting also as a guide for the identification of research gaps.

Most researchers have concluded that aviation has recognised miscommunication as a paramount human factor contributing to errors (Balk & Bossenbroek, 2010; Bureau of Air Safety Investigation, 1997), but there is still much work to be done to eliminate this risk and provide the industry with an error reduced communication. A research gap has been identified in the issues that arise from the communication among different areas within aviation, and there is research underway mitigating these issues (Caldwell, 2005; Mattson et al., 2001). Every aspect of human nature and personality characteristics should be considered, to eliminate the factors that might affect the adequate delivery and comprehensions of a message in the communication process. To achieve this, it is of high importance to place the mechanisms and models of miscommunication in the specific frame of the aviation industry (Anolli et al., 2002) as there is a lot of potential in their implementation and development, especially in aviation maintenance (McRoy, 1998; Mortensen, 1997; Parret, 1994).

Table 2.1 Synopsis of findings of the literature review on communication and trust, including identified research gaps.

Communication
Most researchers have concluded aviation has recognised miscommunication as paramount human factor contributing to errors (Balk & Bossenbroek, 2010; Bureau of Air Safety Investigation, 1997); there is still much work to eliminate this risk and provide industry with error free communication.
Highly important to place mechanisms and models of miscommunication in the aviation industry specific frame (Anolli, Ciceri, & Riva, 2002) as there is a lot of potential in implementation and development there, especially in aviation maintenance (McRoy, 1998).
While debriefs may appear to be cost effective and produce quick results in the organizations' improvement of performance, the study of such processes over the years is scattered across different disciplines with no conclusive results (Tannenbaum & Cerasoli, 2013).
Significant gap has been recognized between the quality of students' oral and written communication skills gained during their studies (especially in the aeronautical area) and the skills required by the aeronautical industry to perform tasks safely (Karanikas, 2015).
Extended research is needed in using new technologies to make them more appealing and resolve managers' and employees' negative attitude to similar platforms (Chaparro & Groff 2002).
Trust
Trust, while extensively researched by organisational researchers and more specifically by certain industries (e.g. web commerce), is understudied in high-reliability organisations, like the aviation industry (Cox, Jones, & Collinson, 2006).
Optimum result would be to obtain a large amount of data from full range of aviation activities, which would enable researchers to analyse results comparatively, inferentially and longitudinally (Taylor & Thomas, 2003a).
Literature on trust in aviation industry is scarce. More research is needed in identifying and associating trust with other traits in actual aviation maintenance environment (Flin, 2007).
Initial levels of trust (individual or company indicated at beginning of collaboration levels of trust) are high. Research can be focused on mechanisms capable to understand and manipulate retention of high trust levels over prolonged time (McKnight et al., 1998).
Trust in technology and the negative effects of excessive interpersonal or organizational trust can be researched further, as these are understudied fields, especially in aviation maintenance.
More extensive research is needed to standardize trust measuring methodologies, in analysing the results and enabling smaller scale research to be compared safely. This will lead to reliable results and interventions (Taylor & Thomas, 2003a). Only over recent years researchers have started trying to unveil the causational factors for maintenance errors (Hobbs & Williamson, 2003).
Communication and Trust
Experimental evidence, regarding the relation between trust and communication, is scarce and more research on that field is needed (Ben-Ner & Putterman, 2009).
The relationship between trust and communication (how they interact with each other) among colleagues, between subordinates and managers/supervisors and between maintenance staff and technology needs to be researched.

Past research indicated that standard terminology and methodology would help reduce human errors occurring in aircraft procedures, especially in the written forms of communication (e.g. documentation, manuals, workcards etc.) (Chervak et al., 1996; Drury, 2013). Because of such endeavours, new technology and improved software are being used in the place of internal communication forms and workcards, stemming encouraging results (Kraus & Gramopadhye, 2001; Liang et al., 2010). Extended research has still to be conducted in this direction to make such hardware and software tools more appealing and subsequently resolve both managers’ and employees’ negative attitude to similar platforms (Chaparro & Groff, 2002). On the other hand, there is a lack of systemic study of maintenance debriefings, which, in turn, does not assist in comprehending and improving this crucial step in maintenance processes (Tannenbaum & Cerasoli, 2013).

Training is the only vehicle that will introduce and facilitate all the required communication skills to maintenance personnel (Patankar & Taylor, 2008; Robertson, 2005; Salas et al., 2001; Taylor & Patankar, 2001). There has been considerable research during the few past decades in developing systems and generating effective training programs. There is, however, the potential for further research in the long-term effectiveness of these training programs as trainees do not appear to acquire the desired level of knowledge and skills (Taylor & Thomas, 2003b).

The framework within inter-organisational trust has a lot of potential for restructuring, enabling the enhancement of business interactions and achieving further development (Bachmann, 2003). This review revealed that literature dealing with trust in the aviation industry is scarce. This alone indicates that there is a need for additional and more focused research in identifying and associating trust with other traits in the actual working environment of aviation maintenance (Flin, 2007). One of the interesting elements of trust is that the *Initial levels of trust* (the levels of trust an individual or a company indicates at the beginning of collaboration) are high. Human factors researchers' efforts can be focused towards the direction of understanding and manipulating the mechanisms which are capable of contributing to maintaining these levels high over a prolonged period (McKnight et al., 1998).

More extensive research is needed to standardise trust measuring methodologies, in analysing the results, and to enable smaller-scale research to be compared safely, which in turn will lead to reliable results and interventions (Taylor & Thomas, 2003a). Only over recent years, researchers have started to unveil the causational factors for maintenance errors (Hobbs & Williamson, 2003). This, eventually, is expected to lead to breakthroughs in the aviation maintenance field, provided that further focused research is undertaken.

Following the example of EU research program ‘Future Sky Safety’ (Silvagni, Napoletano, Graziani, Le Blaye, & Rognin, 2015) and trying to fill in the gap in the human factors research in aviation maintenance, the investigation of the interaction between two factors, such as communication and trust, is pioneering within the aviation maintenance context and it is considered to be very important. The research that has been conducted in aviation human factors so far is mainly single factor research. Therefore, the study of two or more factors and their impact on human performance is a direction more researchers would be expected to follow in the future, given that human reaction is the result of different factors and conditions interacting with each other.

Under the scope of the investigation of factors in combinations, it is beneficial to see further combined research in communication and trust in aviation maintenance. More specifically, the relationship between trust and communication (how they interact with each other) among colleagues, between subordinates and managers/supervisors and between maintenance staff and technology. Furthermore, trust among aviation businesses (including aircraft maintenance organisations) and how they interact with each other would be a domain for further research, as new data and findings could arise. Another aspect is trust in technology, which appears to be bereft of any significant research in the aviation maintenance field. The negative effects of excessive interpersonal or organisational trust can be researched further, as again, this is an understudied field, especially in aviation maintenance.

CHAPTER 3 RESEARCH METHODS

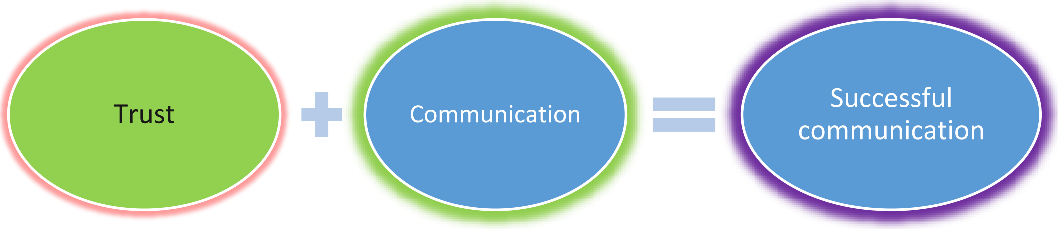
3.1 Purpose Statement

The objective of this study is to explore the relationship between trust (variable) and communication (variable) in aviation maintenance (illustrated schematically in Figure 3.1). Two variables were investigated with every attempt to exclude any bias, following the principles of the correlational research (Fraenkel & Wallen, 2003).

Figure 3.1 Schematic representation of the trust - communication influence.

The review of social sciences literature has indicated that trust is associated with and can contribute to successful communication (Bachmann, 2003; Flin, 2007) (Figure 3.2). Thus, a minimum level of trust should be present with effective communication between two or more counterparts. As discussed in Chapter 2, another interesting fact in the literature is that a high level of trust is identified whenever a new professional relationship begins. This is known as the *high initial trust levels* model (McKnight et al., 1998). The study of trust issues in aviation to date has been scarce (Flin, 2007), and further research is required, particularly in the field of aviation maintenance. Studies which examine the relationship between trust and communication, including initial trust levels, among technical staff, have not been adequately investigated and could play an important role in the maintenance and advancement of aviation safety.

Figure 3.2 Schematic representation of the relation between trust and communication, towards successful communication.



Furthermore, since the new trend in aviation is to study factors in combination, rather than individually (Silvagni et al., 2015), the undertaken research on communication and trust aims to be part of the state-of-the-art research trend in the aviation domain. Only recently scientists have started to deal with the contributing effects of human factors in maintenance errors (Hobbs & Williamson, 2003). More specifically, researchers have highlighted the gap in effective communication between maintenance staff, cabin crew and flight crew, proposing some ways to mitigate this issue (Caldwell, 2005; Fisher, 2016; Mattson et al., 2001).

3.2 Research Design

This study is following the pragmatic paradigm and focuses on the appropriate methodologies to a systematic and in depth investigation of the the identified research area (Mackenzie & Knipe, 2006). Since Pragmatism focuses on a specific scientific problem, researchers that choose to work within this frame mostly prefer a mixed-methods approach rather than solely qualitative or quantitative methods (Mackenzie & Knipe, 2006, Robinson, Emden, Croft, Vosper, Elder, Stirling & Vickers, 2011).

Robinson et al. (2011) argue that the pragmatic approach is the dedicated frame in which researchers can move back and forth between quantitative and qualitative approach to investigate and present their arguments. Moreover, a pragmatic approach is characterised by its combined objectivity and subjectivity, while its data are characterised by their transferable nature (Robinson, et al. 2011). A pragmatic inquiry sets the scenery for an inquiry that seeks for results and specific answers without excluding the philosophical investigation of the subject. Therefore, in this research study, the reasoning will move from a qualitative approach (set the context of the study) to a quantitative approach (to seek for specific answers and measurements) and then back to a qualitative approach again. This will allow to cross-validate and make the findings meaningful to the aviation maintenance setting.

Following the pragmatic paradigm's reasoning, and since this justification falls into the objectives of this study and the examples of past research in this field, the mixed methods approach is chosen as the most appropriate for this study. The first step is to challenge whether trust and communication are detectable in aviation maintenance. A qualitative approach investigates the existence of communication and trust within aviation maintenance (work environment and employees training) (Bachmann, 2003; Flin, 2007). Then, the second step is to quantitatively explore in depth the association between trust (interpersonal and trust towards technology) and communication in aviation maintenance among different groups of maintenance employees, depending on their length of employment, type of license, employment status etc. The data collection and analysis (presented in Chapter 4) indicated that the research hypotheses could not be rejected (Phillips & Burbules, 2000) as cited in Creswell, 2014. Finally, the last step is to qualitatively validate the results from the two previous steps. Blending the results is also part of this final step, which is performed via a proposed model used in diagnosing and identifying communication and trust issues in aviation maintenance (presented in Chapter 5).

In this study, mixed methods were selected to gather and analyse the data. More specifically, the most appropriate procedure to collect the data for this study were from within non-experimental designs and specifically utilising surveys and conducting content analysis. The literature review, which has examined thoroughly the research in the aviation field, has noted that the methods that have been followed in past research were both qualitative and quantitative. It has been considered useful to follow best practice from other researchers on the same field, as this study aims to contribute to the wider research body of knowledge with its findings. Moreover, these findings are targeted to identify patterns to further understand human factors in the specific field of aviation maintenance. The pragmatic paradigm is the one that dictates the use of mixed methods, as the qualitative and quantitative are linked to each other, which offers additional reassurance on the suitability of this research approach.

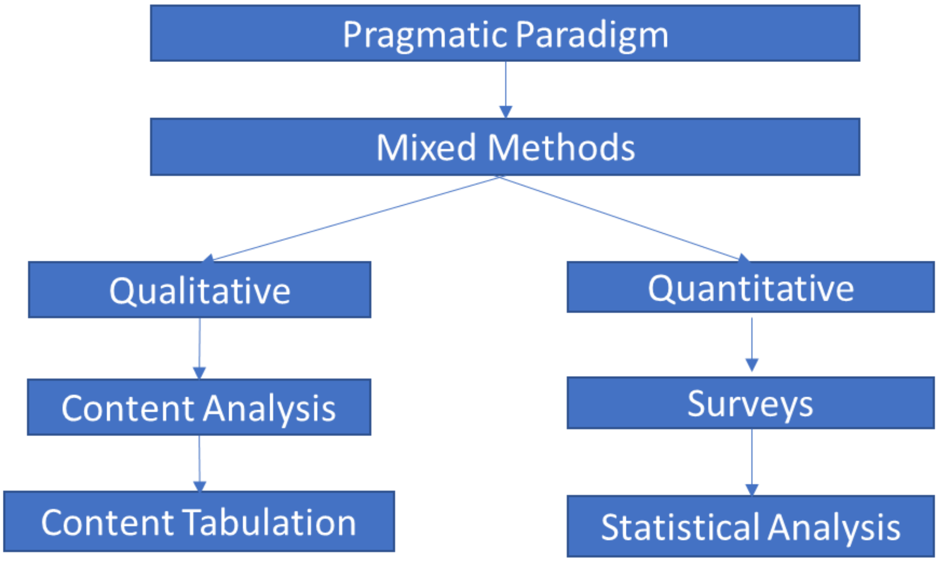
Nonetheless, there are two other research designs which are available to researchers. These are qualitative designs and quantitative designs. In qualitative research, individuals or groups of people are examined by researchers using methods that aim to identify several characteristics and behaviours, and they usually do not target the investigation of any specific trait (Creswell, 2014). The researcher normally needs to interpret the findings, the same way as in any research, but the final written report has a flexible structure with no numbered data that could be analysed through a statistical process (Creswell, 2014).

On the other hand, in quantitative methods, researchers use tools that offer assistance to their objective observation of the traits examined. The researchers use various methods to collect their data in a numerical form and then analyse their finding with the use of mathematics, statistics or numeracy by using computational aids. Their numerical findings help them in presenting them in a clear way, capable of providing either explanation or generalisation of the trait under examination (Babbie, 2010).

The two traits under investigation are communication and trust. The first step was to recognise whether both traits, communication and trust, are observable in the aviation maintenance environment (within aviation maintenance occurrences and aviation maintenance training). Subsequently, this association needs to be explored further, also reverting to a deeper insight in the significance of this association. Therefore, firstly, the content analysis method was utilised (as a qualitative research design technique), followed by the survey method (as a quantitative research design technique), exploring further the two traits. These content analyses' results identified the existence of the two traits, both in the aviation maintenance practice and the human factors basic training curriculum and training material. The survey investigation (a technique widely used in quantitative research in various disciplines) was employed to obtain and interpret the findings, by quantifying and statistically analysing the results. It is also noted that the collection and analysis of data generally precludes the use of mixed-methods research methodologies. This is due to the nature of the mixed methods design, which includes both quantitative and qualitative procedures that are used together to understand thoroughly the research problem (Creswell, 2014).

A synopsis of the research design process, involving a qualitative and quantitative methodology branch, is represented schematically in Figure 3.3. For the quantitative branch of this research, the data were collected through surveys which were administered to different groups of aviation maintenance technicians (Creswell, 2014). More specifically, the survey method employed in this research intends to measure the interaction between the amount of trust and the effectiveness in communication. The qualitative one used the content analysis method to examine and produce results from aviation maintenance accidents/incidents' reports and official training material.

Figure 3.3 Schematic representation of the research design adopted in this study.



In addition, the overall systematic research approach, which is summarised in Table 3.1, presents the research approaches and methods selected and employed to address each one of the research questions and hypotheses. This summary assisted in the course of the research and it is also considered as a useful guide for the reader of this study, as it maps the research questions and hypotheses to the various methodologies. More detailed analysis and discussion are provided in subchapter 3.3 ‘Research Methods’.

Table 3.1 Mapping of research questions and hypotheses with research approaches.

Research Question	**Research Approach**
1. Are trust and communication detectable in aviation maintenance?	Use of qualitative approach (content analysis method) to investigate the existence of communication and trust in the aviation maintenance environment (actual accidents and incidents' reports where aviation maintenance has had a contribution).
2. Are communication and trust covered in aviation maintenance human factors basic training?	Use of qualitative approach (content analysis method) to investigate the content of the aviation maintenance human factors basic training curriculum and training material, in relation to the coverage of communication and trust.
Research Hypothesis	**Research Approach**
1. (a) Aviation maintenance employees' levels of interpersonal trust towards their colleagues has a positive association with their communication satisfaction and (b) supervisors/managers' levels of interpersonal trust towards their subordinates has a positive association with their communication satisfaction.	Use of quantitative approach (survey method) to investigate and measure the association between communication and trust in aviation maintenance.
2. (a) Employees' trust towards the company's software has a positive association with their communication satisfaction and (b) supervisors/managers' trust towards the company's software has a positive association with their communication satisfaction.	
3. (a) Subordinates' levels of interpersonal trust has a positive association with their communication satisfaction and (b) subordinates' trust towards the company's software has a positive association with their communication satisfaction.	
4. High initial trust levels are detectable in (a) interpersonal trust and (b) company's software trust to newly recruited maintenance employees.	

3.3 Research Methods

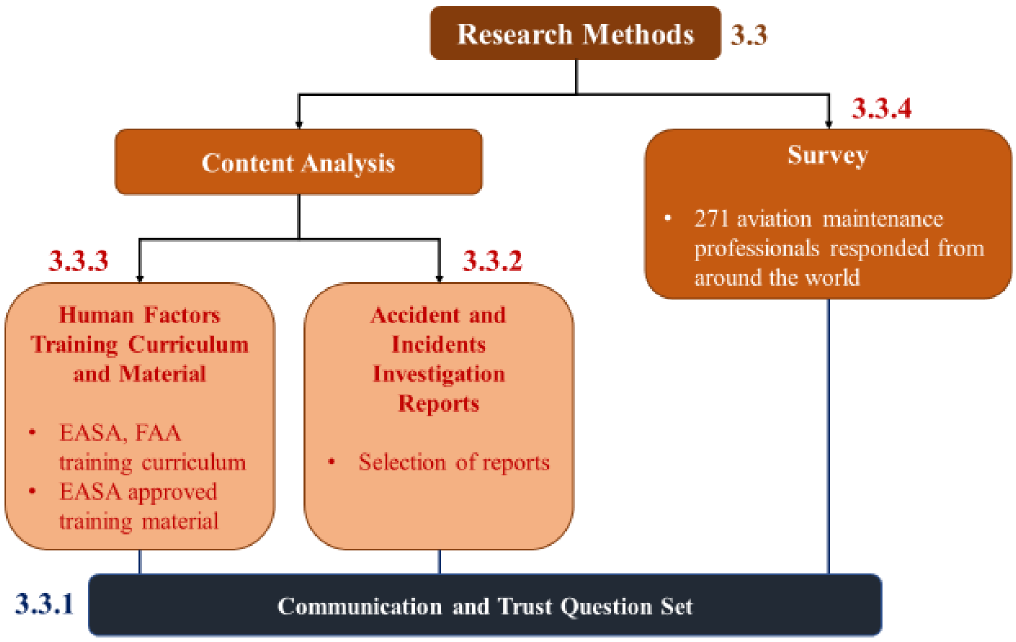
The research methods selected to be used in this study are the content analysis and the survey method. The content analysis method has been selected to investigate the existence of communication and trust:

- In actual aviation safety occurrences (accident and incidents), specifically due to maintenance errors;
- Within the basic aviation maintenance human factors training curriculum and training material.

The survey method intends to identify and measure the association between communication and trust within the aviation maintenance context (technicians around the world surveyed). This is accomplished by exploring the aviation maintenance professionals' perceptions from their current working experience.

Moreover, for the implementation of this methodology, a dual-use tool has been developed and embedded within the content analysis and survey methods. This tool is the Communication and Trust Question Set. The overall research methodology construct is graphically represented in Figure 3.4, with full details described and discussed in the subchapters indicated on the figure.

Figure 3.4 Graphic representation of the study's overall research methodology.



3.3.1 The Communication and Trust Question Set

As discussed in the preamble of the 3.3 ‘Research Methods’ subchapter, a dual-use question set was developed and used in this research, consisting primarily of two parts:

- The Communication Satisfaction Questionnaire;
- The Trust Constructs and Measures Questionnaire.

These two questionnaires are complemented with demographics and general questions’ sections and constitute the communication and trust question set. In the following sections, the background, rationale, description and the final form of the developed question set are discussed in detail.

3.3.1.1 Communication Satisfaction Questionnaire

The Communication Satisfaction Questionnaire is a tool that was developed in 1977 and widely used since then in research projects dealing with communication satisfaction in many different industries such as hospitality, healthcare and automobile manufacturing (Appelbaum et al., 2012; Brunetto & Farr-Wharton, 2004; Carrière & Bourque, 2009; Chan & Lai, 2017; Clampitt & Downs, 1993; Downs & Hazen, 1977; Gochhayat, Giri, & Suar, 2017; Jalalkamali et al., 2016; Mount & Back, 1999; Pincus, 1986; Zwijze-Koning & De Menno, 2007; Zwijze-Koning, 2016). The Communication Satisfaction Questionnaire has been an efficient tool to extract employees’ perceptions of communication within their organisation (Gray & Laidlaw, 2004; Zwijze-Koning & De Menno, 2007; Zwijze-Koning, 2016). This is a 40-item questionnaire, with items categorised in eight communicative themes (dimensions). These dimensions vary from interpersonal communication (e.g. an employee’s evaluation of the communication with his/her supervisor), to the organisation-wide communication climate (Zwijze-Koning & De Menno, 2007). This construct has been found to have a test-retest reliability of 0.94 (Downs & Hazen, 1977).

The Communication Satisfaction Questionnaire has the capability to expose employees’ beliefs on important matters affecting communication within an organisation. The questionnaire’s convergent validity has been compared in the past with other questionnaires, e.g. the Communication Incident Technique (CIT) and it was found to be a very reliable and up to date tool in investigating an organisation’s communication satisfaction (Zwijze-Koning, 2016). Moreover, several researchers have evaluated the reliability, concurrent and construct validity of this questionnaire (DeWine & James, 1988; Lee, Strong, Kahn, & Wang, 2002; Rubin, Palmgreen, & Sypher, 1994; Zwijze-Koning, 2016).

It is noted that this questionnaire has been the primary research tool for various research studies conducted in many different countries and institutions (Rubin et al., 1994). It has been characterised as "arguably the best measure of communication satisfaction in the organisational arena" (Clampitt & Downs, 1993, p. 6) while Rubin et al. (1994, p. 116) agree that "The thoroughness of the construction of this satisfaction measure is apparent. The strategies employed in this study are exemplary".

The content of the Communication Satisfaction Questionnaire used are presented in Table 3.2, where items in sections C 'Communication - My job' and D 'Communication - My job and the people I work with' are addressed to all aviation maintenance professionals and section E 'Communication - Only for managers/supervisors' items to supervisors/managers only. All items are assigned a 7-point Likert scale when used for surveys. Sections C, D and E use the coding: 1 = 'Very Dissatisfied', 2 = 'Dissatisfied', 3 = 'Somewhat Dissatisfied', 4 = 'Neither', 5 = 'Somewhat Satisfied', 6 = 'Satisfied' and 7 = 'Very Satisfied'.

Table 3.2 Content of the Communication Satisfaction Questionnaire.

Section C: Communication - My job	
C1	Information about my progress in my job.
C2	Personnel news.
C3	Information about organisational policies and goals.
C4	Information about how my job compares with others.
C5	Information about how I am being judged.
C6	Recognition of my efforts.
C7	Information about departmental policies and goals.
C8	Information about the requirements of my job.
C9	Information about government action affecting my organisation.
C10	Information about changes in our organisation.
C11	Reports on how problems in my job are being handled.
C12	Information about benefits and pay.
C13	Information about our organisation's financial standing.
C14	Information about accomplishments and/or failures of the organisation.
Section D: Communication - My job and the people I work with	
D1	My superiors know and understand the problems faced by subordinates.
D2	The organisation's communication motivates and stimulates an enthusiasm for meeting its goals.
D3	My supervisor listens and pays attention to me.
D4	My supervisor offers guidance for solving job related problems.
D5	The organisation's communication makes me identify with it or feel a vital part of it.
D6	The organisation's communications are interesting and helpful.
D7	My supervisor trusts me.
D8	I receive in time the information needed to do my job.
D9	Conflicts are handled appropriately through proper communication channels.
D10	The grapevine (person to person informal communication / gossip) is active in our organisation.
D11	My supervisor is open to new ideas.
D12	Communication with my colleagues within the organisation is accurate and free flowing.
D13	Communication practices are adaptable to emergencies.
D14	My work group is compatible.
D15	Our meetings are well organised.
D16	The amount of supervision given me is about right.
D17	The attitudes towards communication in the organisation are basically healthy.
D18	Informal communication is active and accurate.
D19	The amount of communication in the organisation is about right.
D20	Are you a supervisor / manager?
Section E: Communication - Only for managers / supervisors	
E1	My subordinates are responsive to downward directive communication.
E2	My subordinates anticipate my needs for information.
E3	I do not have a communication overload.
E4	My subordinates are receptive to evaluation, suggestions, and criticism.
E5	My subordinates feel responsible for initiating accurate upward communication.

It is noted that a minor modification was deemed necessary and was applied to the original Communication Satisfaction Questionnaire developed by Downs & Hazen (1977). In particular, the following two questions were deemed ambiguous and redundant and, therefore removed:

Removed Question 1: ‘Written directives and reports are clear and concise’	
Reason	In aviation maintenance written communication holds a substantial proportion of the overall communication as this stems from regulatory and quality assurance requirements, such as engineering reports, workcards, work orders, directives, airworthiness notices, service bulletins, discrepancy reports, etc. This item was considered as being too specific, referring only to directives and reports, not reflecting the wide variety of written communication in aviation maintenance. This ambiguity could affect the reliability of the responses. Furthermore, in the questionnaire there are six other items covering the scope and elements of clear and concise written communication. Thus, the item was considered redundant.
Items covering the elements/scope of the removed item	**C3** Information about organisational policies and goals. **C7** Information about departmental policies and goals. **C8** Information about the requirements of my job. **C10** Information about changes in our organisation. **D6** The organisation’s communications are interesting and helpful. **D19** The amount of communication in the organisation is about right.

Removed Question 2: ‘People in my organisation have great ability as communicators’	
Reason	This item was not considered sufficiently clear for the purposes of the survey (open to subjective interpretation to what constitutes ‘great ability’) and the content analysis. This ambiguity could affect the reliability of the responses. Furthermore, in the questionnaire there two other items covering in a clear way the scope and elements of effective communication ability. Thus, the item was considered redundant.
Items covering the elements/scope of the removed item	**D3** My supervisor listens and pays attention to me. **D12** Communication with my colleagues within the organisation is accurate and free flowing.

3.3.1.2 Trust Constructs and Measures Questionnaire

The Trust Constructs and Measures Questionnaire has been developed by Li et al. (2012) and it is in practice a synthesis of various questionnaires developed and used in the past by Gefen (2004), Lowry, Vance, Moody & Beckman (2008), McKnight et al. (2011), McKnight, Choudhury & Kacmar (2002), Nicolaou & McKnight (2006), Stewart & Malaga (2009) and Vance, Elie-dit-cosaque & Straub (2008). The studies performed with the constituent questionnaires have yielded valid and reliable research data and findings, which informed their adoption and adaption from Li et al. (2012). Moreover, the measurement model (reliability scores, construct validity, convergent and discriminant validity) was found to produce statistically significant results (Li et al., 2012). The measurement model results verified that the measurement scales adapted by Li et al., (2012) were valid and reliable in their study. Specifically, web capability and reliability were found to be powerfully belief constituent in assessing trust in the website. This outcome confirmed that the IT-specific scales, that were adopted by Li et al., (2012) were valid in technology trust measurement (Li et al., 2012).

In the present research study, the Trust Constructs and Measures Questionnaire was adapted to measure interpersonal trust (among colleagues and between employees-managers) and trust towards the software package utilised for aircraft maintenance certification and management. In particular, the questionnaire’s basic sections remained unchanged (those covering competence, benevolence, integrity, software capability and software reliability), with modifications introduced to reflect the supervisors/managers' levels (covering competence, benevolence and integrity). In addition, items of the questionnaire were rephrased in accordance with the scope of the study and to match the aviation maintenance context. The modification made is provided in detail in Table 3.3.

Table 3.3 Mapping of the modified items from the original Trust Constructs and Measures Questionnaire from Li, Rong &Thatcher, 2012.

Original Trust Constructs and Measures Questionnaire by Li, Rong & Thatcher (2012)		**Modified Constructs and Measures Questionnaire**	
Original Construct	***Original Item***	***Modified Construct***	***Modified Item***
Trust in Merchant – Competence	*I believe this merchant is effective in assisting and fulfilling my purchases.*	Trust in colleagues' competence	**F1.** My colleagues fulfil my expectations in our collaboration.
	This merchant performs its role of e-vendor very well.		**F2**. My colleagues perform their duties very well.
	Overall, this merchant is a capable and proficient e-vendor.		**F3**. Overall, my colleagues are capable and proficient technical staff.
	In general, this merchant is very knowledgeable about the business it operates.		**F4**. In general, my colleagues are knowledgeable about our organisation.
Trust in Merchant – Benevolence	*I believe that this merchant would act in my best interest.*	Trust in colleagues' benevolence	**F5**. My colleagues act in the best interest of the project.
	If I required help, this merchant would do its best to help me.		**F6**. If I required assistance, my colleagues would do their best to help me.
	This merchant is interested in my well-being, not just its own.		**F7**. My colleagues are interested in my professional well-being, not just their own.
Trust in Merchant – Integrity	*This merchant is truthful in its dealings with me.*	Trust in colleagues' integrity	**F8**. My colleagues are truthful in their contact with me by actively exposing the whole truth on any work-related matter.
	I would characterize this merchant as honest.		**F9**. I would characterize my colleagues as honest by not telling lies.
	This merchant would keep its commitments.		**F10**. My colleagues would keep their verbal commitments.
	This merchant is sincere and genuine.		**F11**. My colleagues are sincere and genuine.
Trust in Website – Capability	*I think this website has the functionality I need.*	Trust in company's software capability	**F12**. My company's software has the functionality I need.
	This website has the ability to do what I want it to do.		**F13** My company's software has the ability to do what I want it to do
	Overall, this website has the capabilities I need.		**F14**. Overall, my company's software has the capabilities I need.
Trust in Website – Reliability	*I think this website is very reliable.*	Trust in company's software reliability	**F15**. My company's software is very reliable.
	To me, this website is dependable.		**F16**. I can depend on the software when I perform/certify maintenance tasks.
	This website performs in a predictable way.		**F17**. This software performs in a predictable way.
Trust in Merchant – Competence	*I believe this merchant is effective in assisting and fulfilling my purchases.*	Trust in managers-subordinates' competence	**G1**. My subordinates are effective in assisting and fulfilling my expectations in our collaboration.
	This merchant performs its role of e-vendor very well.		**G2**. My subordinates perform their duties very well.
	Overall, this merchant is a capable and proficient e-vendor.		**G3**. Overall, my subordinates are capable and proficient technical staff.
	In general, this merchant is very knowledgeable about the business it operates.		**G4**. In general, my subordinates are knowledgeable about our organisation.
Trust in Merchant – Benevolence	*I believe that this merchant would act in my best interest.*	Trust in managers-subordinates' benevolence	**G5**. My subordinates act in the best interest of the project.
	If I required help, this merchant would do its best to help me.		**G6**. If I required assistance, my subordinates would do their best to help me.
	This merchant is interested in my well-being, not just its own.		**G7**. My subordinates are interested in my professional well-being, not just their own.
Trust in Merchant – Integrity	*This merchant is truthful in its dealings with me.*	Trust in managers-subordinates' integrity	**G8**. My subordinates are truthful in their contact with me by actively exposing the whole truth on a matter.
	I would characterize this merchant as honest.		**G9**. I would characterize my subordinates as honest by not telling lies.
	This merchant would keep its commitments.		**G10**. My subordinates would keep their commitments.
	This merchant is sincere and genuine.		**G11**. My subordinates are sincere and genuine.

Following this adaptation, an experts’ evaluation process was conducted to examine the appropriateness of adaptations (modifications). This additional stage was performed to suit the context of this study, test the content validity of scores and check if any further improvement was necessary on the questions (Creswell, 2014). For this purpose, three aviation maintenance professionals were selected. Their background included many years of experience in maintenance practice and instruction (as technical trainers). Their recommendations for the improvement of the questions were thoroughly assessed and implemented in the questionnaire, as they were found to be constructive.

The content of the Trust Constructs and Measures Questionnaire used are presented in Table 3.4, where items in section F ‘Trust’ are addressed to all aviation maintenance professionals and that of section G ‘Trust - Only for managers/supervisors’ to supervisors/managers only. The items were grouped, forming 8 constructs, as were introduced by Li et al. (2012). These constructs are: ‘trust in colleagues’ competence’, ‘trust in colleagues’ benevolence’, ‘trust in colleagues’ integrity’, ‘trust in company's software capability’, ‘trust in company's software reliability’, ‘trust in managers-subordinates’ competence’, ‘trust in managers-subordinates’ benevolence’ and ‘trust in managers-subordinates’ integrity’. However, since two of the three items forming the construct: ‘trust in company's software reliability’, were not used in the statistical analysis, a new single construct was formed with the four remaining questions about software: ‘trust in company's software capability’. All items are assigned a 7-point Likert scale when used for surveys. Sections F and G use the coding: 1 = ‘Strongly Disagree’, 2 = ‘Disagree’, 3 = ‘Somewhat Disagree’, 4 = ‘Neither’, 5 = ‘Somewhat Agree’, 6 = ‘Agree’ and 7 = ‘Strongly Agree’.

Table 3.4 Content of the Trust Constructs and Measures Questionnaire.

Section F: Trust	
F1	My colleagues fulfil my expectations in our collaboration.
F2	My colleagues perform their duties very well.
F3	Overall, my colleagues are capable and proficient technical staff.
F4	In general, my colleagues are knowledgeable about our organisation.
F5	My colleagues act in the best interest of the project.
F6	If I required assistance, my colleagues would do their best to help me.
F7	My colleagues are interested in my professional well-being, not just their own.
F8	My colleagues are truthful in their contact with me by actively exposing the whole truth on any work-related matter.
F9	I would characterize my colleagues as honest by not telling lies.
F10	My colleagues would keep their verbal commitments.
F11	My colleagues are sincere and genuine.
F12	My company's software has the functionality I need.
F13	My company's software has the ability to do what I want it to do.
F14	Overall, my company's software has the capabilities I need.
F15	My company's software is very reliable.
F16	I can depend on the software when I perform/certify maintenance tasks.
F17	This software performs in a predictable way.
F18	Are you a supervisor / manager?
Section G: Trust - Only for managers / supervisors	
G1	My subordinates are effective in assisting and fulfilling my expectations in our collaboration.
G2	My subordinates perform their duties very well.
G3	Overall, my subordinates are capable and proficient technical staff.
G4	In general, my subordinates are knowledgeable about our organisation.
G5	My subordinates act in the best interest of the project.
G6	If I required assistance, my subordinates would do their best to help me.
G7	My subordinates are interested in my professional well-being, not just their own.
G8	My subordinates are truthful in their contact with me by actively exposing the whole truth on a matter.
G9	I would characterize my subordinates as honest by not telling lies.
G10	My subordinates would keep their commitments.
G11	My subordinates are sincere and genuine.

3.3.1.3 Complete Question Set

The complete Communication and Trust Question Set, as discussed, is comprised of the following parts:

- Section A ‘Demographic information of the participants ‘;
- Section B ‘General Questions’;
- Sections C, D and E: ‘Communication Satisfaction Questionnaire’;
- Sections F and G: ‘Trust Constructs and Measures Questionnaire’.

The Section A ‘Demographic’ and B ‘General Questions’ items are shown in Table 3.5.

Table 3.5 Content of the ‘Demographic’ and ‘General Questions’ sections (A and B correspondingly) of the Communication and Trust Question Set.

Section A: Demographic information of the participants	
A1	My current post and duties require me to exercise my aircraft maintenance license privileges.
A2	My company is approved by .... to perform and certify maintenance.
A3	My experience with my current company is: less than 6 months 6 months or more
A4	I have a total of .... years of experience in aviation maintenance.
Section B: General Questions	
B1	How satisfied are you with your job?
B2	In the past 6 months, what has happened to your level of satisfaction?

These items (questions) collected information on the participants’ longevity of employment with current organisation, type of license and regulative authority under current employment, position. The available (answers) for all items were:

- A1 = ‘Yes’ or ‘No’;
- A2 = ‘EASA’, ‘FAA’, ‘CASA’ and ‘Other’;
- A3 = ‘Less than 6 months’ or ‘6 months or more’
- A4: This was a free field;
- B1: A 7-point Likert scale with the following coding: 1 = ‘Very Dissatisfied’, 2 = ‘Dissatisfied’, 3 = ‘Somewhat Dissatisfied’, 4 = ‘Neither’, 5 = ‘Somewhat Satisfied’, 6 = ‘Satisfied’ and 7 = ‘Very Satisfied’;
- B2: ‘Gone up’, ‘Stayed the same’ and Gone done’

The longevity of employment question was expected to separate the sample in two groups regarding their experience:

- The experienced group (6 months of experience and more with current employer);
- The newly recruited (less than 6 months with current employer).

The comparison of the results of the Trust Constructs and Measures Questionnaire items are essential in any observation of the *high initial trust levels* formation within the newly recruited group (Hernandez & Santos, 2010; McKnight et al., 1998). According to McKnight et al. "…*initial trust*, because the parties have not worked together long enough to develop an interaction history" therefore, for the scope of this research the group of employees with experience up to 6 months was selected to measure the initial levels of trust. A maximum period of six months' experience enables a sufficient sample size to be used effectively in statistical analysis, as well as to set an amount of time that employees would not be yet familiar with all their company's systems.

3.3.2 Content Analysis of Accident and Incident Investigation Reports

The first step in this study is to answer Research Question 1 'Are trust and communication detectable in aviation maintenance employees?'. These general and open-ended research questions are appropriately answered though qualitative research methods (Leedy & Ormrod, 2013). At this stage, the information must have been either directly observable or measurable from the professionals that are involved in aviation maintenance and must be obtained through a technique that reveals this information in the most reliable way. A suitable technique to use for this purpose is content analysis (Fraenkel & Wallen, 2003), as it is the most appropriate tool in identifying specific information in an area or a topic. This technique is usually employed to test research questions which are general and open-ended and based on "forms of human communication" notion (Leedy & Ormrod, 2013, p. 148), as in the case of accident and incident investigation reports (as discussed in the sequel).

Since communication and trust have been associated with aviation safety, a reliable source to collect information on the two traits would be from accident and incident investigation reports. These reports reflect a systematic investigation process by a team of aviation experts, who, over an extended period, investigate, analyse and present in a holistic way all contributing factors of an aviation safety occurrence. This phase's aim is to collect descriptive information about a specific area, namely, to explore the association between trust and communication by identifying these traits in aviation safety occurrences.

3.3.2.1 Data Location and Units Specification

Aviation accident and incident investigation reports are real-life sources to obtain information and data about the observation of communication and trust in aviation maintenance. Aviation is a highly regulated global industry which follows global norms and trends in its operation. Every country with an aviation system in place, has developed a formal accident/incident investigation board, which is also required to make publicly available all final reports. The objective of this process is to enable transparency and promote safe practice in all fields of the aviation industry. Each board usually maintains a dedicated online database, available in the public domain, in which the reports are stored and can be downloaded freely.

In order to proceed with the content analysis, the units of this analysis must be determined (Fraenkel & Wallen, 2003). This means that there need to be specific words and/or phrases acknowledged reflecting the meaning of communication and trust in the database of this research. This is a process that helps in the applicability (transferability of the observed values to other domains/industries with similar results) and consistency (ability by other researchers in the replication of the same research) of this technique. Therefore, the reports were firstly scanned to locate the words 'communication' and 'trust'. Further on, the items contained in sections C, D, E, F and G of the Communication and Trust Question Set were used to identify the corresponding issues, with

- The Communication Satisfaction Questionnaire items identifying underlying communication issues and
- The Trust Constructs and Measures Questionnaire items identifying trust issues.

3.3.2.2 Sampling Technique

The collected reports are dealing with accidents and incidents attributed to a technical error due to inappropriate maintenance practice. The content analysis method was selected to enable a thorough investigation of the existence of both communication and trust in real safety occurrences within aviation maintenance practice. Content analysis is usually employed as a qualitative method, which can be useful when an in-depth examination of a body of material is required to identify and analyse specific traits. This in-depth analysis does not necessarily demand a great volume of material to be assembled and review and for the purpose of this process it can be equally served by examining a smaller representative sample (Leedy & Ormrod, 2013).

Since the main goal of this study is to identify the co-existence of communication and trust as preconditions in aviation maintenance occurrences, it was possible to work with a smaller but still representative body of material. Therefore, the large volume of data available online (accident and incident investigation reports) only necessitated the selection of a smaller number of different investigation boards out of the total number in existence around the world (Leedy & Ormrod, 2013). Several accident investigation boards/authorities were selected, applying the following criteria:

- The reports should be in the English language;
- The final body of material would include reports from around the world; therefore, the investigation boards selected included countries with diverse population size, culture and regulatory framework;
- Reports on accidents and incidents that occurred in the last ten years. This criterion was chosen on the basis that the conditions of the maintenance operations when these safety occurrences took place reflected current or as close as possible working conditions (with the latest safety provisions and human factors training in place). It is noted that the aviation industry has been introduced to new technology and modern/updated procedures in the recent years and human factors training has been implemented in many aviation authorities around the world (European Aviation Safety Agency, 2015).

The volume of reports to be investigated was large, as there were many accidents and incidents investigations reports issued by these boards, providing detailed, and in several cases, large pieces of documentation through the years. Thus, from this ten years’ time frame used as a filter, a smaller, yet representative, a sample of reports were selected to reflect different types of accidents and incidents and to cover various aspects of aviation maintenance. A thorough examination, with the use of the content analysis method, was performed on the reports to identify communication and trust elements in the selected range of aviation safety occurrences.

3.3.2.3 Data Analysis

The data analysis of the content analysis method is a crucial step in this process. All accident and incident investigation reports that were selected were thoroughly scrutinised to identify the words ‘communication’ and ‘trust’. In the cases that there was no direct reference to communication and trust, the reports were analysed against the Communication and Trust Question Set items to identify and tabulate communication and trust (Leedy & Ormrod, 2013). After the tabulation, descriptive statistics were used to show the frequencies of communication and trust in the accident and incident investigation reports.

3.3.3 Content Analysis of Human Factors Training Curriculum and Material

The next step in this study is to answer Research Question 2: ‘Are communication and trust covered in aviation maintenance human factors basic training?’. As with Research Question 1, this is a general and open-ended research question and on the basis of “forms of human communication”, which can be answered by employing qualitative research methods (Leedy & Ormrod, 2013). The most suitable way to do that is by obtaining all the information needed directly from approved aviation maintenance training organisations and sources. At this stage, the information must be either directly observable or measurable and must come through a technique that reveals this information in the most reliable way. An appropriate technique to be utilised is the content analysis (Fraenkel & Wallen, 2003), as it is a tool capable to identify specific information in an area or a topic.

Since communication and trust have been associated with aviation safety, a reliable source of information on the two traits would be training material approved by aviation regulatory authorities around the world (e.g. EASA, FAA, CASA, etc). These authorities regulate, among others, aviation maintenance training in every aspect (training organisations, curriculum, examinations, etc). Therefore, the training curriculum and the content of the approved training material adhere to aviation maintenance training regulations within the regulatory authority's jurisdiction.

3.3.3.1 Data Location and Units Specification

The identification of suitable approved training material for the content analysis requires the assembling of information on human factors basic training under different aviation regulatory frameworks around the world. A limitation to the assembly of the relevant information (rules, documentation, authorities' website, training material, etc) is the language they are written in, which needs to be English. This examination was conducted to identify the existence of communication and trust in aviation maintenance basic training. The following four major aviation regulatory authorities were selected for this examination:

- **European Aviation Safety Agency (EASA)**, European Union, 6,252,643 (16.9% of world) registered carrier departures worldwide (The World Bank, 2018): Human factors training is a mandatory requirement in aviation maintenance basic training (European Union Aviation Safety Agency, 2014).
- **Federal Aviation Administration (FAA)**, USA, 9,879,630 (26.7% of world) registered carrier departures worldwide (The World Bank, 2018): Human factors training is not a mandatory requirement in aviation maintenance basic training (Federal Aviation Administration, 2015).
- **Directorate General of Civil Aviation (DGCA)**, India, 1,200,111 (3.2% of world) registered carrier departures worldwide (The World Bank, 2018): Human factors training is a mandatory requirement in aviation maintenance basic training (DGCA has mirrored the curriculum of EASA) (Directorate General Of Civil Aviation, 2019).
- **Civil Aviation Safety Authority (CASA)**, Australia, 665,384 (1.8% of world) registered carrier departures worldwide (The World Bank, 2018): Human factors training is a mandatory requirement in aviation maintenance basic training (CASA has mirrored the curriculum of EASA) (Civil Aviation Safety Authority, 2018).

It is noted that FAA does not stipulate mandatory human factors training in basic training. Therefore, this limits the analysis to approved training material obtained from the other three regulatory regimes (EASA, DGCA and CASA), for the purposes of testing Research Question 2. After closer examination, all authorities use the EASA curriculum for their maintenance human factors training. This is contained in the EASA Part-66 regulation for Module 9 ‘Human Factors’ (European Aviation Safety Agency, 2014) and it has been used in the content analysis method.

In order to proceed with the content analysis, the units of this analysis must be determined (Fraenkel & Wallen, 2003). This means that there need to be specific words and/or phrases acknowledged reflecting the meaning of communication and trust in the database of this research. This is a process that assists in the applicability (transferability of the observed values to other domains/industries with similar results) and consistency (ability by other researchers in the replication of the same research) of this technique. Therefore, the training curriculum and the training material were scanned to locate the words ‘communication’ and ‘trust’. Further on, the items contained in sections C, D, E, F and G of the Communication and Trust Question Set were used to identify the corresponding issues, with:

- The Communication Satisfaction Questionnaire items identifying underlying communication issues and
- The Trust Constructs and Measures Questionnaire items identifying trust issues.

3.3.3.2 Sampling Technique

Since the curriculum of EASA, DGCA and CASA is the same (that of EASA) the training material that is selected, are two EASA Part-66 Module 9 ‘Human Factors’ approved coursebooks. These coursebooks are used for the basic training of Category A ‘Aircraft Maintenance Mechanic’ and Category B ‘Aircraft Maintenance Technician’ aviation maintenance staff. It is noted that both coursebooks are used by different EASA Part-147 maintenance training organisations. Usually, the EASA maintenance training organisations that provide basic maintenance training, develop their own internal course material which is then approved by an EASA competent aviation authority. Therefore, very few published and publicly available EASA Part-66 Module 9 ‘Human Factors’ course material exist. This, in turn, has limited the selection to only two coursebooks. However, as discussed in Chapter 4 ‘Results’, these two coursebooks were the adequate required body of material to answer Research Question 2 by employing the content analysis method.

3.3.3.3 Data Analysis

All material that was selected, was thoroughly scrutinised to identify communication and trust traits (Leedy & Ormrod, 2013). The whole process was divided into a manual word count technique (for the words ‘communication’ and ‘trust’) and then descriptive statistics were used. These descriptive statistics techniques showed the frequencies of communication and trust into the EASA Part-66 Module 9 ‘Human Factors’ curriculum and the approved training material (coursebooks) that were analysed for the purposes of this phase of the study.

The second phase of the data analysis proceeded into the in-depth examination of the EASA human factors training curriculum and the approved coursebook (training) material. This examination aimed towards the identification of the underlying communication and trust issues. Firstly, the curriculum was examined again to identify chapters/content that potentially cover communication and trust which, could be analysed further with the use of the items of the Communication and Trust Question Set. For this purpose, one of the most established and widely used tools in aviation maintenance was used, which is also included in the EASA approved material, the Dirty Dozen (Dupont, 1997), briefly discussed in Chapter 1 ‘Introduction’. The Dirty Dozen was utilising in a mapping exercise between the areas that could contain communication and trust elements and the items of the Communication and Trust Question Set.

The third phase was to proceed with the examination of both Module 9 ‘Human Factors’ coursebooks to identify which of the twelve factors of the Dirty Dozen were included in the course material. Using the previously developed mapping, of each of the twelve factors of the Dirty Dozen against the items of the Communication and Trust Question Set, this process has driven the indirect identification of the communication and trust factors in the course material, even when no direct reference existed to these. This three-step (phased) analysis technique identified all the direct, and concealed elements of communication and trust in the EASA approved basic human factors training material.

3.3.4 Survey

In quantitative designs, there are two major approaches that researchers select, the experimental and non-experimental. In experimental research, the researcher manipulates the conditions of a simulated environment that affects one group and then compares their scores with another group that had no interference with their environment by the researcher (Creswell, 2014).

Trust is a value that has already been observed in people, and more specifically in a certain group of employees, according to the *high initial trust levels* model by McKnight et al. (1998). The element that is missing is the measurement of these levels. Thus, the new element that can contribute to the body of knowledge would be the measurement of the levels of initial trust and not the experimental proof of the existence of initial trust (McKnight et al., 1998). Therefore, experimental techniques were not considered suitable for the investigation of the research hypotheses of this study. The same thinking is used with the measurement of effective communication as it is a factor already observed and indicated as to be fundamental in the maintenance domain (Balk & Bossenbroek, 2010; Bureau of Air Safety Investigation, 1997; Caldwell, 2005; Mattson et al., 2001). Consequently, experimental methods were not chosen for the examination of communication as well in this study.

An appropriate approach to research the hypotheses is to investigate these with the assistance of correlational design. Correlational design examines the relationship between two or more variables (Creswell, 2014). Usually, the tools utilised in such surveys are questionnaires, structured interviews or the combination of both, which enable the collection of data and the extract of results that can be applicable to the general population as well.

3.3.4.1 Data Collection Method

The data collection method used in this research is the survey method. Surveys are designed to examine a smaller part of the general population and project the results to the general population (Creswell, 2014). This helps the researcher to extract information on their behaviour, characteristics or attitudes. In this study, the survey used was the Communication and Trust Question Set, which helped to identify and measure trust and communication satisfaction among maintenance staff. This was part of the process of testing the study's hypotheses.

Personnel with various lengths of work experience were targeted at one point of time, so the survey was applied at this point of time, collecting all the required data needed to confirm or disprove the research hypotheses (Creswell, 2014). This process ensured the validity of the results for the selected point of time, that is representative of each employee's length of experience in the specific company. It is noted that the questionnaire (Communication and Trust Question Set) was provided in English, and no respondent required its translation into a different language.

In order to augment the response rate to the questionnaire, there are some important factors that were taken into account when designing and planning the distribution of the survey. Firstly, aesthetically, the material should look professional, neat and free from errors. Therefore, the questionnaire included high-quality graphics arts and was checked for grammar and syntax consistency. These aspects (cosmetic appearance and presentation accuracy) are critical to augment the response rates (Leedy & Ormrod, 2013). Secondly, considering the nature of aircraft maintenance operations, work in rotating shifts, noisy environment, strict deadlines, etc, the most appropriate mode of data collection was considered to be the internet (email communication). This allows the employees to answer at their convenience, in a non-stressful environment and timing. Moreover, this is a cost-effective and environmentally friendly way to conduct surveys, as no-cost is associated with printing or posting survey material.

In order to cover the requirements and to provide privacy to the participants, the LimeSurvey web-based tool was used. LimeSurvey is available via an institutional (University of Southern Queensland) subscription. LimeSurvey protects the participants' anonymity while assisting the researcher with the aesthetics of the questionnaires' graphics and design, in conjunction with ease of management of the survey.

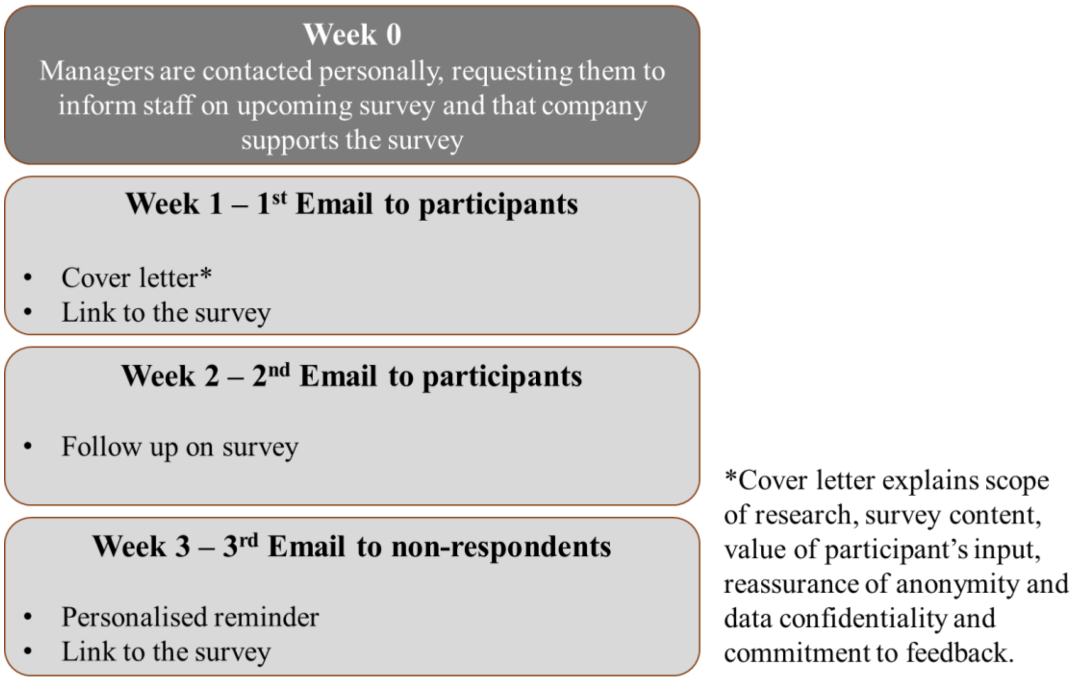
The participants received the invitation to participate by email. The email included a personalised cover letter, addressed to each participant, which outlined the:

- Scope, significance and purpose of this research;
- Value of each participant's input;
- Duration anticipated for the completion of the questionnaires;

- Anonymity guarantees and confidentiality of the data obtained;
- Commitment of offering feedback;
- Information on ethics approval.

The survey administration was structured in phases, each corresponding to a week. This phased approach is based on the process proposed by Creswell (2014). The participants received two weekly reminders in case they had not responded within a week of the initial invitation email. This practice was followed to gradually improve the response rate. The full survey administration process is summarised in Figure 3.5.

Figure 3.5 Survey administration process.



3.3.4.2 Sampling Technique

The respondents of the survey (Communication and Trust Question Set) were aircraft maintenance professionals from around the world, with working experience in civil and military aircraft maintenance organisations. For this study, snowball sampling was used, as firstly participants were selected both randomly and from an initial circle of colleagues and associates. Then, these participants were requested to propose additional participants from their wider circle of colleagues and associates.

Respondents were recruited by using two different approaches:

- **Recruitment Approach 1:** Respondents were contacted through their managers as their company agreed to participate in the survey and
- **Recruitment Approach 2:** Respondents were contacted directly by the principal investigator.

In Recruitment Approach 1, eleven aircraft maintenance organisations were contacted initially for participation, and five accepted the invitation. The questionnaire was sent to 121 aircraft maintenance employees, with full responses from 62, leading to a response rate at 51%, which is consistent with past research (Chan & Lai, 2017; Leedy & Ormrod, 2013). In Recruitment Approach 2, another 380 aircraft maintenance employees were contacted directly by the principal investigator, with full responses from 197 giving a response rate of 52%. In total 259 fully answered (Communication and Trust Question Set) questionnaires were collected, while in total 271 questionnaires were used in SPSS for statistical analysis. This was determined by the set of items to be analysed and the statistical techniques to be used at each step of the analysis (259 fully and 12 partially answered).

3.3.4.3 Data Analysis

The quantitative analysis of the responses to the questionnaire was conducted using the IBM SPSS Statistics 25.0.0 software. A correlational research design was selected to evaluate the relationship between the two traits (communication satisfaction and trust) and avoid implying any causational relationship in any way (Fraenkel & Wallen, 2003). Following data screening, to address any anomalies, the reliability of each construct, communication satisfaction and trust, were measured using the Cronbach's alpha. This was followed by descriptive statistics, correlations between variables, t-tests and analyses of variance (ANOVA).

To assist the reader in understanding the statistical sections of this research study, a brief description of all statistical tools (terms, tests, methods, etc) is provided:

General statistical terms

- **Snowball sampling** is the survey recruitment technique where research participants are requested to recruit other participants for a test or study. It is used where potential participants are hard to find.
- **Descriptive statistical analysis**. A synoptic statistical process that quantitatively describes or summarises features of a collection of information.
- The **null hypothesis** is the hypothesis that there is no significant difference between specified groups.
- **Mean score (M)** is the arithmetic average of a set of given numbers.
- **Standard Deviation (SD)** is a measure that is used to quantify the amount of variation or dispersion of a set of data values. A low standard deviation indicates that the data points tend to be close to the mean the set, while a high standard deviation indicates that the data points are spread out over a wider range of values.

Statistical tests

- **Bivariate (Pearson) correlational methods (r).** It is a measure of linear (straight line) relationships between two variables. Generally describes the simultaneous effect of two or more phenomena; therefore, for this reason, they are linked. A positive r value indicates a positive relationship between the variables, while a negative r value indicates a negative relation.
- **Independent samples t-test**. An inferential statistical test to treat the relevant data and compare the means, to identify if there is statistical evidence to support whether the two compared groups' means are statistically different or not.
- **Hedge's g.** It indicates the effect size of the difference in means (how much one group differs from another group) due to the large difference in sample sizes. Hedge's g is used when sample sizes are very small (<20).
- **Mann-Whitney U test**. A non-parametric test used to assess for significant differences in a scale or ordinal dependent variable by a single dichotomous independent variable. This test is used when a large difference in sample sizes between the examined groups exist and in this study was used to validate results obtained from the independent samples t-tests.

- **One-way analysis of variance (ANOVA).** A statistical method that compares the means of the research's target groups to identify if any of those means are statistically different from the others. This method is used to compare thee or more means of groups that are independent (unrelated) with each other. It specifically tests the null hypothesis $H0=\mu 1=\mu 2=\mu 3=...\mu \kappa$. ($H0$ = null hypothesis, μ = group mean, κ = number of groups). In the case that one-way ANOVA results in the significant difference between some of the groups, the alternative hypothesis is accepted (HA) therefore, at least two of the examined groups appear to have significantly different means.
- **Cohen's d** values were used to measure the effect sizes of differences between different groups of participants, to verify the results of the ANOVA.
- **Bonferroni post hoc test (F).** It is used to treat the relevant data and compare the means, to identify if there is statistical evidence to support whether multiple compared groups' means are statistically different or not. The Bonferroni test is selected to avoid the significant results increases in each test run, due to the simultaneous statistical testing of the multiple groups.
- **Post hoc LSD** tests are used to identify the groups of means with significant statistical differences, as this significant difference was shown at the one-way ANOVA test.
- **Cronbach's alpha** is a function of the number of items in a test, the average covariance between item-pairs, and the variance of the total score. It is used to estimate the reliability of psychometric tests.
- **Harman's one factor analysis**. A technique to identify the existence or absence of the common method bias.

Statistical representation methods

- **Scatterplot** is a type of plot or mathematical diagram using Cartesian coordinates to display values for typically two variables for a set of data. The scatterplot is used for the visualisation of the relationship between two variables.
- The **error bar charts** are graphical representations of the variability of data and used on graphs to indicate the error or uncertainty in a reported measurement. They provide a general representation of how precise a

measurement is, or conversely, how far from the reported value the true (error free) value might be.

The complete set of the statistical analysis methods used for each of the research hypotheses is described in detail in the following sections. These explain the technical aspects of each method, in connection to the examination (answer) of the research hypotheses of this study.

Research Hypothesis 1 ***(a) Aviation maintenance employees' levels of interpersonal trust towards their colleagues has a positive association with their communication satisfaction; and (b) supervisors/managers' levels of interpersonal trust towards their subordinates has a positive association with their communication satisfaction.***	
Statistical Analysis Methods Used	This is explored with correlational methods. Using these methods, the extent of the differences between two traits or variables and their relationship are investigated. The bivariate (Pearson) correlation was selected to treat the relevant data and determine whether the two variables are related. The results are plotted on a scatterplot for visualisation and to allow for easier identification of the relationship between the two variables: **communication satisfaction** and **interpersonal trust** for **all aviation maintenance employees among them**, and the **supervisors/managers** towards their **subordinates**.

Research Hypothesis 2 ***(a) Employees' trust towards the company's software has a positive association with their Communication satisfaction; and (b) supervisors/managers' trust towards the company's software has a positive association with their communication satisfaction.***	
Statistical Analysis Methods Used	This is explored with correlational methods. Using these methods, the extent of the differences between two traits or variables and the relationship between these differences are investigated. The bivariate (Pearson) correlation was selected to treat the relevant data and determine whether the two variables are related. The results are plotted on a scatterplot for visualisation and to allow for easier identification of the relationship between the two variables: **communication satisfaction** and **trust** towards the **company's software** for **all aviation maintenance employees** and the **supervisors/managers**.

Research Hypothesis 3 ***(a) Subordinates' levels of interpersonal trust has a positive association with their Communication satisfaction; and (b) subordinates' trust towards the company's software has a positive association with their CS.***	
Statistical Analysis Methods Used	This is explored with correlational methods. Using these methods, the extent of the differences between two traits or variables and the relationship between these differences are investigated. The bivariate (Pearson) correlation was selected to treat the relevant data and determine whether the two variables are related. The results are plotted on a scatterplot for visualisation and to allow for easier identification of the relationship between the two variables: **communication satisfaction** and **interpersonal trust** for the **aviation maintenance subordinates** and **communication satisfaction** and **trust** towards the **company's software** for the **aviation maintenance subordinates**.

Research Hypothesis 4 ***High initial trust levels are detectable in (a) interpersonal trust and (b) company's software trust to newly recruited maintenance employees.***	
Statistical Analysis Methods Used	Due to the substantial difference in sample sizes of the two groups, the use of descriptive statistical analysis was decided to be the most effective method to treat this set of data. A comparison between the **means of each group** is conducted and is used as an indicator of possible support of both parts of Research Hypothesis 4.

Since the snowball sampling was used, the Harman's one-factor analysis was performed to determine the existence or absence of the common method bias. This analysis identified that the largest single factor explained less than 50% of the variance, i.e. 41%. Therefore, no significant common method bias was identified in this research project.

Regarding the Communication Satisfaction Questionnaire, since this is an established questionnaire that has been used extensively by many other researchers in the past, the statistical analysis method was selected from those methods successfully employed in other past studies. In both the Trust Constructs and Measures Questionnaire and the

Communication Satisfaction Questionnaire the data analysis should compare and contrast the results in the aviation maintenance industry against other industries researched so far, e.g. hospitality industry (Carrière & Bourque, 2009), schools (Zwijze-Koning & De Menno, 2007) automobile industry (Jalalkamali et al., 2016). By analysing the data in a similar way, this research study is contributing directly to the relevant body of knowledge, by reinforcing the questionnaire's validity and reliability (broadening of the sample is broadened). Moreover, this is the first use of the Communication Satisfaction Questionnaire in the aviation industry, which can offer useful conclusions about the specific characteristics of communication within organisations operating in this industry.

Apart from the research hypotheses that were recognised and set at the early stages of this research projects, the nature (different categories of licences, experience, military/civil personnel, etc) of the data allowed further statistical analysis to be conducted. This process assisted in the in-depth analysis and understanding of the association under investigation and contributed greatly to the general scope of this research project. The statistical analyses used in this section, which were conducted beyond the exploration of the research hypotheses, are presented below in detail and each observation is tabulated to the specific method used (Additional Observations).

<table>
<tr><th colspan="2">Additional Observation 1

Differences in the means of communication satisfaction and trust scores for civil aviation maintenance employees when compared with their military counterparts.</th></tr>
<tr><td>Statistical Analysis Methods Used</td><td>The independent samples t-test was selected to treat the relevant data and compare the means, to identify if there is statistical evidence to support whether the two compared groups' means are statistically different or not.

Hedge's g is used here as well, to indicate effect size of the difference in means due to the large difference in sample sizes between the military and civil employees.

Due to the large difference in sample sizes between the two groups of employees, Mann-Whitney U tests were conducted as well to validate the results of the two previous methods used.

The results are graphically represented on error bar charts for visualisation and to allow for easier identification of the relationship between the three scores: overall communication satisfaction score, interpersonal trust score and software trust score for the two groups (civil and military aviation maintenance personnel).</td></tr>
</table>

Additional Observation 2 ***Differences in the means of communication satisfaction and trust scores for managers compared with subordinates in aviation maintenance.***	
Statistical Analysis Methods Used	The independent samples t-test was selected to treat the relevant data and compare the means, to identify if there is statistical evidence to support whether the two compared groups' means are statistically different or not. Cohen's d values were used to measure effect sizes of differences between managers and subordinates on the three traits, to verify the results of the independent samples t-test. The results are graphically represented on error bar charts for visualisation and to allow for an easier identification of the relationship between the three scores: mean overall **communication satisfaction** score, **interpersonal trust** score and **software trust** score for **the two groups** (**managers** and **subordinates**).

Additional Observation 3 ***Differences in traits of communication satisfaction and trust amongst four groups based on years of experience (0 to 9.5, 10 to 19.5, 20 to 29.5 and 30 and more).***	
Statistical Analysis Methods Used	The one-way analysis of variance (ANOVA) was selected to treat the relevant data and compare the means, to identify if there is statistical evidence to support whether these four compared groups' means are statistically different or not. Cohen's d values were used to measure effect sizes of differences between managers and subordinates on the three traits, to verify the results of the ANOVA. The results are graphically represented on error bar charts for visualisation and to allow easier identification of the relationship between the three scores: overall **communication satisfaction** score, **interpersonal trust** score and **software trust** score for the **four groups** based on **years of experience**.

<table>
<tr><td colspan="2">Additional Observation 4

Differences in the traits of communication satisfaction and trust among six different groups of the employees, based on the type of license held (no license, EASA, FAA, CASA, multiple licenses, military).</td></tr>
<tr><td>Statistical Analysis Methods Used</td><td>The one-way analysis of variance (ANOVA), using the Bonferroni post hoc test, was selected to treat the relevant data and compare the means, to identify if there is statistical evidence to support whether these six compared groups' means are statistically different or not. The Bonferroni test is selected to avoid the significant results increases in each test run, due to the simultaneous statistical testing of the six groups.

Hedge's g is used here as well, to indicate effect size of the difference in means due to the large difference in sample sizes between the different groups of employees, based on the type of license held.

The results are graphically represented on error bar charts for visualisation to allow for easier identification of the relationship between the three scores: overall communication satisfaction score, interpersonal trust score and software trust score for the six groups based on the type of license held.</td></tr>
</table>

3.3.4.4 Ethical Considerations

A fundamental part of any research project is the ethical considerations. Every researcher must comply with the ten principles of ethical considerations, as they have been formed after extensive research in ethical guidelines of nine professional social sciences research associations (Bryman & Bell 2007). Having in mind these principles, this study was designed and implemented to meet the requirements of the National Statement on Ethical Conduct in Human Research (2007) and a full ethical approval has been granted by the University of Southern Queensland (approval No. H17REA156). The questionnaire and any material that was distributed to the participants included appropriate, a polite non-discriminatory language that assured the researcher's and the participants' dignity. There was also care in the distribution of the questionnaires through an online tool (LimeSurvey) which protected the anonymity of the participants and as a result, made them feel reassured and confident for their participation. The data collected were treated securely, and no person other than those authorised by the University of Southern Queensland had access to them. It is also noted that the highest level of objectivity in all aspects of this study was ensured, throughout all facets of the research.

CHAPTER 4 CONTENT ANALYSIS AND SURVEY RESULTS

4.1 Content Analysis of Accident and Incident Investigation Reports

4.1.1 Results

As per Chapter 3 ‘Research Methods’, the content analysis technique was used to answer Research Question 1: ‘Are trust and communication detectable in aviation maintenance?’. Content analysis was chosen for its capability for a thorough investigation of the existence of both communication and trust in real occurrences within aviation maintenance. As discussed in section 3.3.2.2 of Chapter 3, the selection of the accident and incident investigation reports would be performed by applying criteria in relation to the language, origin and recency of the report. When applying these criteria, the following accident and incident investigation authorities/bodies were shortlisted:

1. Komite National Keselamatan Transportasi (Republic of Indonesia);
2. Air Accident Investigation Unit (Ireland);
3. Australian Transport Safety Bureau (Australia);
4. Dutch Safety Board (Netherlands);
5. Air Accidents Investigation Board (UK);
6. National Transportation Safety Board (USA);
7. Directorate General of Civil Aviation (India);
8. Japan Transport Safety Board (Japan);
9. Gabinete de Precenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviarios (Portugal);
10. Accident Investigation Division (Hong Kong);
11. United States Air Force Accident Investigation Board (USA).

Initial filtering of the databases of these authorities/bodies was performed with the term ‘maintenance’, producing an extensive list of (100+) accidents/incidents. Thus, further shortlisting was necessary, in this case performed by searching in the internet for incidents/accidents considered as ‘high profile’ (based on their order of appearance in the google search engine results) and for reports containing substantial information (in terms of volume and detail) on the maintenance related causal factors. This shortlisting exercise identified the fifteen representative (for the purposes of this study) accidents/incidents selected for the content analysis. It is noted that an exhaustive investigation (involving a higher volume of reports) would not add more to the scope of this analysis, as the reports selected were able to reveal the existence of these two traits (communication and trust) and, most importantly, answer Research Question 1. The reports which were selected to be analysed corresponded to accidents, incidents or serious incidents that included maintenance error, are listed here:

- **Report 1 (R1):** Airbus A320-214, EI-GAL, 07/05/2019, Air Accident Investigation, Ireland (Serious Incident) (Air Accident Investigation Unit, 2019);
- **Report 2 (R2):** Airbus A320-216, PK-AXC, 30/11/2015, Komite National Keselamatan Transportasi, Republic of Indonesia (Accident) (Komite National Keselamatan Transportasi, 2015);
- **Report 3 (R3):** de Havilland Canada DHC 6-300, C-GSGF, 18/02/2016, Air Accident Investigation Unit, Ireland (Serious Incident) (Air Accident Investigation Unit, 2016);
- **Report 4 (R4):** Airbus A320, VH-VGZ, 22/03/2019, Australian Transport Safety Bureau, Australia (Incident) (Australian Transport Safety Bureau, 2019);
- **Report 5 (R5):** Bombardier DHC-8-Q402, G-JECP, 23/02/2017, , Dutch Safety Board, Netherlands (Accident) (The Dutch Safety Board, 2018);
- **Report 6 (R6):** Boeing 747-443, G-VROM, 01/10/2015, Air Accidents Investigation Board, UK (Serious Incident) (Air Accidents Investigation Branch, 2015a);
- **Report 7 (R7):** Airbus A330-243, A6-EYJ, 06/05/2016, Australian Transport Safety Bureau, Australia (Serious Incident) (Australia Transport Safety Bureau, 2016);
- **Report 8 (R8):** Boeing 767, N360AA, 07/12/2012, National Transportation Safety Board, USA (Incident) (National Transportation Safety Board, 2012);
- **Report 9 (R9):** Boeing 767, N669US, 28/09/2016, National Transportation Safety Board, USA (Incident) (National Transportation Safety Board, 2016);
- **Report 10 (R10):** Airbus A319, VT-SCQ, 16/09/2016, Directorate General of Civil Aviation, India (Accident) (Directorate General of Civil Aviation, 2016);

- **Report 11 (R11):** Boeing 737-800, B 18616, 21/08/2009, Japan Transport Safety Board, Japan (Accident) (Japan Transport Safety Board, 2009);
- **Report 12 (R12):** Airbus A319-131, G-EUOE, 14/07/2005, Air Accident Investigation Branch, UK (Accident) (Air Accidents Investigation Branch, 2015b);
- **Report 13 (R13):** Embraer 190-100LR, P4-KCJ, 02/05/2019, Gabinete de Precenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviarios, Portugal (Accident) (Gabinete de Precenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviarios, 2019);
- **Report 14 (R14):** Airbus A330-342, B-HLL, 03/07/2013, Accident Investigation Division, Hong Kong (Accident) (Accident Investigation Division, 2013);
- **Report 15 (R15):** Lockheed WC-130H, 65-0968, 09/10/2018, United States Air Force Accident Investigation Board, USA (Accident) (United States Air Force Accident Investigation Board, 2018).

Each report was thoroughly scanned for the keywords: ‘communication’ and ‘trust’. In the case that a keyword was found in the report this is mentioned accordingly. From the previous keywords, the only found was ‘communication’ (‘trust’ was not found in any report). In this case, the items of the Communication and Trust Question Set were used to identify any underlying communication or trust factor. The Communication Satisfaction Questionnaire items were used to identify underlying communication issues while the Trust Constructs and Measures Questionnaire items to locate trust issues. The preconditions for errors identified were mapped against the questionnaire items, with a detailed justification provided. The output of this identification and mapping exercise is presented in detail in the following sections. It is noted that direct quoting from the accident/incident investigation report is included in this analysis, in order to unveil the underlying issues related to communication and trust. An example of the full analysis performed is presented in section 4.1.1.1 for three of the reports (R3, R6 and R7), while for the remaining reports the results are presented for brevity in section 4.1.1.2 in a summarised way.

4.1.1.1 Examples of Full Analysis

Example 1: Report 3 (R3) - de Havilland Canada DHC 6-300, C-GSGF, 18/02/2016, Air Accident Investigation Unit, Ireland (Serious Incident)

Synopsis of the incident
"On take-off (…) the nose cone from the right-hand mission equipment pod fell from the aircraft (…). The Flight Crew experienced a significant amount of yaw to the right which they felt through the flying controls. The aircraft (…) landed safely." (Air Accident Investigation Unit, 2016).

The contribution of maintenance in this incident was narrowed down to six distinct maintenance errors. These maintenance errors are presented below, with communication and trust factors recognised and analysed as contributing factors (based on the Communication and Trust Question Set).

R3.1 Precondition for Maintenance Error ***"…The personnel who carried out this check advised (…) that the Operator's standard practice calls for the fitting of flagging tape when parts are removed and that the flagging tape should only be removed following re-installation of the removed part(s)… The Operator informed the Investigation that at the time of the event the use of flagging tape was a standard practice but was not in the Operator's Policy Manual… (…) the personnel involved advised (…) that flagging tape was not fitted…" (Air Accident Investigation Unit, 2016)***	
Communication Factor Identified	The operator had the fitting of the flagging tape as a **standard practice** during the removal of parts. However, the investigation indicated the **lack of the relevant organisational policy** that would communicate this practice to the maintenance personnel. This indicates that the information about organisational policies and goals was not satisfactory, item **C3 'Information about organisational policies and goals'** of the Communication and Trust Question Set.

R3.2 Precondition for Maintenance Error ***"…The Operator's standard practice of attaching flagging tape to highlight when components are removed during maintenance was not followed..." (Air Accident Investigation Unit, 2016).***	
Trust Factor Identified	Maintenance personnel **failed to follow the company's standard practice**. This indicates that the maintenance personnel deviated from an expected good practice in their duties. Specifically, by using the Communication and Trust Question Set the following three items are identified in this failure: **F2 'My colleagues perform their duties very well'**, **F3 'Overall, my colleagues are capable and proficient technical staff'** and **F5 'My colleagues act in the best interest of the project'**. Items F2 and F3 fall in the construct of trust in colleagues' competence while item F5 falls in the construct of trust in colleagues' benevolence.

<table>
<tr><td colspan="2">R3.3 Precondition for Maintenance Error
“(…) during the EM Pod maintenance, while the nose cone was being re-installed, a fault was detected with its sensor system. Re-installation of the nose cone was halted pending identification of the cause of the fault and consequently only the top two nose cone retaining screws were re-installed. Troubleshooting subsequently traced the origin of the sensor problem to a location inboard of the pod and the fault was rectified. The Inspection was then completed but the 14 remaining nose cone retaining screws were not re-installed…” (Air Accident Investigation Unit, 2016).</td></tr>
<tr><td>Trust Factor Identified</td><td>Maintenance personnel failed to re-install the nose cone. This indicates that the maintenance personnel deviated from an expected good practice in their duties. Specifically, by using the Communication and Trust Question Set, the following three items are identified in this failure: F2 ‘My colleagues perform their duties very well’, F3 ‘Overall, my colleagues are capable and proficient technical staff’ and F5 ‘My colleagues act in the best interest of the project’. Items F2 and F3 fall in the construct of trust in colleagues’ competence while item F5 falls in the construct of trust in colleagues’ benevolence.</td></tr>
<tr><td>Communication Factor Identified</td><td>Maintenance personnel involved in the re-installation of the nose cone, did not communicate that the 14 remaining nose cone retaining screws were not re-installed. This demonstrates issues in relation to items: D19 ‘The amount of communication in the organisation is about right’, D12 ‘Communication with my colleagues within the organisation is accurate and free flowing’ and D17 ‘The attitudes towards communication in the organisation are basically healthy’.</td></tr>
</table>

<table>
<tr><td colspan="2">R3.4 Precondition for Maintenance Error
“…The two maintenance engineers who were responsible for the maintenance carried out on the previous day also carried out a pre-flight check of the aircraft on the morning of the event. The Investigation noted that the Aircraft Technical Logbook (ATL) entry simply stated, “Supplemental Inspection 125 Hr requirements carried out as per MSA PAH-6656-DHC-6 – Satisfactory”. The engineers informed the Investigation that it would not have been clear to the pilots from the ATL that the EM pod nose cone had been removed…” (Air Accident Investigation Unit, 2016).</td></tr>
<tr><td>Communication Factor Identified</td><td>This statement by the two maintenance engineers, that the information passed to the pilots from the ATL was not clear, indicate that there were issues in the written communication among them. The communication problems identified here are in relation to items: D19 ‘The amount of communication in the organisation is about right’ and D12 ‘Communication with my colleagues within the organisation is accurate and free flowing’.</td></tr>
</table>

R3.5 Precondition for Maintenance Error **_"…AFMS No. SGL1298 prescribes, inter alia, the pre-flight Inspections to be carried out on the EM Pods. Of particular relevance to this Investigation is the requirement to "check that all visible attaching fasteners are installed and secure" …" (Air Accident Investigation Unit, 2016)._**	
Trust Factor Identified	In this instance, maintenance personnel failed to check the installation and security of all visible attaching fasteners. This indicates that the maintenance personnel deviated from an expected good practice in their duties. Specifically, by using Communication and Trust Question Set, the following three items are identified: **F2 'My colleagues perform their duties very well', F3 'Overall, my colleagues are capable and proficient technical staff'** and **F5 'My colleagues act in the best interest of the project'**. Items F2 and F3 fall in the construct of trust in colleagues' competence while item F5 falls in the construct of trust in colleagues' benevolence.

R3.6 Precondition for Maintenance Error **_"…The initial maintenance error was not detected during separate walkaround inspections by engineering personnel…" (Air Accident Investigation Unit, 2016)._**	
Trust Factor Identified	In this instance, maintenance personnel failed to detect this maintenance error, in the opportunity of the walkaround. This indicates that the maintenance personnel deviated from an expected good practice in their duties. Specifically, by using the Communication and Trust Question Set, the following three items are identified: **F2 'My colleagues perform their duties very well'**, **'Overall, my colleagues are capable and proficient technical staff** 'and **F5 'My colleagues act in the best interest of the project'**. Items F2 and F3 fall in the construct of trust in colleagues' competence while item F5 falls in the construct of trust in colleagues' benevolence.

Example 2: Report 6 (R6) - Boeing 747-443, G-VROM, 01/10/2015, Air Accidents Investigation Board, UK (Serious Incident)

Synopsis of the serious incident
"The aircraft departed (…) for a scheduled flight (…). Following retraction of the landing gear after take-off, low quantity and pressure warnings occurred on hydraulic system 4, due to a hydraulic fluid leak. The required checklists were completed, and the aircraft returned to land (…). As the landing gear extended during the approach, the right-wing landing gear struck the gear door, preventing the gear leg from fully deploying. The crew carried out a go-around and, following a period of troubleshooting and associated preparation, a non-normal landing was successfully completed. It was subsequently determined that the hydraulic retract actuator on the right-wing landing gear had been incorrectly installed." (Air Accidents Investigation Branch, 2015a).

R6.1 Precondition for Maintenance Error ***"…The maintenance teams tasked with the replacement of the gear actuator (…) faced a number of problems. They were not able to locate a number of the specialist tools required by the AMM, including the hoist which the manufacturer specified for safe lifting of the weight of the actuator whilst it was being manoeuvred into place…" (Air Accidents Investigation Branch, 2015a).***	
Trust Factor Identified	Maintenance personnel were unable to locate the tools required for their task. This incident shows their ignorance on their organisation specific equipment's availability and/or their location on its premises. This indicates that the maintenance personnel **deviated from an expected good practice** in their duties. Specifically, by using the Communication and Trust Question Set, the **F4 'In general, my colleagues are knowledgeable about our organisation'** item is identified in this failure. Item F4 falls in the construct of trust in colleagues' competence.
Communication Factor Identified	Maintenance personnel were not knowledgeable about the company's equipment availability. Therefore, the maintenance personnel **did not have the adequate information** to proceed with their task successfully, so the communication problem identified here is at the information about the requirements of the maintenance personnel's job, item **C8 'Information about the requirements of my job'** of the Communication and Trust Question Set.

R6.2 Precondition for Maintenance Error **_"…the maintenance team (…) elected not to use any form of mechanical support, thus greatly increasing the difficulty and risk associated with installing the replacement actuator. The result of this decision was that the task became so physically demanding that the maintenance team became entirely focused on just attaching the actuator to the aircraft, in order to relieve themselves of the 85 kg weight they had manually supported for over 30 minutes. As such, they had no remaining capacity to ensure they installed the actuator in the correct orientation. It was subsequently determined that they had rotated it 180° about its long axis during installation, effectively installing it upside down…" (Air Accidents Investigation Branch, 2015a)._**	
Trust Factor Identified	Maintenance personnel chose to use no mechanical support, putting themselves into an extreme physically challenging and error prone situation. This indicates that the maintenance personnel **deviated from an expected good practice** in their duties. Specifically, by using the Communication and Trust Question Set, the following three items are identified in this failure: **F2 'My colleagues perform their duties very well'**, **F3 'Overall, my colleagues are capable and proficient technical staff'** and **F5 'My colleagues act in the best interest of the project'**. Items F2 and F3 fall in the construct of trust in colleagues' competence while item F5 falls in the construct of trust in colleagues' benevolence.

R6.3 Precondition for Maintenance Error **_"…However, the team identified that even if the hoist had been available, the manual did not specify how to operate the sling, or how best to utilise it together with the hoist in the difficult task of manoeuvring the actuator through the wing structure surrounding the actuator location. The AMM is the main source of guidance for completing any maintenance task. If specific guidance is not found in the AMM, then engineers and technicians might develop improvised techniques to accomplish a task, particularly outside normal office support hours such as during night shifts…" (Air Accidents Investigation Branch, 2015a)._**	
Communication Factor Identified	Maintenance personnel were able to identify the lack of information provided in the manual about the usage of specific equipment. In this case, the maintenance personnel did not have the adequate information to proceed with their task successfully, so the communication problem identified here is in relation to items **C8 'Information about the requirements of my job'** and **D19 'The amount of communication in the organisation is about right'**.

Example 3: Report 7 (R7) - Airbus A330-243, A6-EYJ, 06/05/2016, Australian Transport Safety Bureau, Australia (Serious Incident)

Synopsis of the serious incident
" (…) Airbus A330 (…) landed at Brisbane airport and was taxied to the terminal. Approximately 2 hours later, the aircraft was pushed-back from the gate for the return flight (..). The captain rejected the initial take-off attempt after observing an airspeed indication failure (…). The aircraft taxied back to the terminal where troubleshooting was carried out, before being released back into service. During the second take-off roll, the crew became aware of an airspeed discrepancy (…). Once airborne, the crew declared a MAYDAY and (…) an overweight landing was carried out. Engineering inspection (…) found that the Captain's pitot probe was almost totally obstructed by an insect nest, consistent with mud-dauber wasp residue. The pitot obstruction had occurred during the 2-hour period that the aircraft was on the ground at Brisbane and was not detected during troubleshooting after the initial rejected take-off.…" (Australia Transport Safety Bureau, 2016).

R7.1 Precondition for Maintenance Error ***"…Pitot probe covers were not installed by maintenance staff during the period the aircraft was at the gate. The maintenance staff advised that the use of pitot covers was dependent on customer requirements and was not a standard practice. Operators can minimise the risk of pitot probe obstruction by consistently using pitot covers, even during short transit periods…" (Australia Transport Safety Bureau, 2016).***	
Trust Factor Identified	Maintenance personnel did not install pitot covers, resulting in the formation of the wasps' nest which caused the airspeed indication failure on the pilot's display. This indicates that the maintenance personnel **deviated from an expected good practice**. By using the Communication and Trust Question Set, the following three items from the Communication and Trust Question Set are identified: **F2 'My colleagues perform their duties very well'**, **F3 'Overall, my colleagues are capable and proficient technical staff'** and **F5 'My colleagues act in the best interest of the project'**. Items F2 and F3 fall in the construct of trust in colleagues' competence while item F5 falls in the construct of trust in colleagues' benevolence.
Communication Factor Identified	Maintenance personnel were aware that even on aircraft's short stays, the operators benefit from the use of the pitot covers. However, they did not apply it as a standard practice and this practice was dependent on the operator's requirements. In this case, the maintenance personnel **did not have the adequate information** to proceed with their task successfully, so the communication problem identified here is in relation to items: **C7 'Information about departmental policies and goals'**, **C8 'Information about the requirements of the maintenance personnel's job'** and **D19 'The amount of communication in the organisation is about right'**.

R7.2 Precondition for Maintenance Error ***"…Although no 'hard' (permanent) faults had been identified, the engineer, in consultation with the operator's Maintenance Control Centre considered that the best resolution would have been to make ADR 1 inoperative. However, this was not permitted under the MEL requirements for ETOPS16 dispatch. Therefore, the engineer transposed ADIRU 1 and 2 and performed a BITE test of both units. The aircraft was dispatched with the ADR part of ADIRU 2 inoperative (switched off) in accordance with the MEL. The FO's air data source was switched to ADIRU 3 and the captain's air data source remained switched to the normal (ADIRU 1) position. As a result, the blocked captain's pitot probe remained undetected and the aircraft was dispatched with only one of the three airspeed sources able to provide valid data…" (Australia Transport Safety Bureau, 2016).***	
Trust Factor Identified	maintenance personnel failed to detect the blocked captain's pitot at the troubleshooting that followed the initial rejected take-off. This indicates that the maintenance personnel **deviated from an expected good practice**. Specifically, by using the Communication and Trust Question Set, the following four items are identified: **F1 'My colleagues fulfil my expectations in our collaboration'**, **F2 'My colleagues perform their duties very well'**, **F3 'Overall, my colleagues are capable and proficient technical staff**' and **F5 'My colleagues act in the best interest of the project'**. Items F1, F2 and F3 fall in the construct of trust in colleagues' competence while item F5 falls in the construct of trust in colleagues' benevolence, see Table 4.1.

R7.3 Precondition for Maintenance Error ***"…The blocked captain's pitot probe was not detected by engineering staff after the initial rejected take-off. The relevant tasks in the trouble shooting manual did not specifically identify the pitot probe as a potential source of airspeed indication failure. [Safety issue] …" (Australia Transport Safety Bureau, 2016).***	
Trust Factor Identified	The relevant manual did not contain the specific information required to successful handling of the task. In this case, the maintenance personnel **did not have the adequate information** to proceed with their task successfully, so the communication problem identified here is in relation to items: **C7 'Information about departmental policies and goals'**, **C8 'The information about the requirements of the maintenance personnel's job'** and **D19 'The amount of communication in the organisation is about right**' of the Communication and Trust Question Set.

4.1.1.2 Summarised Results

The summarised results from the analysis of all (fifteen) accident and incident investigation reports are presented in Table 4.1. This table offers a quick view of the items of the Communication and Trust Question Set identified in these reports.

Table 4.1 Tabulation of the accident and incident investigation reports analysed.

No	Aircraft, Registration, Date, Accident Investigation Authority, Country (Type of Occurrence)	Preconditions for Maintenance Errors identified in Report	Trust Factor: Survey items that indicate the existence of trust issues	Communication Factor: Survey items that indicate the existence of communication issues
R1	Airbus A320-214, EI-GAL, 07/05/2019, Air Accident Investigation, Ireland (Serious Incident)	R1.1	F2, F3, F5	
		R1.2		C3
		R1.3	F2, F3, F5	
R2	Airbus A320-216, PK-AXC, 30/11/2015, Komite National Keselamatan Transportasi, Republic of Indonesia (Accident)	R2.1	F2, F3, F5	
		R2.2		D19, D8, C7
R3	de Havilland Canada DHC 6-300, C-GSGF, 18/02/2016, Air Accident Investigation Unit, Ireland (Serious Incident)	R3.1		C3
		R3.2	F2, F3, F5	
		R3.3	F2, F3, F5	D19, D12, D17
		R3.4		D19, D12
		R3.5	F2, F3, F5	
		R3.6	F2, F3, F5	
R4	Airbus A320, VH-VGZ, 22/03/2019, Australian Transport Safety Bureau, Australia (Incident)	R4.1	F2, F3, F5	D19, D12, D17
		R4.2	F2, F3, F5	D17
		R4.3	F2, F3, F5	D19, D17, D8, C7
		R4.4	F2, F3, F5	D19, D17, D8, C7
R5	Bombardier DHC-8-Q402, G-JECP, 23/02/2017, , Dutch Safety Board, Netherlands (Accident)	R5.1	F2, F3, F5	
		R5.2	F2, F3, F5	
		R5.3		D19, D17, D8, C7
R6	Boeing 747-443, G-VROM, 01/10/2015, Air Accidents Investigation Board, UK (Serious Incident)	R6.1	F4	C8
		R6.2	F2, F3, F5	
		R6.3		C8, D19
R7	Airbus A330-243, A6-EYJ, 06/05/2016, Australian Transport Safety Bureau, Australia (Serious Incident)	R7.1	F2, F3, F5	C7, C8, D19
		R7.2	F1, F2, F3, F5	
		R7.3		C7, C8, D19
R8	Boeing 767, N360AA, 07/12/2012, National Transportation Safety Board, USA (incident)	R8.1	F2, F3, F5	
		R8.2		C8, D19
R9	Boeing 767, N669US, 28/09/2016, National Transportation Safety Board, USA (Incident)	R9.1	F2, F3, F5	
		R9.2		C8, D19, D8
R10	Airbus A319, VT-SCQ, 16/09/2016, Directorate General of Civil Aviation, India (Accident)	R10.1	F2, F3, F5	
		R10.2		C8, D19, D8
R11	Boeing 737-800, B 18616, 21/08/2009, Japan Transport Safety Board, Japan (Accident)	R11.1	F2, F3, F5, F8, F9, F11	D19, D17, D8, D12
		R11.2		D19, C10, D8, C8
R12	Airbus A319-131, G-EUOE, 14/07/2005, Air Accident Investigation Branch, UK (Accident)	R12.1	F2, F3, F5	
		R12.2		D19, D17, D8, C7
		R12.3	F2, F3, F5	D19, D17, D8, D6
		R12.4	F2, F3, F5	
		R12.5		D19, D17, D6, D8
		R12.6		D19, D15, D17, D12, D3, D6
		R12.7		D19, D6, D17, D12, D3, D6
		R12.8	F1, F2, F4, F5, F7	
		R12.9	F1, F2, F4, F5, F7, F8, F11	D19, D2, C3, D8, D6, D17, C7, D15, D12, D3, D6
		R12.10	F12, F13, F14	
R13	Embraer 190-100LR, P4-KCJ, 02/05/2019, Gabinete de Precenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviarios, Portugal (Accident)	R13.1	F2, F3, F5	
		R13.2		D19, C8, D17, C3, D6, D8
		R13.3	F1, F2, F3, F5	D19, D17, D16, D12, D13, D15, D6
		R13.4	F1, F2, F3, F4, F5	D19, D17, C3, D6, D8, D12, D15, D2, D6, C7, D3
R14	Airbus A330-342, B-HLL, 03/07/2013, Accident Investigation Division, Hong Kong (Accident)	R14.1	F1, F2, F3, F4, F5	D19, D2, C3, D8, D6, D17, C7, D15, D12, D3, D6
		R14.2	F1, F2, F3, F4, F5	D19, D2, C3, D8, D6, D17, C7, D15, D12, D3, D6
		R14.3	F1, F2, F3, F4	D19, D2, C3, D8, D6, D17, C7, D15, D12, D3, D6
R15	Lockheed WC-130H, 65-0968, 09/10/2018, United States Air Force Accident Investigation Board, USA (Accident)	R15.1	F1, F2, F3, F4, F5	D19, D2, C3, D8, D6, D17, C7, D15, D12, D16, C1, C8, D3, D4, D6
		R15.2	F1, F2, F3, F4, F5, F8, F9, F11	D19, D2, C3, D8, D6, D17, C7, D15, D12, D16, C1, C8, D3, D4, D6
		R15.3	F1	D19, D17, D16, D12, D13, D15, D6
		R15.4	F1, F2, F3, F4	D19, D2, C3, D8, D6, D17, C7, D16, D15, D12, D3, D6

4.1.2 Discussion

Considering all data obtained from the content analysis (as summarised in Table 4.1), it stems that both trust and communication are detectable in the aviation maintenance sector. Therefore, based on these findings, a positive answer can be offered to Research Question 1. Trust and communication, as they are reported in the accident and incident investigation reports, are identified as distinct preconditions in the vast majority (78%) of the distinct maintenance errors. In six of the examined distinct maintenance errors (accounting to 14% of the total 42) trust only can be identified as a precondition to maintenance error, while communication is identified in just four distinct maintenance errors (corresponding to 8% of the errors analysed) (Table 4.2).

Table 4.2 Absolute number and percentage (%) of maintenance errors where trust, communication and combination of both identified as preconditions within the accident and incident investigation reports analysed.

Total Number of Distinct Maintenance Errors Analysed	**Distinct Maintenance Errors where … were identified as Precondition(s)**		
	Trust only	**Communication only**	**Trust and Communication**
42	**6**	**4**	**31**
	14%	8%	78%

Only 22% (out of the total forty-two errors analysed in this phase of the study) included solely one (communication or trust) as an error precondition and not both. It is, however, noted that these numerical results are not conclusive, as the investigation reports reflect the accident/incident investigators' exposition of evidence. This means that the investigators were not necessarily looking for 'communication' or 'trust' evidence; therefore, both factors may have not been exhaustively investigated (and subsequently reported).

The issues identified concerning trust were about interpersonal trust and software trust. The Trust Constructs and Measures Questionnaire items are grouped in different constructs, with each group indicating specific attributes of trust. Therefore, the specific characteristics identified here were trust towards colleagues' competence, integrity and benevolence and trust towards the company software's capability.

Regarding the communication satisfaction, the issues identified were in relation to satisfaction with the organisation's communication climate, their superiors, the organisation's integration, the media quality, the general organisational perspective and the horizontal informal communication. These are the wider groups of the Communication Satisfaction Questionnaire items, that were initially introduced by Downs and Hazen (1977) and can describe categorically the specific issues with communication satisfaction identified in these scenarios.

Nonetheless, the aim of the content analysis here is to identify qualitatively the co-existence of these two factors as maintenance error preconditions. Considering the limitation of this analysis method, which has been explained above, a positive answer may be offered to Research Question 1, since both factors were revealed through the technique and process employed.

4.2 Content Analysis of Human Factors Training Curriculum and Material

4.2.1 Results

The best way to answer Research Question 2 'Are communication and trust covered in aviation maintenance human factors basic training?' is to obtain all the required information directly from official/approved aviation maintenance training sources. Since it has been noted that the Federal Aviation Administration (FAA) does not include mandatory human factors training, it is the European Union Aviation Safety Agency (EASA), Directorate General of Civil Aviation, Government of India (DGCA) and the Civil Aviation Safety Authority (CASA) from which approved training material can be obtained for review. All three regulatory authorities practically share the same curriculum for their maintenance human factors training; thus, the analysis is performed on the EASA Part-66 Category A and B Module 9 'Human Factors' curriculum (Table 4.3).

Table 4.3 Curriculum of the EASA (2012) Part-66 Category A and B Module 9 ‘Human Factors’.

Chapter	Title	Content
9.1	**General**	The need to take human factors into account; Incidents attributable to human factors/human error; ‘Murphy's’ law.
9.2	**Human Performance and Limitations**	Vision; Hearing; Information processing; Attention and perception; Memory; Claustrophobia and physical access.
9.3	**Social Psychology**	Responsibility: individual and group; Motivation and de-motivation; Peer pressure; ‘Culture’ issues; Team working; Management, supervision and leadership.
9.4	**Factors Affecting Performance**	Fitness/health; Stress: domestic and work related; Time pressure and deadlines; Workload: overload and underload; Sleep and fatigue, shift work; Alcohol, medication, drug abuse.
9.5	**Physical Environment**	Noise and fumes; Illumination; Climate and temperature; Motion and vibration; Working environment.
9.6	**Tasks**	Physical work; Repetitive tasks; Visual inspection; Complex systems.
9.7	**Communication**	Within and between teams; Work logging and recording; Keeping up to date, currency; Dissemination of information.
9.8	**Human Error**	Error models and theories; Types of error in maintenance tasks; Implications of errors (i.e. accidents); Avoiding and managing errors.
9.9	**Hazards in the Workplace**	Recognising and avoiding hazards; Dealing with emergencies.

Aircraft maintenance training under the EASA framework is highly regulated with provisions of consistency and high quality in the delivered course material by all approved maintenance training organisations (commonly referred as EASA Part-147 organisations, reflecting the applicable regulatory set). As discussed in section 3.3.3.3 of Chapter 3, two coursebooks were selected for the content analysis, which were the following:

- **Coursebook 1:** ‘Module 9-Human Factors’ (by C. Strike), published in 2018 by Cardiff and Vale College in the UK (Strike, 2018);
- **Coursebook 2:** ‘Human factors for A level Certification, module 9’ (by N. Gold), published in 2015 by Aircraft Technical Book Company in the USA (Gold, 2015).

The first examination of these coursebooks determined that both followed the EASA curriculum, as expected. Furthermore, the content of both books was found to cover the curriculum in a similar way, having a comparable structure and content. Therefore, these two coursebooks were the adequate required body of material for answering Research Question 2 with the use of the content analysis technique.

The EASA curriculum and the two coursebooks were examined to locate the words ‘communication’ and ‘trust’. The EASA Part-66 Module 9 ‘Human Factors’ curriculum covers only the chapters and subchapters of the material approved to be taught. In the curriculum, the word ‘trust’ is not used while the word ‘communication’ is solely used in chapter seven (Communication) one time in the title of the chapter. The next step was to scan the two EASA Part-66 Module 9 coursebooks for the same words. The results were as follows:

- In Coursebook 1 (Strike, 2018), the word count in Chapter Seven-Communication, for the word ‘communication’ is 52, while for the word ‘trust’ is 0. It is noted that in the whole Chapter Seven-Communication, there is no reference to trust, even though communication is analysed and different communication techniques are presented there.
- In Coursebook 2 (Gold, 2015), the word count in Sub-module 07, Communication, for the word ‘communication’ is 63 while for the word ‘trust’ is 1. Trust towards a message sender is referred one time, in the communication chapter, as a precondition in the effective receipt of a message.

The summary of findings in the curriculum and the coursebooks are shown in Table 4.4.

Table 4.4 Word count of 'communication' and 'trust' in the EASA Part-66 Module 9 curriculum and the two coursebooks.

EASA Part 66 Module 9 'Human Factors' Curriculum and Training Material Examined	Word count	
	Communication	Trust
Curriculum	1	0
Coursebook 1	52	0
Coursebook 2	63	1

The second phase of this examination continued into the in-depth analysis to identify any concealed elements of communication and trust into the twelve elements of the Dirty Dozen tool (see subchapters 1.1 and section 3.3.3.3). As explained in detail in section 3.3.3.3, the results of this analysis were obtained by the mapping of the twelve elements of the Dirty Dozen with the use of the Communication and Trust Question Set. The results of this process are presented next.

Dirty Dozen Element 1 ***Lack of communication can result to maintenance error which can be potentially responsible for an aviation incident or accident***	
Items of the Communication and Trust Question Set Identified	***Communication Preconditions*** All communication items in sections C, D and E can describe communication preconditions that can lead to ineffective communication, namely: C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, D1, D2, D3, D4, D5, D6, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, D19, E1, E2, E3, E4 and E5.
	Trust Preconditions Ineffective communication (oral, written, emails, documentation etc) can produce either interpersonal or software trust preconditions. These preconditions may lead to maintenance error and consequently to an aviation incident or accident. This occurrence can be further analysed with the items consisting the following trust constructs: trust in colleagues' competence, trust in colleagues' benevolence, trust in colleagues' integrity, trust in company's software capability, trust in company's software reliability, trust in managers-subordinates' competence, trust in managers-subordinates' benevolence and trust in managers-subordinates' integrity. The identified items, linked to ineffective communication, are: F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F11, F12, F13, F14, F15, F16, F17, G1, G2, G3, G4, G5, G6, G7, G8, G9, G10 and G11.

Dirty Dozen Element 2 ***Complacency can lead to not having the need to double check, question or try one's best over it. An aviation professional might experience complacency during repetitive tasks while having established an overreliance on his/her relative abilities***	
Items of the Communication and Trust Question Set Identified	***Communication Preconditions*** Symptoms from complacency can be prevented with proper training. Training can promote knowledge on the subject which again can enable maintenance professionals to actively look for complacency signs on oneself and communicate them to others. This communication can promote the successful completion of tasks. All communication items in sections C, D and E describe communication preconditions that can lead to ineffective communication, namely: C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, D1, D2, D3, D4, D5, D6, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, D19, E1, E2, E3, E4 and E5.

Dirty Dozen element 3 ***Lack of knowledge can lead to a gap to the aviation professional's knowledge and perform his/her duties unsuccessfully***	
Items of the Communication and Trust Question Set Identified	***Trust Preconditions*** Lack of knowledge is caused by the aviation maintenance professional's insufficient preparation to proceed to the task in hand. This lack of knowledge can stem from insufficient training, studying, obtaining current information on modifications etc. Lack of knowledge also may refer to the obtained ability in the proper use of all high-tech aids in the maintenance activities e.g. tools, materials, equipment, software. Therefore, the trust preconditions that may lead to maintenance error and consequently to an aviation incident or accident can be further analysed by the items consisting the following trust constructs: trust in colleagues' competence, trust in colleagues' benevolence, trust in colleagues' integrity, trust in company's software capability, trust in company's software reliability, trust in managers-subordinates' competence, trust in managers-subordinates' benevolence and trust in managers-subordinates' integrity. The identified items, linked to ineffective communication, are: F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F11, F12, F13, F14, F15, F16, F17, G1, G2, G3, G4, G5, G6, G7, G8, G9, G10 and G11.

Dirty Dozen element 4 ***Distractions might prevent the professionals to attend accurately back to their work, possibly resulting in a maintenance task process error***	
Items of the Communication and Trust Question Set Identified	***Trust Preconditions*** Distractions lead aviation maintenance professionals to lose concentration and return inaccurately back to their task. This situation may result in maintenance error and consequently to an aviation incident or accident. Regardless of the cause of destruction, the potential error reveals issues in the following constructs of the questionnaire: trust in colleagues' competence, trust in colleagues' benevolence, trust in colleagues' integrity, trust in company's software capability, trust in company's software reliability, trust in managers-subordinates' competence, trust in managers-subordinates' benevolence and trust in managers-subordinates' integrity. The identified items, linked to ineffective communication, are: F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F11, F12, F13, F14, F15, F16, F17, G1, G2, G3, G4, G5, G6, G7, G8, G9, G10 and G11.

Dirty Dozen element 5 ***Lack of teamwork due to failure to establish mutual understanding and cooperation, there is a great risk of a maintenance error occurrence***	
Items of the Communication and Trust Question Set Identified	***Communication Preconditions*** Unsuccessful teamwork can find its causes into the lack of mutual understanding, which stems in problematic communication. All communication items in sections C, D and E describe communication preconditions that can lead to ineffective communication, namely: C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, D1, D2, D3, D4, D5, D6, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, D19, E1, E2, E3, E4 and E5.
	Trust Preconditions Unsuccessful teamwork reveals issues in the collaboration between colleagues. These preconditions can potentially lead to maintenance error and consequently to an aviation incident or accident. This occurrence can be further analysed with the items consisting the following trust constructs: trust in colleagues' competence, trust in colleagues' benevolence, trust in colleagues' integrity, trust in managers-subordinates' competence, trust in managers-subordinates' benevolence and trust in managers-subordinates' integrity. The identified items, linked to ineffective communication, are: F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F11, F12, F13, F14, F15, F16, F17, G1, G2, G3, G4, G5, G6, G7, G8, G9, G10 and G11.

Dirty Dozen element 6 *Fatigue can affect aviation maintenance employees' performance and relevant training is necessary to promptly recognize symptoms of physical tiredness or mental and/or emotional fatigue on oneself or colleagues*	
Items of the Communication and Trust Question Set Identified	***Communication Preconditions*** Symptoms from fatigue can be prevented with proper training. Training can promote knowledge on the subject which again can enable maintenance professionals to actively look for tiredness signs on oneself and colleagues and communicate them to others. This communication can promote the successful completion of tasks. All communication items in sections C, D and E describe communication preconditions that can lead to ineffective communication, namely: C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, D1, D2, D3, D4, D5, D6, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, D19, E1, E2, E3, E4 and E5.

Dirty Dozen element 7 *Lack of resources (time, personnel, equipment) might lead to an error prone situation*	
Items of the Communication and Trust Question Set Identified	***Communication Preconditions*** When maintenance employees deal with lack of resources, unless they communicate it to their colleagues, it may lead to maintenance error occurrences. Communication can promote the successful completion of tasks. All communication items in sections C, D and E can describe communication preconditions that can lead to ineffective communication, namely: C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, D1, D2, D3, D4, D5, D6, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, D19, E1, E2, E3, E4 and E5.

Dirty Dozen element 8 *Pressure refers to the management's-imposed expectations or self-induced pressure for prompt and flawless employees' performance*	
Items of the Communication and Trust Question Set Identified	***Communication Preconditions*** Symptoms from self or management-imposed pressure can be prevented with proper training. Training can promote knowledge on the subject which again can enable maintenance professionals to actively look for pressure signs on oneself and colleagues and communicate them to others. Communication can promote the successful completion of tasks. All communication items in sections C, D and E describe communication preconditions that can lead to ineffective communication, namely: C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, D1, D2, D3, D4, D5, D6, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, D19, E1, E2, E3, E4 and E5.

Dirty Dozen element 9 ***Lack of assertiveness may lead to maintenance errors as it can leave maintenance deviations undetected***	
Items of the Communication and Trust Question Set Identified	***Communication Preconditions*** Lack of assertiveness can be prevented with proper training. Training can promote knowledge on the subject which again can enable maintenance professionals to actively communicate their concerns and opinions to others. Communication can promote the successful completion of tasks. All communication items in sections C, D and E describe communication preconditions that can lead to ineffective communication. These items are: C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, D1, D2, D3, D4, D5, D6, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, D19, E1, E2, E3, E4 and E5.

Dirty Dozen element 10 ***Stress can affect work performance***	
Items of the Communication and Trust Question Set Identified	***Communication Preconditions*** Symptoms from stress can be prevented with proper training. Training can promote knowledge on the subject which again can enable maintenance professionals to actively look for stress signs on oneself and communicate them accordingly. Communication can promote the successful completion of tasks. All communication items in sections C, D and E describe communication preconditions that can lead to ineffective communication, namely: C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, D1, D2, D3, D4, D5, D6, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, D19, E1, E2, E3, E4 and E5.

Dirty Dozen element 11 ***Lack of awareness can be the cause in the failure of foreseeing all possible consequences by one’s actions***	
Items of the Communication and Trust Question Set Identified	***Communication Preconditions*** Lack of awareness can be prevented with proper training. Training can promote knowledge on the subject which again can enable maintenance professionals to actively look for awareness resources and communicate this issue to others. Communication can promote the successful completion of tasks. All communication items in sections C, D and E describe communication preconditions that can lead to ineffective communication, namely: C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, D1, D2, D3, D4, D5, D6, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, D19, E1, E2, E3, E4 and E5.

Dirty Dozen element 12 Norms can be either in accordance or not with the organisation's policies and therefore can follow unsafe practices and procedures	
Items of the Communication and Trust Question Set Identified	***Trust Preconditions*** Following rules that are unofficial and potentially unsafe, can potentially lead to maintenance error and consequently to an aviation incident or accident. A safety occurrence can be further analysed with the items consisting the following trust constructs: trust in colleagues' competence, trust in colleagues' benevolence, trust in colleagues' integrity, trust in managers-subordinates' competence, trust in managers-subordinates' benevolence and trust in managers-subordinates' integrity. The identified items, linked to ineffective communication, are: F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F11, F12, F13, F14, F15, F16, F17, G1, G2, G3, G4, G5, G6, G7, G8, G9, G10 and G11.

All Dirty Dozen elements refer to the total population of the aviation maintenance professionals; therefore, all levels of management are included (sections E and G of the Communication and Trust Question Set which are only for supervisors/managers). Ten factors appear to have either the communication or trust elements concealed into their meaning. Two of them, the lack of communication and lack of teamwork, appear to have both communication and trust concealed. For illustrative purposes, the overall mapping of the Communication and Trust Question Set items against the Dirty Dozen elements is provided in Table 4.5.

Table 4.5 Mapping of Communication and Trust Question Set items against the Dirty Dozen elements.

Communication and Trust Question Set Items	***Dirty Dozen element***											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
C1	X	X			X	X	X	X	X	X	X	
C2	X	X			X	X	X	X	X	X	X	
C3	X	X			X	X	X	X	X	X	X	
C4	X	X			X	X	X	X	X	X	X	
C5	X	X			X	X	X	X	X	X	X	
C6	X	X			X	X	X	X	X	X	X	
C7	X	X			X	X	X	X	X	X	X	
C8	X	X			X	X	X	X	X	X	X	
C9	X	X			X	X	X	X	X	X	X	
C10	X	X			X	X	X	X	X	X	X	
C11	X	X			X	X	X	X	X	X	X	
C12	X	X			X	X	X	X	X	X	X	
C13	X	X			X	X	X	X	X	X	X	
C14	X	X			X	X	X	X	X	X	X	
D1	X	X			X	X	X	X	X	X	X	
D2	X	X			X	X	X	X	X	X	X	
D3	X	X			X	X	X	X	X	X	X	
D4	X	X			X	X	X	X	X	X	X	
D5	X	X			X	X	X	X	X	X	X	
D6	X	X			X	X	X	X	X	X	X	
D7	X	X			X	X	X	X	X	X	X	
D8	X	X			X	X	X	X	X	X	X	
D9	X	X			X	X	X	X	X	X	X	
D11	X	X			X	X	X	X	X	X	X	
D12	X	X			X	X	X	X	X	X	X	
D13	X	X			X	X	X	X	X	X	X	
D14	X	X			X	X	X	X	X	X	X	
D15	X	X			X	X	X	X	X	X	X	
D16	X	X			X	X	X	X	X	X	X	
D17	X	X			X	X	X	X	X	X	X	
D18	X	X			X	X	X	X	X	X	X	
D19	X	X			X	X	X	X	X	X	X	
E1	X	X			X	X	X	X	X	X	X	
E2	X	X			X	X	X	X	X	X	X	
E3	X	X			X	X	X	X	X	X	X	
E4	X	X			X	X	X	X	X	X	X	
E5	X	X			X	X	X	X	X	X	X	
F1	X		X	X	X							X
F2	X		X	X	X							X
F3	X		X	X	X							X
F4	X		X	X	X							X
F5	X		X	X	X							X
F6	X		X	X	X							X
F7	X		X	X	X							X
F8	X		X	X	X							X
F9	X		X	X	X							X
F10	X		X	X	X							X
F11	X		X	X	X							X
F14	X		X	X	X							X
F15	X		X	X	X							X
F16	X		X	X	X							X
F17	X		X	X	X							X
G1	X		X	X	X							X
G2	X		X	X	X							X
G3	X		X	X	X							X
G4	X		X	X	X							X
G5	X		X	X	X							X
G6	X		X	X	X							X
G7	X		X	X	X							X
G8	X		X	X	X							X
G9	X		X	X	X							X
G10	X		X	X	X							X
G11	X		X	X	X							X

The third phase included the scanning of the EASA Part-66 Module 9 ‘Human Factors’ course material against the elements of the Dirty Dozen. This scanning (using the mapping of the Dirty Dozen elements to the Communication and Trust Question Set) revealed the concealed elements of communication and trust in Coursebook 1 and 2. The summary of the findings is presented in Table 4.6. From this analysis, it stems that both coursebooks include all factors of the Dirty Dozen and consequently include indirectly and concealed both communication and trust elements in their content.

Table 4.6 Dirty Dozen elements found in the examined EASA Part-66 Module 9 ‘Human Factors’ coursebooks in relation to communication and trust elements.

Coursebook	**Dirty Dozen Element included in the Coursebook**	**Preconditions identified based on the Dirty Dozen mapping**	
		Communication	**Trust**
Coursebook 1 (Strike, 2018)	1. Lack of Communication	X	X
	2. Complacency	X	
	3. Lack of knowledge		X
	4. Distraction		X
	5. Lack of teamwork	X	X
	6. Fatigue	X	
	7. Lack of resources	X	
	8. Pressure	X	
	9. Lack of assertiveness	X	
	10. Stress	X	
	11. Lack of awareness	X	
	12. Norms		X
Coursebook 2 (Gold, 2015)	1. Lack of Communication	X	X
	2. Complacency	X	
	3. Lack of knowledge		X
	4. Distraction		X
	5. Lack of teamwork	X	X
	6. Fatigue	X	
	7. Lack of resources	X	
	8. Pressure	X	
	9. Lack of assertiveness	X	
	10. Stress	X	
	11. Lack of awareness	X	
	12. Norms		X

4.2.2 Discussion

Considering all data from the content analysis (presented in Table 4.4), the answer to Research Question 2 is negative, as trust is not considered to be covered sufficiently in the aviation maintenance human factors basic training. In particular, the EASA curriculum has no mention of trust, neither as a separate chapter nor in any other chapters (and most importantly in the communication chapter). In the two examined coursebooks' chapters covering communication, there was only one mention to trust. Therefore, there is neither direct mention nor further explanation/discussion on trust. However, with the assistance of the mapping of the Dirty Dozen factors with the items of Communication and Trust Question Set, concealed communication and trust elements were identified into the material of the two coursebooks. The direct absence of the trust factor in the training material may be partially covered by these concealed elements, although this has limited pedagogic value and effectiveness.

4.3 Survey

In the survey phase of this study, both interpersonal trust and company software trust are investigated. In correspondence with the technology trust (Li, Rong, & Thatcher, 2012), software trust is the aviation maintenance employees' beliefs of the trustworthiness towards their company software's performance. The purpose is to explore the association between communication satisfaction and trust of the aviation maintenance employees. This population is chosen for this study for its critical characteristics. These characteristics are mainly influenced by its global nature, yet it is governed by different laws in different geographical areas. The aviation maintenance profession is highly complex, highly skilled and highly regulated around the world. Aviation maintenance employees, after multiyear training to obtain their qualifications, can work autonomously in a busy, constantly physically challenging working environment. Their work requires a fast pace, long hours, overtime due to shortages in staffing, shift work, and ongoing training as new technology and legislation are constantly introduced. Additionally, full attention and situational awareness can be limited due to the physical restrictions of their immediate working environment. Considering that the managers' posts do not require the same hours as the rest of the employees (morning shifts) and the same locations (offices rather than ramps or painting shops etc), it is believed that communication and trust between them may influence safety. Therefore, ongoing research of human factors, and especially the investigation of traits such as communication and trust, will continue to contribute to aviation maintenance safety and more efficient performance.

4.3.1 Results

4.3.1.1 Descriptive Statistics

The respondents were mostly civil aircraft maintenance employees (83%) while their military counterparts made up 13% of respondents (4% of the sample did not state their civil/military status). The newly hired employees (less than 6 months of experience) comprised just 7%. Respondents were found to be evenly equally distributed according to their total experience: 19% had total experience between 0 to 9.5 years, 26% 10 to 19.5 years, 31% between 20 to 29.5 years and 24% more than 30 years of experience.

Approximately half of the respondents were either holding a supervisory or a managerial post. Of the respondents 51% held one license and worked for a maintenance company regulated by the European Aviation Safety Agency (EASA), 6% held a single license from the Federal Aviation Administration (FAA), and 9% held a single license from the Civil Aviation Safety Authority (CASA). 12 % of the respondents held military license while another 12% held multiple licenses and the remaining held no license.

The Cronbach's alpha values were measured for both the Communication Satisfaction Questionnaire and the Trust Constructs and Measures Questionnaire and the different group of questions (constructs) that each questionnaire was divided in: the managers' questions group in Communication Satisfaction Questionnaire and the 7 constructs of the Trust Constructs and Measures Questionnaire. All of these Cronbach's alpha values ranged between 0.77 and 0.97. Particularly, the Cronbach's alpha for the whole Communication Satisfaction Questionnaire was 0.97 similar to that found by past researchers who used the same questionnaire (Downs & Hazen, 1977; Mount & Back, 1999) , the whole Trust Constructs and Measures questionnaire was 0.91, the Communication Satisfaction Questionnaire managers' group was 0.88 and the Trust Constructs and Measures Questionnaire's Trust in the company's software Capability was 0.92. These were high-reliability scores and were, therefore, considered acceptable for this research.

The full results of the mean and standard deviation for all items of the Communication and Trust Question Set are provided in Table 4.7.

Table 4.7 The mean and standard deviation (SD) calculated for all items contained in the Communication and Trust Question Set.

Item	Mean	SD
C1	**5.01**	1.57
C2	**4.99**	1.40
C3	**4.73**	1.51
C4	**4.80**	1.57
C5	**4.71**	1.62
C6	**4.81**	1.73
C7	**4.71**	1.59
C8	**5.26**	1.45
C9	**4.23**	1.58
C10	**4.43**	1.52
C11	**4.35**	1.60
C12	**4.51**	1.79
C13	**4.53**	1.78
C14	**4.76**	1.39

Item	Mean	SD
D1	4.55	1.68
D2	4.15	1.67
D3	5.09	1.77
D4	5.10	1.62
D5	4.56	1.67
D6	4.51	1.55
D7	5.89	1.29
D8	4.83	1.58
D9	4.62	1.58
D11	5.08	1.69
D12	5.27	1.43
D13	5.14	1.38
D14	5.45	1.24
D15	4.55	1.61
D16	5.30	1.43
D17	4.65	1.55
D18	4.75	1.44
D19	4.45	1.54

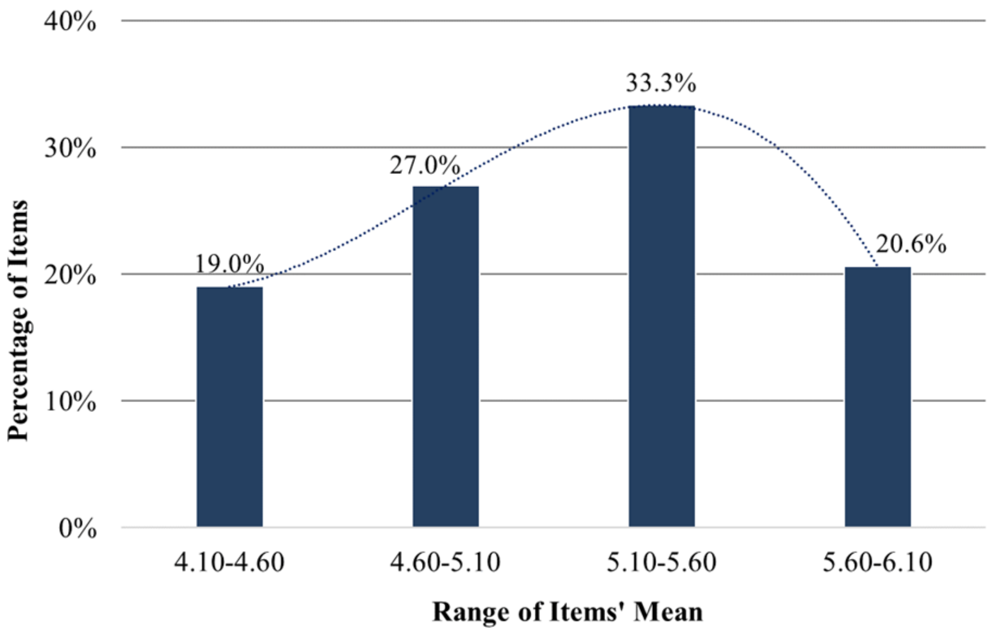
Item	Mean	SD
E1	5.52	1.13
E2	5.40	1.24
E3	5.06	1.38
E4	5.34	1.19
E5	5.27	1.30

Item	Mean	SD
F1	5.48	1.17
F2	5.66	1.06
F3	5.89	0.97
F4	5.56	0.98
F5	5.54	1.13
F6	6.05	1.06
F7	5.13	1.42
F8	5.45	1.31
F9	5.67	1.14
F10	5.56	1.09
F11	5.54	1.15
F14	5.46	1.77
F15	4.48	1.77
F16	4.76	1.67
F17	4.89	1.51

Item	Mean	SD
G1	5.66	0.90
G2	5.81	0.96
G3	6.00	0.86
G4	5.48	0.97
G5	5.77	0.97
G6	5.97	0.96
G7	5.25	1.23
G8	5.55	1.14
G9	5.69	1.05
G10	5.65	0.99
G11	5.68	0.99

The 33% of the items' mean scores range is between 5.10 to 5.60, while the maximum range of 5.60 to 6.10 is 20.6% of the questionnaire's items. Similar percentage holds the minimum range of the mean scores (4.10 to 4.60), while the remaining range (4.60 to 5.10) holds 27% of the items (Figure 4.1).

Figure 4.1 The range of the items' mean scores and their percentages



The question D10 ‘The grapevine (person to person informal communication/gossip) is active in our organisation’ was included in the questionnaire that was distributed to the participants; however, it was inconsistent with the other items’ (based on reliability measures) and was therefore excluded from the analysis. Furthermore, other researchers have excluded the same question from their research projects as it was found to be unclear to the participants (Chan & Lai, 2017; Mount & Back, 1999). Also, the two questions, F12 ‘My company's software has the functionality I need’ and F13 ‘My company's software has the ability to do what I want it to do’ were included in the questionnaire that was distributed to the participants. However, these questions showed problematically high correlations to F14 ‘Overall, my company's software has the capabilities I need’. As a result, they were not included in the statistical analysis.

A comparison of the mean and standard deviation for various groups of questions of this study was conducted with the results of two published research studies. The importance of this comparison, presented in Table 4.8, lays to the fact that four different categories of professionals (aviation maintenance, teachers, nurses and administrative) have responded to the same questionnaire and therefore they have provided comparable data and results. In particular, the following observations are made:

- Two of these categories, aviation maintenance and nurses, are operating within a highly regulated environment, while teachers and administrative employees do not share this distinct characteristic within their working environment.
- Aviation maintenance employees and nurses work in rotating shifts, during weekdays, weekends and public holidays, while the teachers and administrative employees have standard morning weekdays working hours.
- Aviation maintenance employees and nurses are assigned tasks in teams. Their working structure is based on the formation of teams and team leaders and the tasks are assigned under the criteria of the personnel's qualifications, seniority, experience. Teachers and administrative personnel, even though they operate under organisational team structures, they usually operate independently from a team.
- Aviation maintenance employees are the only among these four categories under examination in this section that have safety/quality management systems in place in their working operations and human factors basic training. These aspects increase the employees’ awareness and caution around communication within their working environment.

When examining the means provided in Table 4.8 and having in mind the different characteristics for each one of the professional groups that are described above, substantial diversity is observed. In Dimension 1 ‘Satisfaction with Communication Climate’, aviation employees have the maximum mean score (M = 4.54) while the minimum is M = 3.37 for administration employees. In Dimension 2 ‘Satisfaction with superiors’, the mean scores for the aviation employees, administrators and teachers do not differ greatly (teachers have the maximum mean score at M = 5.21) while the nurses have less than half mean score (M = 2.35). In Dimension 3 ‘Satisfaction with Organizational Integration’, the four groups have a completely different picture as they do not group in any direction and no group appears to have a mean more than 5 (aviation employees have the maximum mean score of M = 4.90).

Table 4.8 Comparison of the statistical results obtained in this study with published studies where the Communication Satisfaction Questionnaire was used.

Communication Satisfaction Questionnaire Dimensions	***Present Study***		***Zwijze-Koning & de Jong (2007)***		***Brunetto & Farr-Wharton (2017)***			
	Aviation maintenance professionals N= 271		**Teachers N= 165**		**Nurses public sector N= 92**		**Admins public sector N= 165**	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
1. Satisfaction with Communication Climate	4.54	1.63	4.03	1.10	4.41	1.05	3.37	1.02
2. Satisfaction with Superiors	5.02	1.61	5.21	1.20	2.35	1.20	4.96	1.22
3. Satisfaction with Organizational Integration	4.90	1.56	4.54	-	2.47	1.09	3.18	1.19
4. Satisfaction with Media Quality	4.88	1.50	4.21	-	3.29	0.87	3.74	1.01
5. Satisfaction with Horizontal Informal Communication	5.15	1.37	5.08	0.89	-	-	-	-
6. Satisfaction with General Organizational Perspective	4.54	1.56	3.94	-	2.23	0.61	3.26	1.29
7. Satisfaction with Communication with Subordinates	5.32	1.25	5.57	0.73	-	-	-	-
8. Satisfaction with personal feedback	4.64	1.64	4.35	-	2.96	0.85	3.77	1.17

In Dimension 4 ‘Satisfaction with Media Quality’, again, aviation employees have the highest mean score (M = 4.88), while nurses again hold the minimum score (M = 3.29). In Dimension 6 ‘Satisfaction with General Organizational Perspective’, aviation employees mean score is the highest among all four groups (M = 4.52), with nurses the lowest of all groups across all dimensions (M = 2.23). In dimension 8 ‘Satisfaction with personal feedback’, aviation employees show the higher satisfaction of all four groups (M = 4.64) and nurses again have the lowest satisfaction on their feedback (M = 2.96). Looking at all these findings together, it stems that aviation personnel show the highest satisfaction among all four groups of professionals across all dimensions except Dimension 2 ‘Satisfaction with Superiors’. On the other hand, nurses show the lowest satisfaction among the four groups, at all dimensions except for Dimension 1 'Satisfaction with Communication Climate'.

The results presented above were extracted from different research papers, published in peer-reviewed journals, followed similar methodology, but not all row data were available. Due to this limitation, further statistical analysis and interpretation of the results were not possible. The comparison of these mean scores indicates the existence of differences in communication satisfaction within the different dimensions among the different groups of employees. Further investigation of the significance of the differences between aviation maintenance and nursing professionals and the exploration of the association with trust and its implications with safety would offer a better understanding of these two highly regulated industries.

4.3.1.2 Results from the Hypotheses Testing

Hypothesis 1(a)(b) are suggesting that interpersonal trust is positively linked to overall communication satisfaction among aircraft maintenance employees and between supervisors/managers (referred as managers in the rest of the text) and their subordinates. Hypothesis 1 (a) was supported using the bivariate correlation. This correlation indicated a positive association between interpersonal trust and overall communication satisfaction among employees (r = 0.56, p < 0.01, N = 271) and is illustrated in Figure 4.2. In Figure 4.2 it should be noted there are some outliers present that have increased slightly the strength of the association. The overall communication satisfaction score for all employees and their interpersonal trust score are the means of the scores of all items of Communication Satisfaction Questionnaire (sections C, D excluding D10 and D20) and the items F1 to F11 of the Trust Constructs and Measures Questionnaire respectively. The overall scores are measured on the same scale as the original scores and this applies to all scores measured in this section.

For Hypothesis 1(b) the strong association between the managers' communication satisfaction towards their subordinates and the managers' interpersonal trust towards their subordinates (r = 0.75, p < 0.01, N = 129) is shown in Figure 4.3. It is noted here that the outliers do not significantly alter the correlation. The managers-subordinates communication satisfaction score and the managers-subordinates' interpersonal trust score are the means of the scores of all items of Communication Satisfaction

Questionnaire that were responded to by managers only (section E) and all items of the section G of the Trust Constructs and Measures Questionnaire respectively.

Hypothesis 2(a)(b) was statistically well supported. The correlations indicated the positive association between trust towards the company's software for employees and their overall communication satisfaction, as well as the managers' trust towards the company's software and their overall communication satisfaction. For Hypothesis 2(a) the Pearson correlation r between employees' overall communication satisfaction and their software trust was $r = 0.51$, $p < 0.01$, $N = 271$. The association between employees' software trust and overall communication satisfaction is shown in Figure 4.4, indicating moderate-large scatter about the line of best fit. The employees' overall communication satisfaction score and their trust towards the company's software score are the means of the scores of all items of Communication Satisfaction Questionnaire (sections C, D excluding D10 and D20) and the items F14 to F17 of the Trust Constructs and Measures Questionnaire respectively. For Hypothesis 2(b) the correlation between the managers' levels of trust for the company's software and their communication satisfaction towards their subordinates indicated a weak association ($r = 0.33$, $p < 0.01$, $N = 132$), as illustrated by the large scatter in Figure 4.5.

It is worth mentioning here that, even though there is a statistically significant correlation between these two traits, the association is quite weak. On the other hand, the correlation between the managers' levels of trust for the company's software and their communication satisfaction towards their company and peers indicated a stronger association ($r = 0.57$, $p < 0.01$, $N = 132$), see Figure 4.6. It should be noted there are some outliers present that have increased slightly the strength of the association. The managers-subordinates communication satisfaction score and the managers' trust towards the software score are the means of the scores of the items in section E of the Communication Satisfaction Questionnaire and managers' responses in items of the Trust Constructs and Measures Questionnaire (items F14 - F17) respectively. The managers' Communication satisfaction towards their company and peers score is the mean of the score of the items in sections C and D for the selected cases of the managers.

Hypothesis 3(a)(b) was supported as well. Specifically, for Hypothesis 3(a) the correlation between the subordinates' overall communication satisfaction and their interpersonal trust, indicated a moderate relationship between the two traits ($r = 0.60$, $p < 0.01$, $N = 129$) with Figure 4.7 supporting the evident association of this form of trust with the subordinates' overall communication satisfaction. The subordinates' overall communication satisfaction score and their interpersonal trust score are the means of the scores of the items in sections C and D of the Communication Satisfaction Questionnaire for the subordinates' as selected cases and items of the Trust Constructs and Measures Questionnaire (items F1 - F11) respectively.

For Hypothesis 3(b) the correlation between the subordinates' overall communication satisfaction and their trust towards the company's software, showed a medium-strength relationship between the two traits ($r = 0.45$, $p < 0.01$, $N = 129$) and indicated some association of this form of trust with the subordinates' overall communication satisfaction. In particular, see Figure 4.8, where a moderate-large scatter about the line of best fit is observed. The subordinates' overall communication satisfaction score and their trust towards the company's software score are the means of the scores of the items in sections C and D of the Communication Satisfaction Questionnaire for the subordinates' as selected cases and items of the Trust Constructs and Measures Questionnaire (items F14 - F17) respectively.

Concerning Hypothesis 4(a)(b), for this analysis, the sample size of the newly hired personnel ($N = 17$) was anticipated and found to be very small compared to the rest of the experienced personnel ($N = 244$). Due to the large difference in sample sizes of the two groups, descriptive statistical analysis was conducted and a comparison between the means of each group was used as an indicator of possible support of each part of this hypothesis. In particular: For Hypothesis 4(a), while measuring interpersonal trust, the newly hired group showed greater levels of trust (M: 5.90, $SD = 0.72$) in comparison to the experienced group (M: 5.57, $SD = 0.87$). For Hypothesis 4(b) the levels of trust towards the company's software were found to be greater among the newly hired group (M: 5.51, $SD = 0.87$) than the levels of trust in the experienced group (M: 4.59, $SD = 1.53$). Furthermore, the group of newly hired personnel showed greater overall communication satisfaction (M: 5.40, $SD = 0.97$) than the group of more experienced personnel (M: 4.75, $SD = 1.09$).

Figure 4.2 Scatterplot of interpersonal trust score and overall communication satisfaction score for all employees.

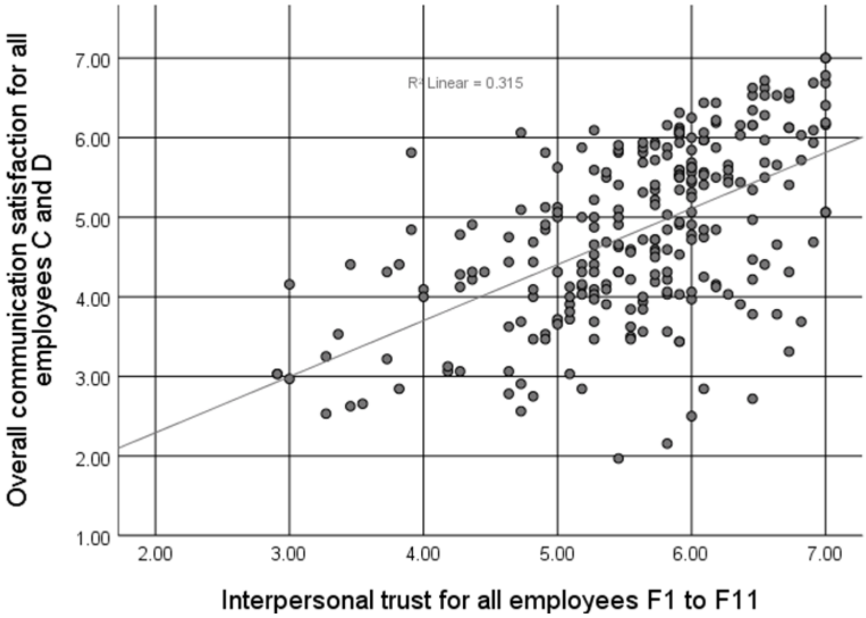


Figure 4.3 Scatterplot of managers' communication satisfaction towards subordinates and managers' interpersonal trust towards subordinates.

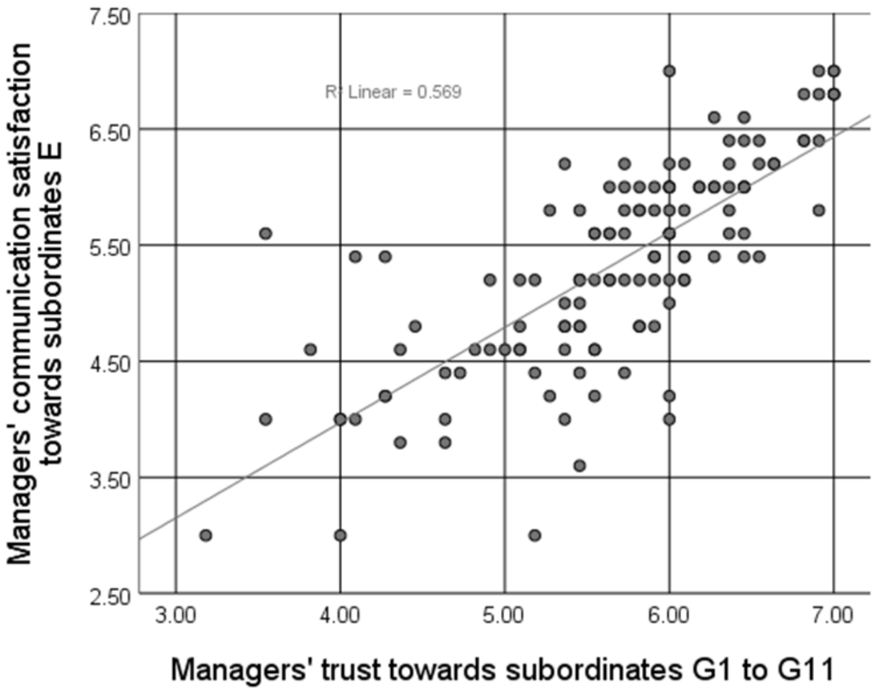


Figure 4.4 Scatterplot of employees' overall communication satisfaction and their software trust.

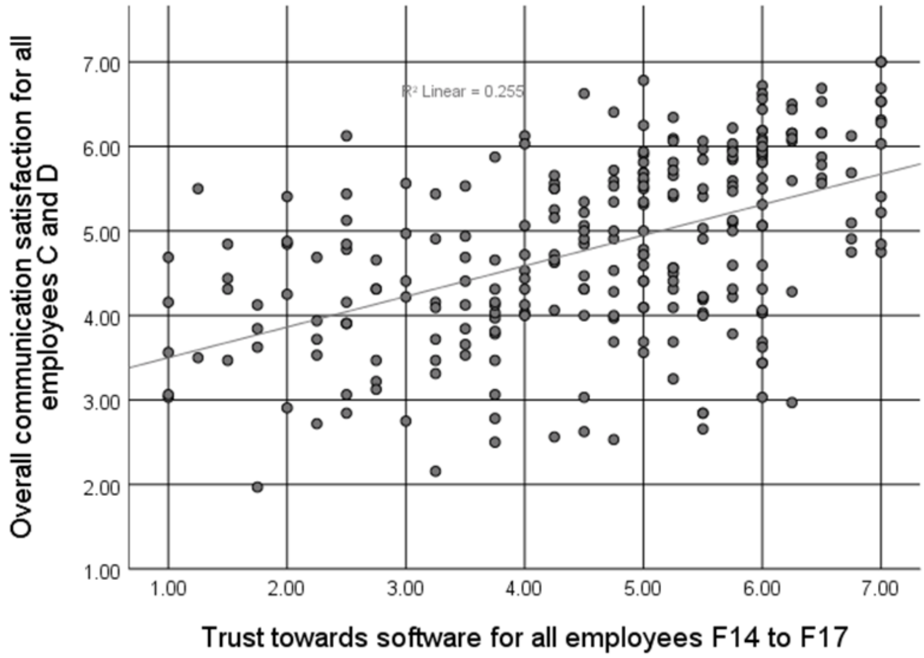


Figure 4.5 Scatterplot of managers' levels of trust for the company's software and their overall communication satisfaction towards their subordinates.

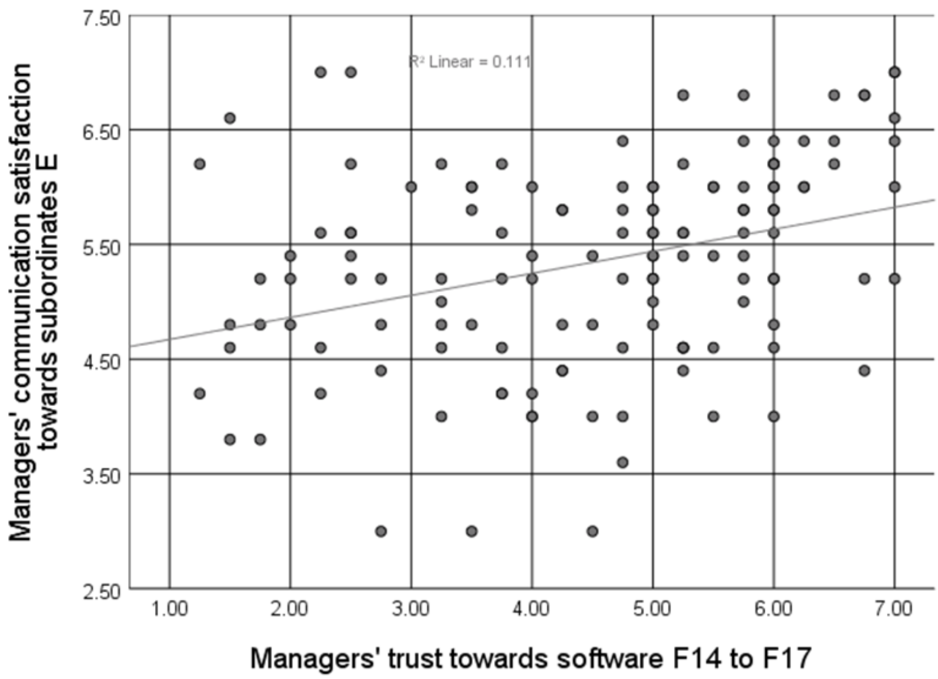


Figure 4.6 Scatterplot of managers' levels of trust for the company's software and their overall communication satisfaction towards their company and peers.

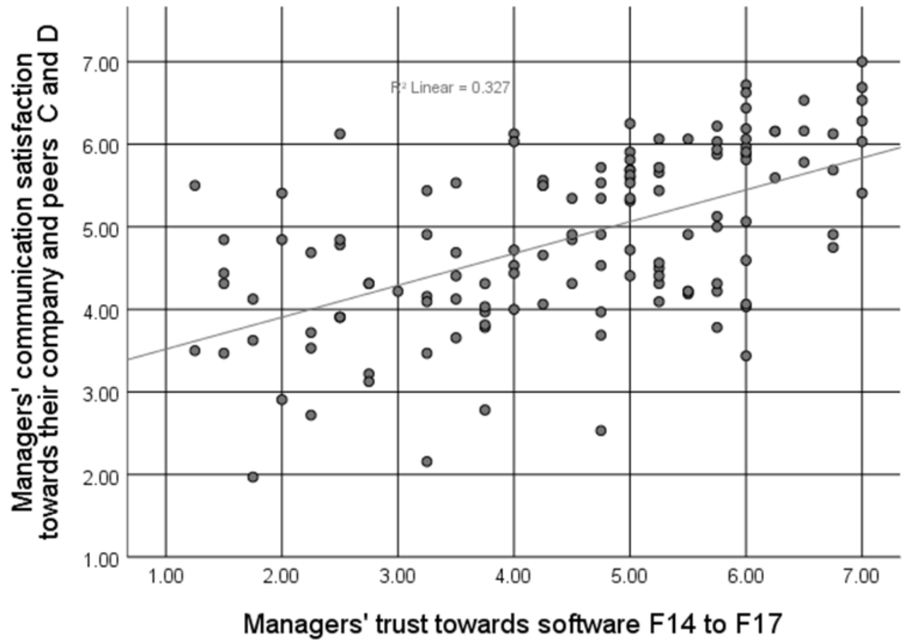


Figure 4.7 Scatterplot of subordinates' levels of interpersonal trust and their communication satisfaction.

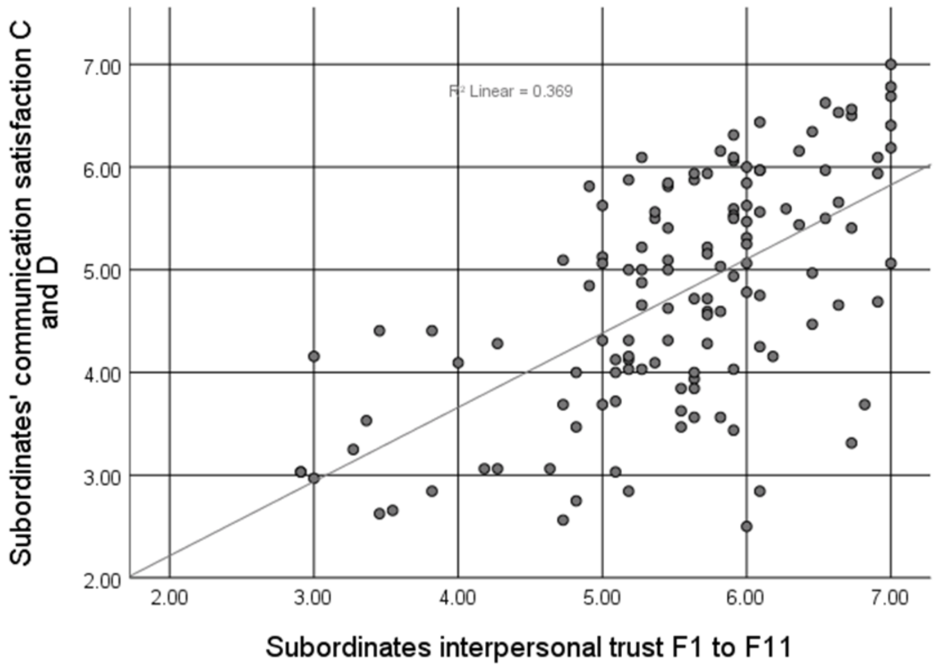
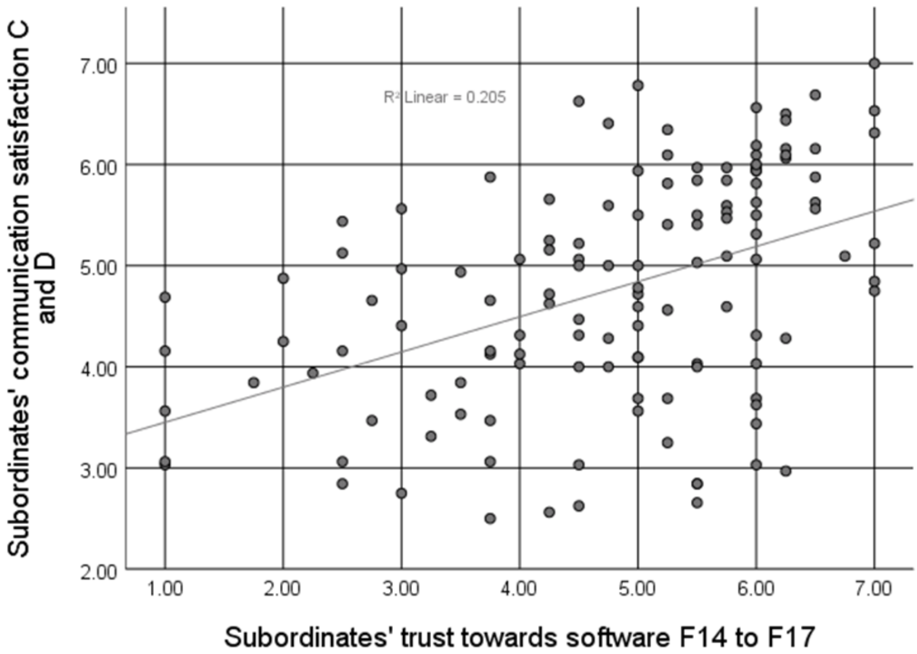


Figure 4.8 Scatterplot of subordinates' levels of trust for the company's software and their communication satisfaction.



4.3.1.3 Additional Observations

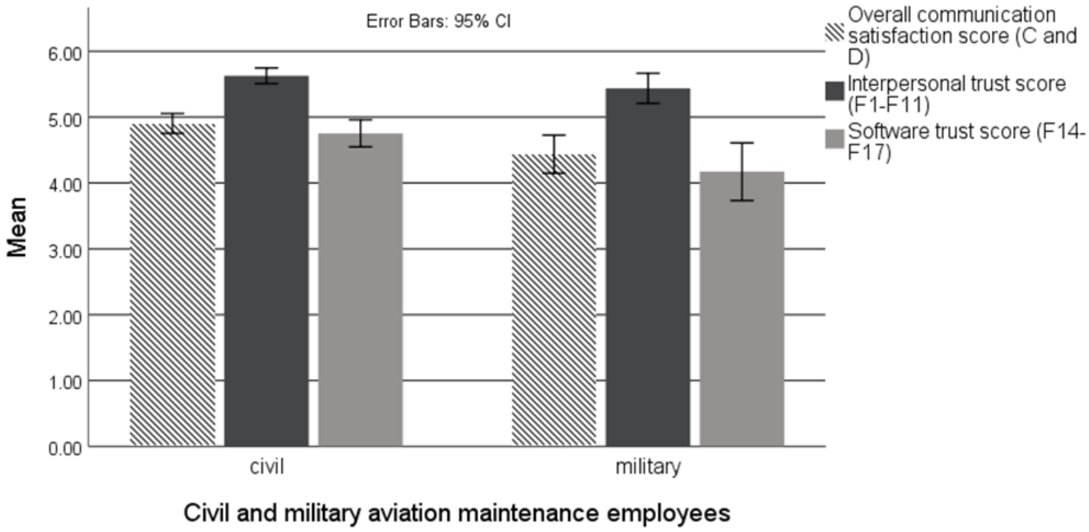
As discussed in subsection 3.3.4.3 'Data Analysis', a set of four additional observations (Additional Observation 1 to 4) were formed to analyse the data beyond the scope of the research hypotheses. The results from the analysis of these additional observations are provided in the subsequent sections.

4.3.1.3.1 Additional Observation 1

Differences in the means of communication satisfaction and trust scores for civil aviation maintenance employees when compared with their military counterparts.

An independent samples t-test was conducted to examine these differences, obtaining the results shown in Figure 4.9.

Figure 4.9 Means of overall communication satisfaction, interpersonal trust and software trust for civil and military aviation maintenance employees.



The independent samples t-test showed a statistically significant difference in the means for the overall communication satisfaction score and trust towards software between the civil and military employees. However, the difference in the means of the interpersonal trust scores between civil and military employees was not statistically significant (Table 4.9). It is noted here that the means of all three traits in Table 4.9 are higher for the civil than the military employees. The Hedge's g is used here to indicate the effect size of the difference in means due to the large difference in sample sizes between the military and civil employees. The Hedges' g values for the effect size the difference between the two types of employees with reference to overall communication satisfaction and software trust represent a small to medium effect size and were found to be statistically significant, while the Hedge's g for the interpersonal trust represents a small effect size and is not statistically significant (Table 4.9). Due to the large difference in sample sizes between the two groups of employees, Mann-Whitney U tests were conducted and since they led to the same conclusions as those from the t-tests, it was deemed that only results from the t-tests need be reported.

Table 4.9 T-tests for communication satisfaction and trust between civil and military aviation maintenance employees.

Traits	Group	N	Mean	SD	t	df	p	Hedges' g
Overall communication satisfaction score (C and D)	Civil	227	4.88	1.12	2.75	58.98	0.008*	0.40
	Military	38	4.44	0.88				
Interpersonal trust score (F1-F11)	Civil	210	5.63	0.88	1.27	246	0.206	0.22
	Military	38	5.44	0.70				
Software Trust score (F14-F17)	Civil	210	4.75	1.51	2.22	246	0.027*	0.39
	Military	38	4.17	1.33				

*Statistically significant

4.3.1.3.2 Additional Observation 2

Differences in the means of communication satisfaction and trust scores for managers compared with subordinates in aviation maintenance.

Accordingly, independent samples t-tests were conducted to examine the differences in the means of communication satisfaction and trust scores for managers compared with subordinates in aviation maintenance, as shown in Figure 4.10 and 4.11. The t-tests indicated no statistically significant differences in communication satisfaction and trust scores for managers compared with subordinates (Table 4.10). Thus, it is noted here that the overall communication satisfaction score, the interpersonal trust score and the trust towards the company's software are statistically no different for the groups of managers and subordinates in aviation maintenance as all *p* values are greater than 0.05 (Table 4.10). Differences were not statistically significant as Cohen's d values were used to measure effect sizes of differences between managers and subordinates on the three traits and all were found to be small.

Figure 4.10 Means of overall communication satisfaction for managers and subordinates.

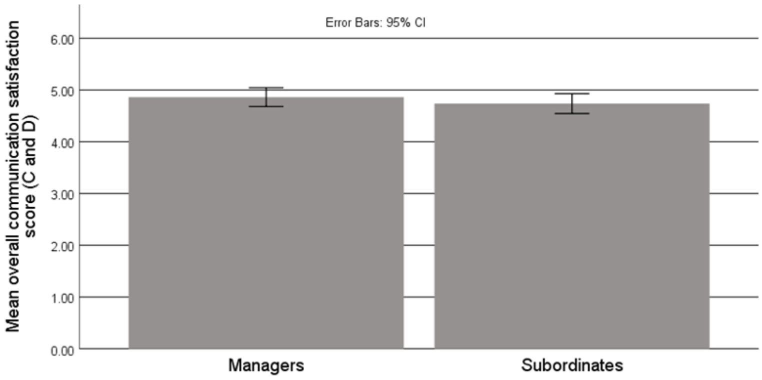


Figure 4.11 Means of interpersonal trust and software trust for managers and subordinates.

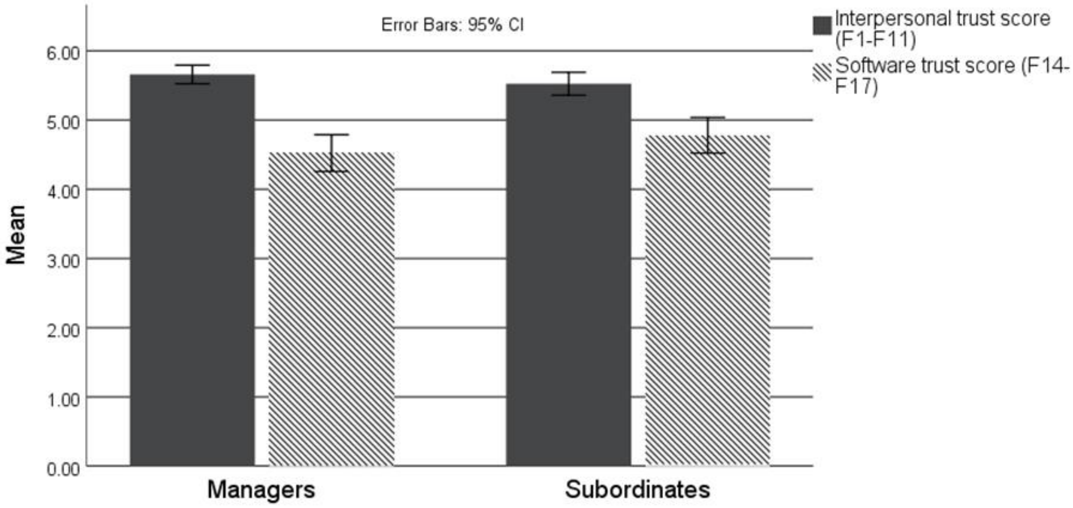


Table 4.10 T-tests for communication satisfaction and trust between managers and subordinates in aviation maintenance.

Traits	Group	N	Mean	SD	t	df	p	Cohen' g
Overall communication satisfaction score (C and D)	Managers	136	4.86	1.07	0.93	269	0.353	0.11
	Subordinates	135	4.74	1.13				
Interpersonal trust score (F1-F11)	Managers	133	5.66	0.78	1.25	259	0.211	0.16
	Subordinates	128	5.52	0.94				
Software trust score (F14-F17)	Managers	133	4.52	1.54	-1.37	259	0.171	0.17
	Subordinates	128	4.77	1.47				

4.3.1.3.3 Additional Observation 3

Differences in traits of communication satisfaction and trust amongst four groups based on years of experience (0 to 9.5, 10 to 19.5, 20 to 29.5 and 30 and more).

Differences in traits of communication satisfaction and trust amongst four groups based on years of experience were investigated using a one-way analysis of variance (ANOVA) as shown in Figure 4.12. The differences in communication satisfaction mean scores across the levels of experience were found to be statistically significant ($F = 5.96$, $p < 0.01$). Post hoc LSD tests showed significant differences amongst the groups as follows: 0 to 9.5 years of experience compared with 20 to 29.5 years ($p = 0.001$, Cohen's d= 0.57), indicating a medium effect size; 0 to 9.5 years of experience compared with 30 years and more ($p = 0.001$, Cohen's d = 0.56). Also, it indicates a medium effect size; 10 to 19.5 years of experience compared with 20 to 29.5 years ($p = 0.001$, Cohen's d = 0.44) indicating a small to medium effect size; and 10 to 19.5 years of experience compared with 30 years and more ($p = 0.001$, Cohen's d = 0.43) indicating a small to medium effect size (Table 4.11).

Figure 4.12 Means of overall communication satisfaction, interpersonal trust and software trust for all participants in their total years of experience.

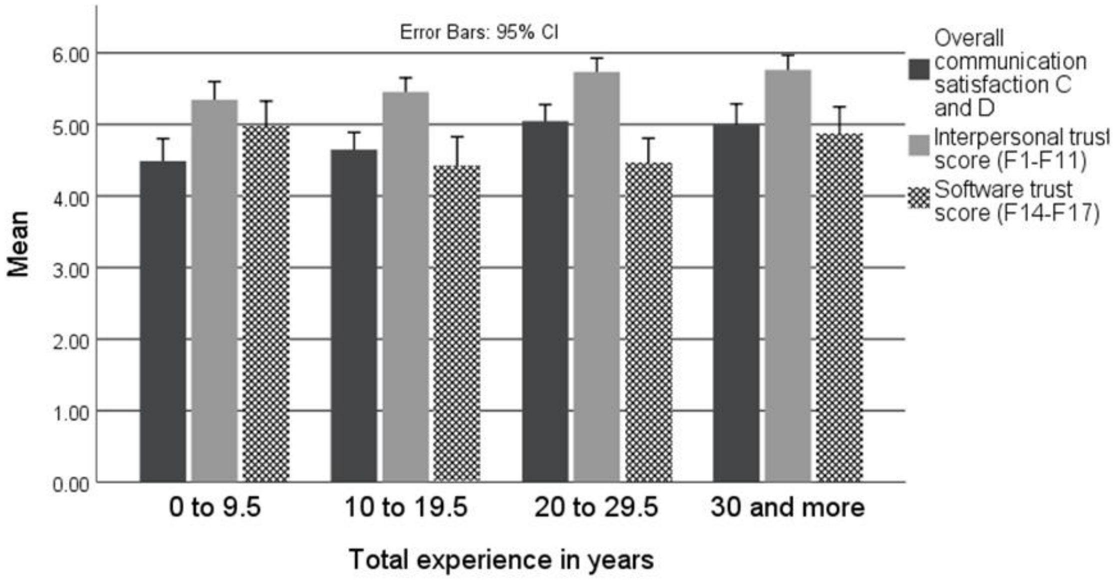


Table 4.11 Means and standard deviations of communication satisfaction for groups of aviation maintenance employees based on years of experience.

Total Years of Experience	N	Mean	SD
0 to 9.5	55	4.41	1.16
10 to 19.5	71	4.60	1.00
20 to 29.5	87	5.04	1.02
30 years and more	65	5.06	1.12
Total	278	4.81	1.10

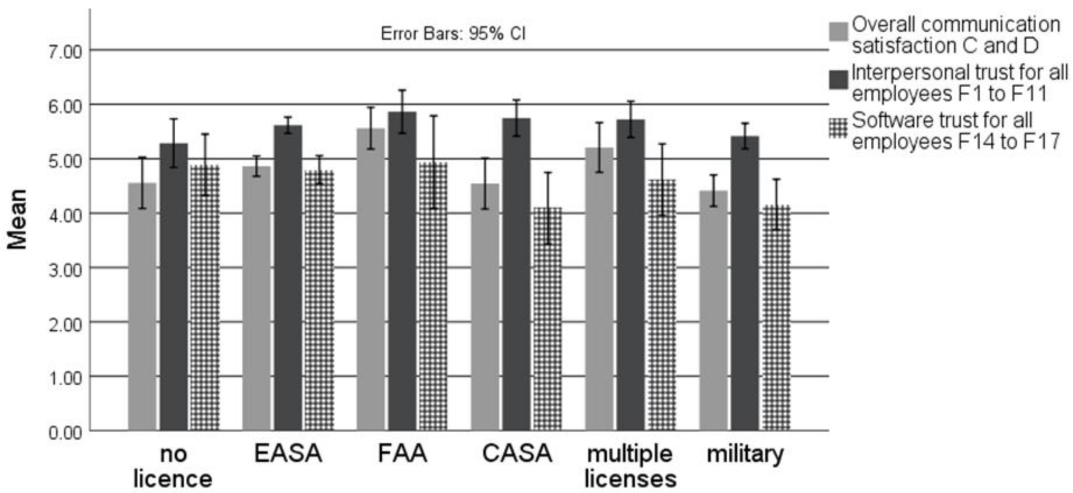
There was no significant statistical difference between the 0 to 9.5 years group and the 10 to 19.5 years group, as well as between the 20 to 29.5 years group and the 30 years and more group. Furthermore, the differences in the means of interpersonal trust and software trust were investigated using one-way ANOVA tests, among the different groups by level of experience, and none were statistically significant. Another observation from Table 4.11 is that the employees with less experience (0 to 9.5 and 10 to 19.5 years) have lower communication satisfaction scores than the employees with more years of experience (20 to 29.5 and 30 years and more).

4.3.1.3.4 Additional Observation 4

Differences in the traits of communication satisfaction and trust among six different groups of the employees, based on the type of license held (no license, EASA, FAA, CASA, multiple licenses, military).

One-way ANOVA, using the Bonferroni post hoc test, was run to identify the differences in the traits communication satisfaction and trust among six different groups of the employees, based on type license held (no license, EASA, FAA, CASA, multiple licenses, military) as shown in Figure 4.13. The differences in communication satisfaction mean scores were investigated, across the different licenses under which employees are operating, and was found statistically significant ($F = 3.71$, $P < 0.003$). The two pairs of groups that showed significant differences in the post hoc tests are as follows: FAA-CASA ($p = 0.037$, Hedge's g = 1.13) indicating a large effect size and FAA-military ($p = 0.008$, Hedge's g = 1.43) also indicating a large effect size. As a verification, due to concerns about violations of assumptions and large differences in sample sizes amongst the groups, the Kruskal-Wallis test was run for the same traits and gave the same results (see Table 4.12) for means and standard deviations of communication satisfaction).

Figure 4.13 Means of overall communication satisfaction, interpersonal trust and software trust for all participants according to the type of license held.



Statistically significant differences were not indicated between the following pairs: no license-EASA, no license-CASA, EASA-CASA, EASA-multiple licenses, FAA-multiple licenses, military-EASA, military-CASA, military-no license, military-multiple licenses, FAA-EASA and FAA-no license. Furthermore, the differences in the means of interpersonal trust and software trust among the different license groups were investigated with a one-way ANOVA, and none were found to be statistically significant.

Table 4.12 Means and standard deviations of communication satisfaction for the different license groups of aviation maintenance employees.

License Groups of Employees	N	Mean	SD
No license	27	4.61	1.18
EASA	142	4.82	1.11
FAA	16	5.56	0.72
CASA	24	4.50	1.05
Multiple licenses	33	5.15	1.19
Military	36	4.43	0.82
Total	278	4.81	1.10

4.3.2 Discussion

The Communication Satisfaction Questionnaire has been used in the past and results from past research projects were used to compare the results of this study. Similar results from two research projects were used to compare the means of three more professional groups in the Communication Satisfaction directions, as they were introduced by Downs and Hazen (1977). The comparison indicated aviation maintenance employees to have the maximum mean score in the majority of the dimensions while nurses have the minimum mean score again in the majority of the dimensions. These findings, due to the limitations that have been presented in the previous section, cannot be generalised or lead to any conclusive results without being investigated further. This further investigation, with the proper preparation, can research in depth different groups from completely different backgrounds.

All four research hypotheses were supported by the statistical results and findings of the survey. The highest correlation was found between communication satisfaction and interpersonal trust between managers and their subordinates (Figure 4.3). The communication satisfaction and interpersonal trust association of the subordinates follow in strength the association identified to managers towards their subordinates. In overall communication satisfaction for all employees, the 31% in variation comes next in strength and can be explained by variation in interpersonal trust, with a high supporting correlation between these two traits as well. The association, even though it is not as strong as that of the managers, is considered strong enough to support a statistically significant positive association.

On the other hand, the weakest association identified in this study was trust towards the company's software and communication satisfaction (especially for the managers towards their subordinates). The association between the subordinates' communication satisfaction and their software trust is only slightly greater ($r = 0.45$), while the association of the managers communication satisfaction towards their company and peers and their trust towards the company's software ($r = 0.57$), is slightly higher than the previous two, but still weak.

Then, a t-test was run to investigate the statistical significance between managers and subordinates in regard to the association between their interpersonal trust, software trust and communication satisfaction. The results indicated that there is not enough evidence to show that differences between the managers and the subordinates' levels of communication satisfaction, interpersonal trust and software trust were statistically significant. However, a t-test identified statistically significant differences in their levels of communication satisfaction and software trust, with the civil employees having larger means for both these traits.

The civil aviation employees were broken down into smaller groups, according to their different licence status, to proceed with a more detailed investigation. This division has led to the formation of the following six groups (no license, EASA, FAA, CASA, multiple licenses, military), which were investigated to determine the differences in their communication satisfaction and the various types of trust. The use of one-way ANOVA for these groups revealed that there were no differences for the different groups in their interpersonal and software trust, but there were significant differences in the communication satisfaction for two of the pairs of the groups (FAA-CASA and FAA-military).

In relation to the exploration of the two traits (communication satisfaction and trust) in the span of the employees' experience, differences were identified in the levels of the communication satisfaction between the less experienced and more experienced employees. The significant differences in the levels of communication satisfaction appear when any one of the less experienced groups is compared with any one of the more experienced groups. Thus, it stems that communication satisfaction is a trait that changes as the level of experience increases and since the mean scores of communication satisfaction are larger for the more experienced groups, it is considered reasonable to infer that communication satisfaction levels increase with experience build-up.

With regards to the limitations of this statistical analysis, it is noted that this survey was conducted using a sample of aviation maintenance employees that is not necessarily a representative sample of the total of these employees' population. More specifically, there were small numbers of participants from many different geographical areas, and this does not mean that they would be representative of the total population of these areas. Therefore, it is suggested that further research is necessary before any results can be generalised for aviation maintenance professionals in a single country or at a global level.

CHAPTER 5 COMMUNICATION AND TRUST MODEL

5.1 Diagnosis of Communication and Trust in Aviation Maintenance

In this research study, the first and most important step was to identify, directly and indirectly, communication and trust in the aviation maintenance context. The answer to this question (Research Question 1: Are trust and communication detectable in aviation maintenance?) was the starting point and the motivation for this research study. The dual answer to Research Question 1, negative to the direct and positive to the indirect inquiry of both traits in the reports, led the way for a deeper and wider investigation.

The aviation maintenance human factors basic training material was thoroughly examined, again, for the direct and indirect identification of communication and trust. The answer to this question (Research Question 2: Are communication and trust covered in aviation maintenance human factors basic training?) was negative with regards to the direct identification of trust, while communication was found to be covered in the course material (positive answer). However, the answer was positive to the indirect identification of both traits as the elements of communication and trust were found to be concealed in the course material. Aviation maintenance professionals from around the world (see subchapter 4.3.1) were asked to participate in a survey to examine their perception on the association between these traits. This survey offered valuable results on the association among communication satisfaction, interpersonal trust and software trust.

Following the confirmation of the hypothesised positive association among those three aspects of the two traits, the next step would be to employ a similar process in an additional step, prediction. Prediction can form different hypothetical occurrences (possible events and scenarios) by using the survey's results as a guide and can, therefore, contribute to the process of the examination of the two traits. More specifically, this step includes hypothetical scenarios about possible aviation maintenance deviations that can take place in real life.

In turn, a new model is proposed for the diagnosis of communication and trust in the aviation maintenance environment, expanding and formalising the multifaceted research methodology and processes developed and implemented in this research. The following sections describe in detail the development, form and the implementation of this model in a case study. Moreover, the model's usability in Safety Management Systems (SMS) is discussed.

5.2 The DiCTAM Model

5.2.1 Development

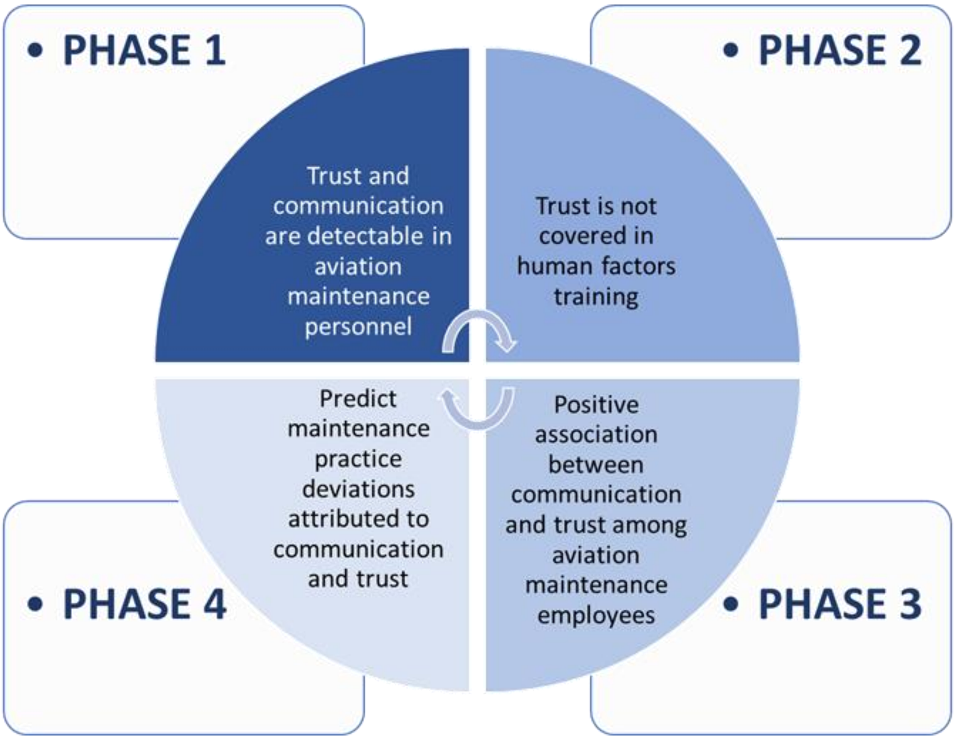
The process described in subchapter 5.1 'Diagnosis of Communication and Trust in Aviation Maintenance' (accidents/incidents' reports content analysis, aviation maintenance training content analysis, survey and prediction case study) can be formalised to become a conceptual process that can be used for the diagnosis of communication and trust issues. Examining closely the methodology construct followed in this study, it is noticed that it can form a cyclical process. This cyclical process follows the logic and sequence of the research questions and hypotheses and forms a closed circle. The starting point can differ depending on the topic/project/theme researched. This process can be used as a pattern in aid of predicting any deviation in maintenance practice, possibly caused by communication and trust preconditions. Thus, the following four-phase Conceptual Investigation Process is proposed (schematically represented in Figure 5.1):

- **Phase 1:** The two traits, communication and trust, are examined whether they exist or not in the aviation maintenance environment (which has been described in subchapter 4.1 'Content Analysis of Accident and Incident Investigation Reports');
- **Phase 2:** Relevant training material is examined to determine whether the aviation maintenance employees are trained for communication and trust, and consequently if they have developed awareness and relevant good practices in their work (which has been described in subchapter 4.2 'Content Analysis of Human Factors Training Curriculum and Material');
- **Phase 3:** The aviation maintenance sector is investigated (safety occurrences' reports or any other relevant data indicating safety performance) for the detection and measurement of the relation between the communication and trust (which has been described in subchapter 4.3 'Survey');
- **Phase 4:** Having completed Phase 1, 2 and 3, with all information and data available, the researcher can predict any communication and trust precondition,

as a possible cause of error in any already established or new maintenance procedure/process/task in the workplace (described in this Chapter).

As this is a cycle, the starting point may also be Phase 4, which can act as the trigger to the process. In this case, Phases 1, 2 and 3 can act as the preparatory steps for the work that will happen in Phase 4. The introduced Conceptual Investigation Process can also be very helpful in the visualisation and synthesis of the four steps in order to investigate the traits of communication and trust holistically and efficiently.

Figure 5.1 Conceptual Investigation Process used for the diagnosis of communication and trust in aviation maintenance.



A common tool is used in all Phases of this conceptual process, which is the Communication and Trust Question Set (which has been described in section 3.3.1 of Chapter 3 ‘Research Methods’). This tool, customised for aviation maintenance, was instrumental for the successful design and implementation of this research study. The Communication and Trust Question Set has been used both as a qualitative tool (having a recognition function) and a quantitative tool (having a diagnosis function). As a qualitative tool, its recognition function was used not only in actual aviation occurrences (accident and incident investigation reports; Phase 1 of the Conceptual

Investigation Process) but also in the hypothetical scenarios of a prediction process (prediction case study; Phase 4 of the conceptual process) (Figure 5.1).

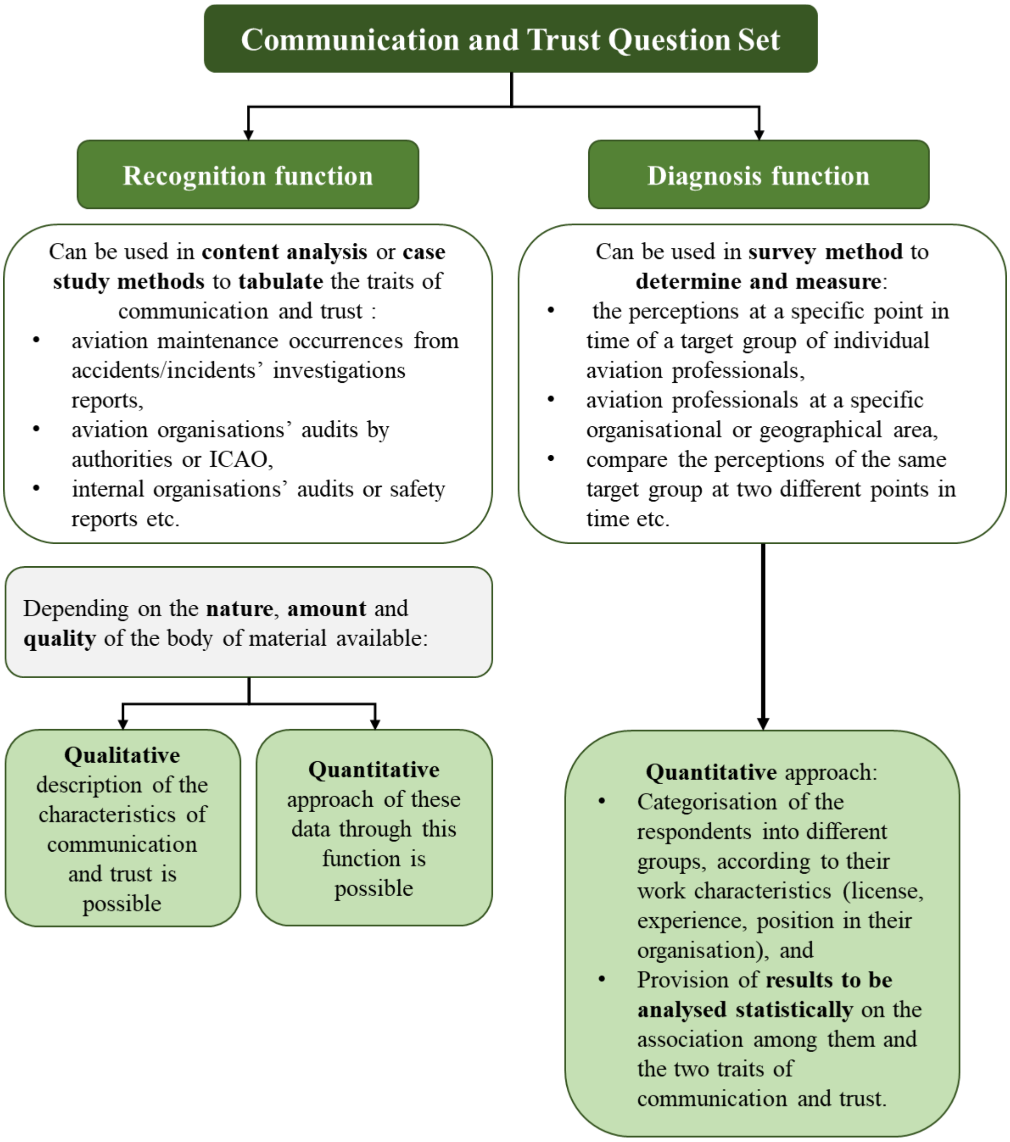
The Conceptual Investigation Process can have a qualitative and a quantitative use. Its qualitative functionality in this research project, depended on the volume, nature and quality of the data. However, there is no limitation in its quantitative use, even in qualitative methods such as the content analysis or the case study method. As a quantitative tool, its diagnosis function was used in the survey phase of this study (Phase 3 of the Conceptual Investigation Process), which explored the perceptions of aviation maintenance professionals about their work (Figure 5.1).

The recognition function of this tool can describe qualitatively the characteristics of communication and trust which are recognised/identified within aviation maintenance. Besides aviation maintenance occurrences from accident and incident investigation reports, other areas of aviation maintenance can be explored for the recognition of communication and trust, such as audits by aviation authorities/ICAO/etc, internal audits, discrepancy and safety reports etc. Also, depending on the nature and amount of the body of material available, a quantitative approach of these data through this function is possible.

The tool's diagnosis function can treat and present the traits of communication and trust quantitatively. This can be performed via a survey method, which can determine and measure the perceptions at a specific point in time of a target group of aviation professionals (i.e. aviation professionals at a specific organisational or geographical area). With this functionality, it can categorise the respondents into different groups, according to their work characteristics (license, experience, position in their organisation) and provide results to be analysed statistically (exploring the association among them and the two traits of communication and trust). Also, it could compare the perceptions of the same target group at two different points in time.

The overall construct and functionalities of the Communication and Trust Question Set are illustrated in Figure 5.2.

Figure 5.2 Multifunctional uses of the Communication and Trust Question Set.



It is highlighted that the use of the same tool (Communication and Trust Question Set) in all four Phases of the Conceptual Investigation Process ensures the consistency of this research project, as all aspects of communication and trust, are treated and measured with the same identification codes (items contained in the Communication and Trust Question Set).

5.2.2 Formulation

The Conceptual Investigation Process, matched with the use of the Communication and Trust Question Set (as a multifunctional tool), has been described extensively in this research study. The formulation of a complete model is, therefore, the logical next step towards formalising the overall construct of the research methodology developed. In connection with the foundations of this research study on communication and trust, this model would aim to:

- Establish a structured methodological approach;
- Extract usable data and draw meaningful results;
- Contribute to the promotion of safe practice within aviation maintenance.

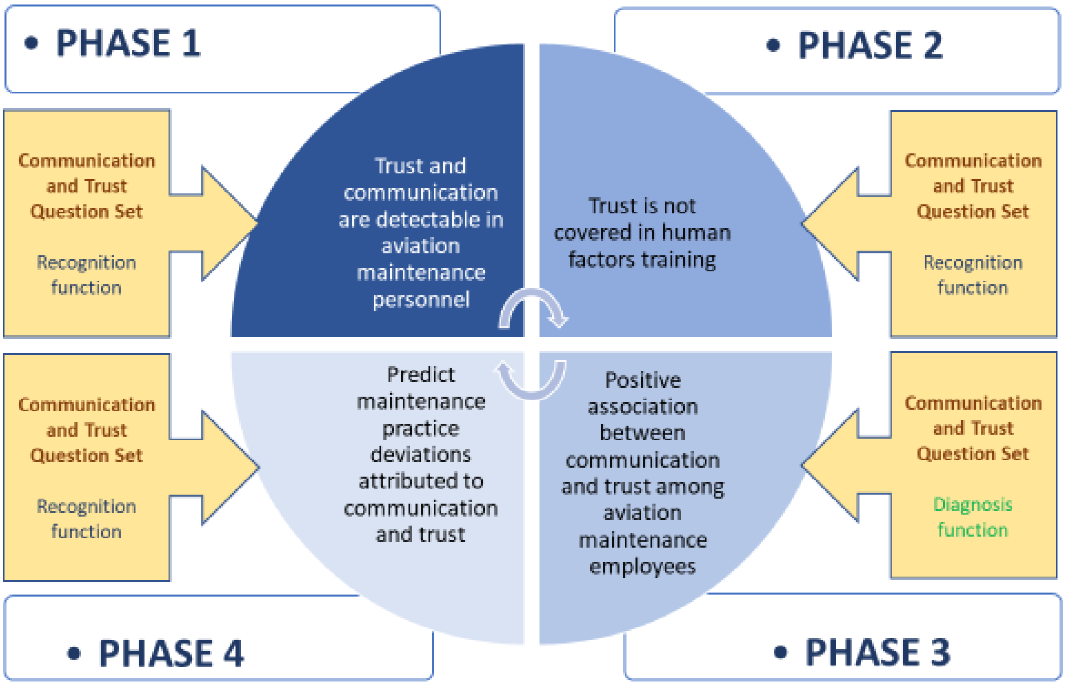
Therefore, the Diagnosis of Communication and Trust in Aviation Maintenance (DiCTAM) model proposed answers in the most inclusive way the Research Questions and Hypotheses. The formulation of the DiCTAM model is provided schematically in Figure 5.3, where the merge of the overarching Conceptual Investigation Process with the Communication and Trust Question Set shown, along with the description of the different functions performed in each of the Phases. In summary, the DiCTAM model is capable to:

- Detect the traits of communication and trust,
- Examine in depth the extent of the aviation maintenance employees' exposure to them, through their training.

The model's capability of investigating the aviation maintenance professionals' perceptions and synthesising all these results into the deviations prediction aspires to examine holistically the traits of aviation and trust in the aviation maintenance environment with a goal to promote safe operations in this field.

The novelty of this model lies in the development and utilisation of a dedicated (Communication and Trust Question Set) survey/question tool for aviation maintenance, which addresses methodically, for the first time, the association between communication and trust in aviation maintenance. The model can predict hypothetical deviations during maintenance practice attributed to communication and trust preconditions. These preconditions are identified (and can be quantified) based on the target group's perceptions on communication and trust. This model is expected to contribute to the advancement of research in this area, having, in turn, a positive contribution to the promotion of aviation maintenance safety.

Figure 5.3 The Diagnosis of Communication and Trust in Aviation Maintenance (DiCTAM) model.



The operation of the DiCTAM model is described and discussed in detail through its implementation in a hypothetical case study presented in subchapter 5.3 ‘DiCTAM Model Implementation Case Study’.

5.2.3 Transferability

As discussed, the overarching Conceptual Investigation Process of the DiCTAM model is a cyclical process:

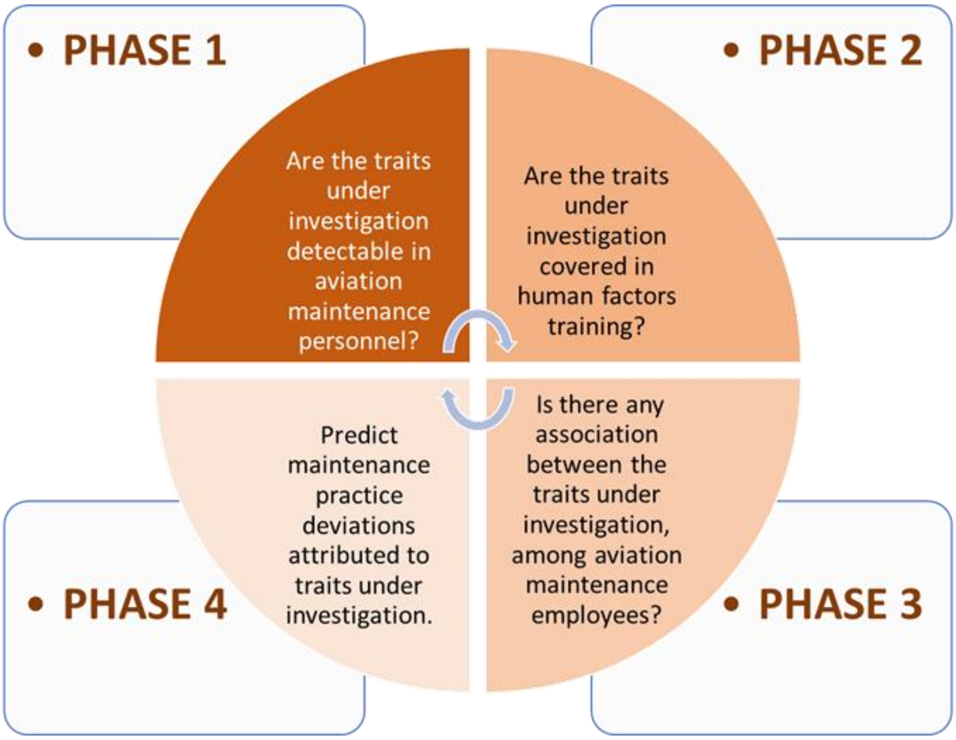
- Identifying, investigating and associating the perceptions of the people involved and
- Predicting their actions regarding communication and trust preconditions in aviation maintenance.

This process can be expanded to include more preconditions and offer a structured approach applicable to other similar research projects. Thus, the Conceptual Investigation Process would be transferable to other human factors preconditions, which, similarly to communication and trust, are present in aviation maintenance and affect safety. This would render the Conceptual Investigation Process a useful tool for aviation maintenance human factors researchers. To accommodate this extension and the transferability of the Conceptual Investigation Process, the following adaptation to the Phases is performed (also presented graphically in Figure 5.4):

- **Phase 1:** The two traits, which are under investigation, are examined whether they exist or not in the aviation maintenance environment;
- **Phase 2:** Relevant training material is examined to determine whether the aviation maintenance employees are trained for these two traits, and consequently if they have developed awareness and relevant good practices in their work;
- **Phase 3:** The aviation maintenance sector is investigated (safety occurrences' reports or any other relevant data indicating safety performance) for the detection and measurement of the relation between the two traits which are under investigation;
- **Phase 4:** Having completed Phase 1, 2 and 3, with all information and data available, the researcher can predict any precondition that is under investigation, as a possible cause of error, in any already established or new maintenance procedure/process/task in the workplace.

In this process, general questions, similar to the research questions asked in this study, can provide the methodical process into the prediction of possible maintenance practice deviations. These deviations can reveal to be in a causal relationship with the different human factors traits under investigation.

Figure 5.4. The Conceptual Investigation Process as transferred to other human factors' research areas.



5.3 DiCTAM Model Implementation Case Study

The case study presented has the purpose of presenting the operation of the DiCTAM model, as well as exemplifying its use. The case study approach has been considered a simple and illustrative way to cover both aspects, allowing the reader to develop a clear understanding of the model's functionality and practical value. A well-known case has been selected, that of the engine fan cowl door losses experienced in the Airbus A320 family fleet in worldwide level.

5.3.1 Background

Several Airbus A320 family engine fan cowl door (FCD) (Figure 5.5) losses have occurred in the past due to uninspected unlocked situations that have occurred in service (Air Accidents Investigation Branch, 2015b). This issue has been known to the industry for almost 18 years; however, it has not been addressed adequately by the aircraft manufacturer (Airbus) and the various operators or regulating authorities. Similar issues have been faced in the past with other aircraft types, such as the ATR-42 (Aircraft Engineering and Aerospace Technology, 2002).

Figure 5.5 A British Airways Airbus A319-100, where the (blue-painted) fan cowl doors (FCDs) surrounding the engines are shown.

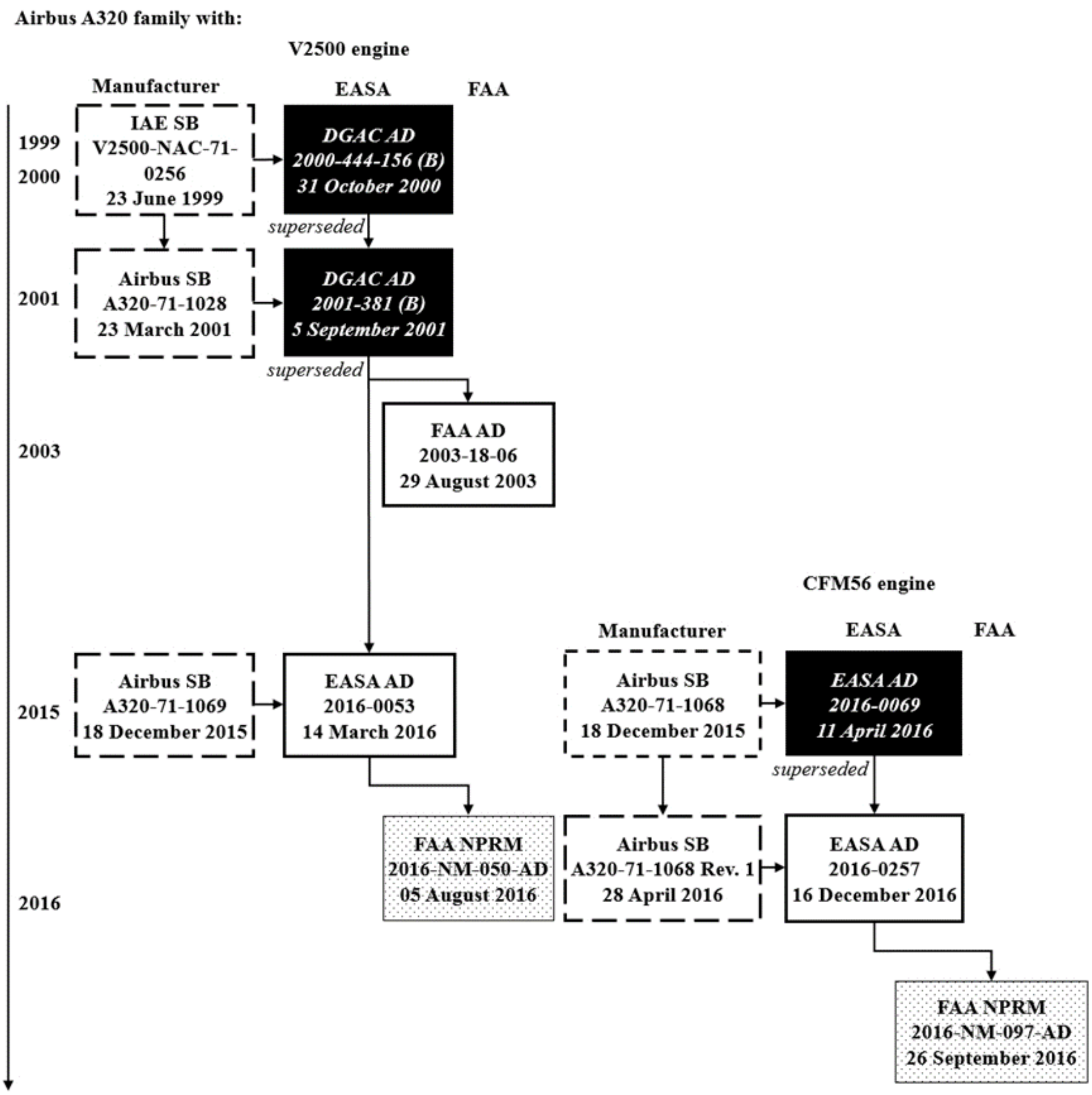
(photograph by Adrian Pingstone)
[https://commons.wikimedia.org/wiki/File:Britaw.a319-100.g-eupu.arp.jpg. Public domain].

A historical overview offers an interesting insight on the FCD safety issue, by looking at the preceding modifications (manufacturers' SBs), issued by EASA and Federal Aviation Authority (FAA) ADs and FAA proposed rulemaking documents (Notice for Proposed Rule Making, NPRM) (Figure 5.6). What stems from this brief examination is that following an activity in the early 2000's, the issue was practically silenced (from the standpoint of redesign and safety regulation) for 12 years, despite the ongoing incidents. Airbus, as the aircraft design approval holder, has re-opened the investigation and mitigation of this safety issue in reaction to an accident investigation report released in 2015 by the United Kingdom (UK) Air Accidents Investigation Branch (AAIB).

In particular, it was a double FCD loss from a British Airways Airbus A319 in 2013 (Figure 5.7) that has led to the escalation of this issue, following the release of the 2015 AIB accident investigation report (Air Accidents Investigation Branch, 2015b). Airbus, in an attempt to address the issue permanently, proceeded in redesigning the FCD locking arrangement and control philosophy (Airbus, Service Bulletin A320-71-1068, 18 December 2015; Airbus, Service Bulletin A320-71-1069, 18 December 2015), which were subsequently adopted by the European Aviation Safety Agency

(EASA), in 2015 and 2016, as Airworthiness Directives (ADs) (EASA, 2016c; EASA, 2016d). Both EASA ADs are currently under consideration by FAA (FAA, 2016a; FAA, 2016b).

Figure 5.6 A historical overview of the manufacturers' and regulating authorities' (EASA, FAA) actions on the Airbus A320 family engine FCD safety issue.



Note: DGAC refers to the French aviation regulator ('Direction Générale de l'Aviation Civile').

Figure 5.7 Remaining parts of the right-hand engine inboard FCD of the British Airways Airbus A319-131 G-EUOE following the 24 May 2013 accident.

(photograph reproduced from the AAIB Aircraft Accident Report 1/2015 (Air Accidents Investigation Branch, 2015b)

The 2016 EASA ADs and the relevant Airbus Service Bulletins (SBs) describe the modification that the aircraft operators have to implement on all affected models of the Airbus A320 family (A318/319/320/321) fitted with the IAE V2500 and CFM56 engines. The main features introduced by this modification are (EASA, 2016c; EASA, 2016d):

- A new FCD front latch which locks/unlocks with use of a specific key (the two other latches remain unchanged) (Figure 5.8). This key cannot be removed once the latch is unlocked.
- A new locking/unlocking key for the FCD front latch with a ('remove before flight') flag fitted on it (Figure 5.8). The flag increases the visibility-detectability of an unlatched condition since the key-flag assembly is attached to the latch as long as it remains in the open position.
- A key keeper assembly at a designated storage area in the cockpit, where the key and the ('remove before flight') flag assembly are kept when once the FCD is closed.
- Aircraft Maintenance Manual (AMM) adaptation, to include provisions for a logbook entry requirement when opening/closing the FCDs is performed, as a way to assist communication and raise awareness over the matter.

Figure 5.8 Modified A320 family engine FCD with new latch and key - ‘remove before flight’ flag assembly.

However, as part of the EASA ADs’ consultation process (conducted prior to their issue), a number of major operators (United Airlines, American Airlines, All Nippon Airways, Air Canada) have expressed reservations on the effectiveness of the Airbus redesign, on the basis of human factors issues, potential financial impact on operations and implementation cost (EASA, 2016a; EASA, 2016b). For example, United Airlines, in their comments to EASA (EASA, 2016a) argued that the implementation of another visual cue does not guarantee that the people involved will not miss it unless they are careful and attentive. In the same response, United Airlines highlighted that dual sign-off for the FCD closure and other steps they have introduced in their operational procedures (towards increasing the awareness of the technical staff) have proved to be successful in addressing human factor related issues. United Airlines has not had any incidents occurring since the introduction of these; human factor focused, measures in 2006. Similarly, Air Canada supported the suitability and effectiveness of the dual sign procedure, expressing a strong negative view on the usefulness of the modification (EASA, 2016b). As Air Canada highlighted in their comments, a uniform solution approach is not likely to be effective, since each organisation should work towards changing the technical staff culture to address the safety issues around FCDs (EASA, 2016b). As also recorded in the (EASA, 2016a; EASA, 2016b), one may note that, in response to these comments, EASA did not make any changes in the final ADs, while they suggested that operators may apply for an Alternative Means of Compliance

(AMC) to the AD, by providing data supporting their requests (for exemption from the AD).

The EASA's reasoning behind the adoption of the Airbus FCD SB is not described in the ADs. Moreover, the design principles employed by Airbus, in the development of the SB, is not known (as the SB is not publicly available). The adopted solution is considered peculiar for aviation maintenance, from the point of view of human factors, since it is not usual practice to restrict access to aircraft compartments via specific keys, rather than standard or special tools. An extensive review has failed to identify similar solutions utilised in civil aviation.

This subchapter intends to examine and discuss in a systematic way, the possible operational and safety implications that the FCD modification can have in aircraft maintenance practice.

5.3.2 Method

5.3.2.1 Overview

The method of the case study is a suitable method to examine hypothetical scenarios in the Fan Cowl Doors (FCDs) maintenance occurrences (after the implementation of the new procedures, provisioned by the latest EASA ADs). The case study methodology assists in the holistic examination of these hypothetical occurrences to unveil concealed elements and identify or even predict future trends or patterns (Leedy & Ormrod, 2013).

At this stage of the study, the aim is to examine these hypothetical scenarios for the identification of communication and trust elements and then, based on these findings, to predict the possibility of occurrence of each scenario. The complete process is explained in detail in the subsequent sections.

5.3.2.2 Scenarios

Considering the aircraft modifications and the changes in the maintenance processes, which occur from the EASA ADs, steps in the new procedures have been identified and examined. These steps may prove problematic from the point of view of safety effectiveness (increase errors or lead to deviations from safe practice) and disruption of operations (create delays/obstructions in aircraft dispatch/maintenance). An array of error-prone scenarios is presented and analysed under the prism of the human element. The scenarios, after their development, were validated by consulting aircraft maintainers having prior experience on the A320 family aircraft. Thus, both the development and validation of the scenarios did not require any physical work on aircraft (or any interaction with an aircraft maintenance organisation). Then, these scenarios were scanned to identify the items of the Communication and Trust Question Set. The analysis of the seven scenarios aimed to reveal any underlying communication and/or trust causal preconditions.

Moreover, accident prevention solutions are proposed for each of the scenario examined. It is noted that within the EASA framework, these recommendations are part of the existing Maintenance Resource Management (MRM) training and the EASA Part-66 and Part-145 human factors training requirements (EU, 2014). Errors related to handovers generally have more severe and dangerous consequences, as approximately half of the aircraft maintenance failures, due to ineffective communication, are related to the shift handover (Parke & Kanki, 2008). Debriefs which are based upon human factors considerations have the potential to enhance productivity by 20%–25% (Tannenbaum & Cerasoli, 2013).

Effective teamwork is known to be essential in safer aviation maintenance practice (Leonard et al, 2004; Robertson, 2005; Sexton et al, 2000), mainly due to the nature of the profession (organisational structure of work, rather than individuals working in isolation). Time pressure, such as that experienced in the flight line environment, is a primer for errors (Goglia et al, 2002; Reason 2000) and, in this case, it is considered important to be examined. Overall, teamwork, dual sign-offs, effective time management and request for assistance from colleagues and supervisors (whenever required) constitutes good practice in aviation MRM.

According to the FAA, MRM can also act as a training programme, as it aims to alter the technicians' attitude and perspectives in order to establish safety as their primary goal (Robertson 2005). As regularly reported in the literature, training in aviation is important and it acts beneficiary, while its design, delivery and implementation need to be tailored to the needs of the organisation (Lappas and Kourousis, 2016; Salas et al, 2012; Taylor and Thomas, 2003). Consequently, aircraft maintenance managers should consider the training process as a proactive safety measure and actively support MRM training. It is of note that employees, working within the highly regulated aviation industry, are inclined towards safety than productivity (Karanikas et al, 2017). This is a strong indicator of how the 'safety over productivity' equilibrium can be positively influenced (towards safety) by regulation.

It is interesting to look at the definition of Wiegmann,et al, (2004) on safety culture "as the shared values, beliefs, assumptions, and norms that may govern organisational decision making, as well as individual and group attitudes about safety". Focusing on the norms of an organisation, these set the framework within employees are expected to think and operate (Wreathall, 1995). Therefore, if the norms contradict the organisation's safety policy, they should be revised or abolished. Any organisation, in order to action changes in culture, must establish effective safety communication between the various organisational and managerial levels. In aircraft maintenance training, this can include the establishment of a thorough safety training programme (Geldart et al, 2010; Hall et al, 2016).

The devised seven scenarios are not intended to be exhaustive, in terms of presenting the full spectrum of combinations of actions. However, they represent several cases which are deemed likely to occur in service, and that can have a considerable impact on safety and operations. All scenarios start from the case of a maintenance task requiring access to the area enclosed by the FCD (in the cases examined 'engine failure troubleshooting'), which is secured by the specific key (introduced with the Airbus modification/EASA ADs). Each precondition that was identified is presented separately with the relevant matching item/s of the Communication and Trust Question Set with the relevant justification.

The sequence of the events and causes for each of the seven Scenarios (1 to 7) is graphically represented in Figure 5.9, where all interconnections are shown. The graph illustrates characteristically the complexity of the various problematic situations that may arise out of the subject matter FCD safety modification.

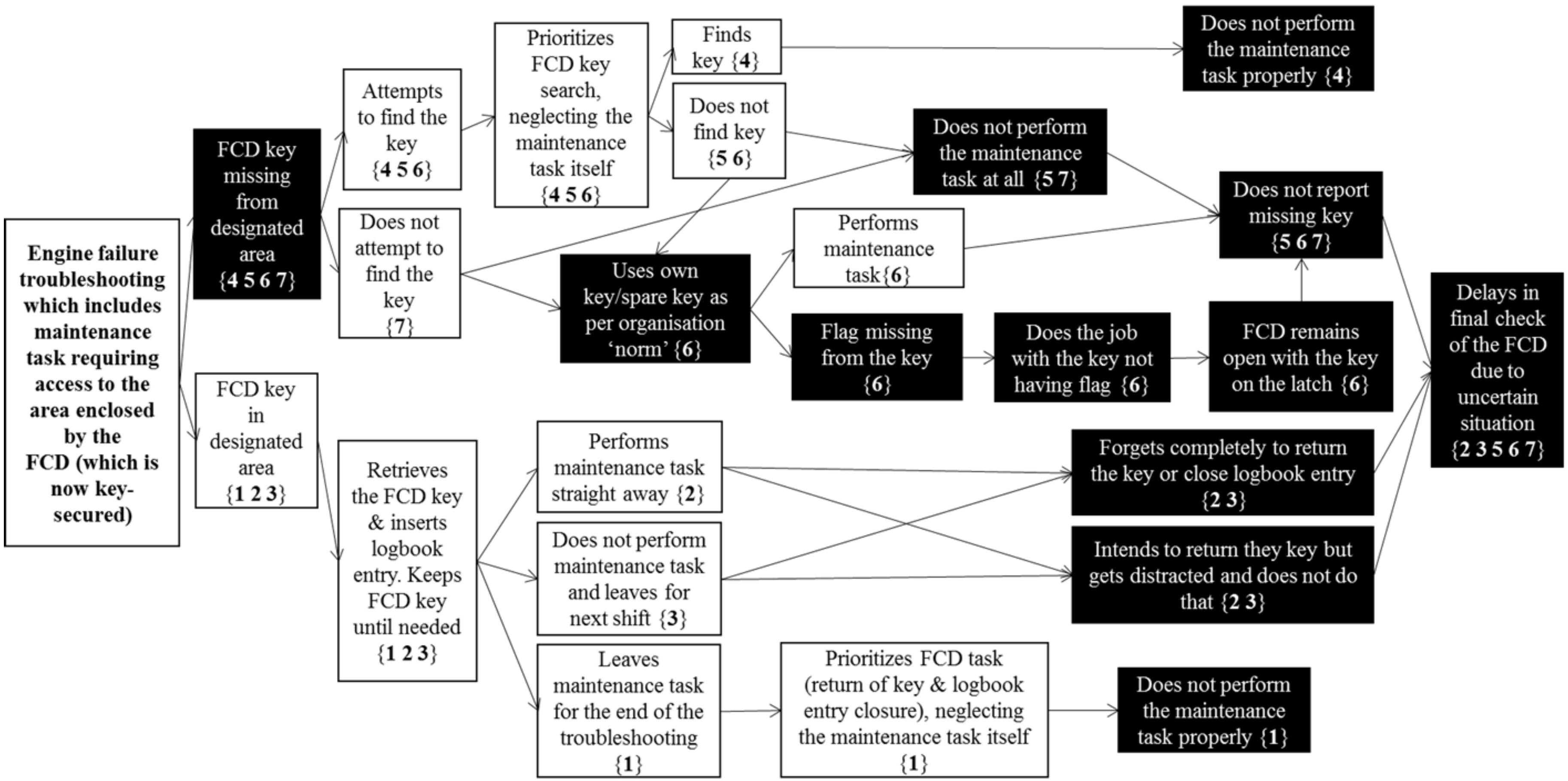


Figure 5.9 Graphical representation of the sequence of the events and causes described in each of the Scenarios examined (1 to 7). In { } the relevant Scenario number(s) is (are) indicated.

Since all scenarios are realistic, they are considered more or less probable. Typically, these may be encountered by technicians working both in the line and base level aircraft maintenance environment. However, since these scenarios are neither exhaustive nor have been tested/validated in actual aircraft maintenance practice further analysis is necessary. For that purpose, a substantial survey, which should include a wider array of scenarios, would be necessary to obtain the necessary data for a quantitative (statistical) analysis.

The seven scenarios are divided into two broader groups, those which are occurring from two different situations:

- The technician retrieves the FCD key from the designated storage area in the cockpit and inserts a logbook entry for the opening/closing of the FCD (Scenarios 1, 2 and 3), presented in subsection 5.3.2.2.1;
- The technician does not find the FCD key in the designated storage area in the cockpit (Scenarios 4, 5, 6 and 7), presented subsection 5.3.2.2.2.

5.3.2.2.1 FCD Key in Designated Area

Scenario 1 ***The technician leaves the maintenance task (in the area enclosed by the FCD) for the end of the failure troubleshooting. He/she performs the maintenance task at the end of his/her shift. However, he/she does not dedicate adequate time for the maintenance task, as he/she inadvertently prioritised the FCD task [return of the key, closure of the logbook entry (‘FCD closed’)], in an effort to avoid the FCD is not left open. This poor practice may result in reduced maintenance quality, under stressful or very time constrained situations, since FCD-related tasks are added to the existing workload.***	
Trust factor identified	Maintenance personnel failed to dedicate the time required for this task, risking the quality of this work. This indicates that the maintenance personnel deviated from an expected good practice in their duties. Specifically, by using the Communication and Trust Question Set, the following three items are identified in this failure: F2 ‘My colleagues perform their duties very well’, F3 ‘Overall, my colleagues are capable and proficient technical staff’ and F5 ‘My colleagues act in the best interest of the project’. Items F2 and F3 correspond to the ‘construct of trust in colleagues’ competence’ category while item F5 in the ‘construct of trust in colleagues’ benevolence’ category.
Possible Prevention Measures	Putting more focus on time management techniques and requesting assistance from peer-workers/team leader in stressful/time-pressing situations.

Scenario 2 ***The technician performs the maintenance task straight away but leaves the key return and logbook entry closure for later. Since these steps were left for a later time, the technician either forgets completely to return the key/close the logbook entry or gets distracted near that time, having the same result. As a consequence, the aircraft release to service can be delayed, since the involved personnel (flight crew, technical staff) will have to locate the missing key and complete the FCD sign-off in the logbook.***	
Communication factor identified	Not performing a proper handover, makes the ideal preconditions for errors. This deviation from accurate reporting can result in lack of effective communication between colleagues and can prevent from the proper actions taken to mitigate the errors. Therefore, the communication problems identified here are in relation to items: D19 'The amount of communication was not about right', D2 'The organisation's communication motivates and stimulates an enthusiasm for meeting its goals', C3 ' Information about organisational policies and goals', D8 ' Personnel receive in time the information needed to do their job', D6 'The organisation's communications are interesting and helpful, item', D17 'Issues whether the attitudes towards communication in the organisation are healthy', C7 'Information about departmental policies and goals, item C7', D15 'Meetings are well organised', D12 'Communication with colleagues within the organisation is accurate and free flowing', D3' Supervisor listens and pays attention to personnel' and D6 'The organisation's communications are interesting and helpful, item D6'.
Possible Prevention Measures	A dual sign off practice would offer the opportunity for a confirmation check and reduce the possibility of misses and errors.

Scenario 3 ***The technician does not perform the maintenance task and has to pass it over to the next shift. Since these steps were left for the next shift, he/she either forgets to return the key/close the logbook entry or gets distracted to do that. In case that the shift handover is not performed properly, the FCD tasks are not completed. As a consequence, similarly to Scenario 2, the aircraft release to service can be delayed, since the missing key has to be located and the logbook signed off.***	
Communication factor identified	As with Scenario 2, not performing a proper handover, makes the ideal precondition for errors. This deviation from accurate reporting can result in lack of effective communication between colleagues and can prevent from the proper actions taken to mitigate the errors. Therefore, the communication problems identified here are in relation to items: D19, D2, C3, D8, D6, D17, C7, D15, D12, D3 and D6.
Possible Prevention Measures	As with Scenario 2, the dual sign off practice can mitigate this issue. Moreover, a thorough (verbal and written) shift handover would be helpful in avoiding communication gaps in relation to the FCD tasks (reducing the possibility for misses and errors).

5.3.2.2.2 FCD missing from Designated Area

Scenario 4 ***The technician attempts to find the FCD key. He/she prioritises this task over the maintenance task itself. In the case that he/she finds the key, the amount of time spent on the search does not allow him/her to focus on the maintenance task, thus this is not performed adequately.***	
Trust factor identified	Similarly to Scenario 1, maintenance personnel, failed to dedicate the time required for this task, risking the quality of this work. This indicates that the maintenance personnel deviated from an expected good practice in their duties. Specifically, following three items are identified in this failure: F2, F3 and F5.
Possible Prevention Measures	Similarly, to Scenario 1, it would be beneficial if better time management techniques were practiced, as well as if the technician requested assistance.

Scenario 5 ***The technician attempts to find the FCD key, prioritising the search over the maintenance task (same as in Scenario 4). He/she does not manage to find the key, leaving the maintenance task unaccomplished. In the case that the technician is forgetful or distracted, he/she will not report the missing key, causing more delay, as other personnel in later time will repeat the search process.***	
Communication factor identified	As with Scenario 2 and 3, not performing a proper handover, makes the ideal precondition for errors. This deviation from accurate reporting can result in lack of effective communication between colleagues and can prevent from the proper actions taken to mitigate the errors. Therefore, the communication problems identified here are in relation to items: D19, D2, C3, D8, D6, D17, C7, D15, D12, D3 and D6.
Possible Prevention Measures	Similarly to other scenarios, the dual sign off in conjunction with a robust handover process could mitigate this miss.

Scenario 6 ***The technician attempts to find the FCD key, prioritising the search over the maintenance task (same as in Scenario 4 and 5). He/she does not manage to find the key, therefore deciding to use his/her own key or the spare key as per the organisation's 'norm and fills in the logbook entry ('open FCD'). After completing the maintenance task, the technician is forgetful/omits or gets distracted and does not report the missing key. As with Scenario 5, this may cause a delay in the future. Moreover, using his/her own key means that this may not have the 'remove before flight' flag attached, increasing the probability of leaving the cowl door open (since this modified visual cue will be missing).***	
Trust factor identified	Maintenance personnel deliberately chooses to use own key, opposite to the company's policies, which might not include the dedicated visual cue. This indicates that the maintenance personnel deviated from an expected good practice in their duties. Specifically, by using the Communication and Trust Question Set, the following four items are identified in this failure: F2 'My colleagues perform their duties very well', F3 'Overall, my colleagues are capable and proficient technical staff', F 'In general, my colleagues are knowledgeable about our organisation' and F5 'My colleagues act in the best interest of the project'. Items F2, F3 and F4 fall in the construct of trust in colleagues' competence while item F5 falls in the construct of trust in colleagues' benevolence.
Communication factor identified	As with Scenario 2, 3 and 5, not performing a proper handover, makes the ideal precondition for errors. This deviation from accurate reporting can result in lack of effective communication between colleagues and can prevent from the proper actions taken to mitigate the errors. Therefore, the communication problems identified here are in relation to items: D19, D2, C3, D8, D6, D17, C7, D15, D12, D3 and D6.
Possible Prevention Measures	Similarly to previous scenarios, the dual sign off in conjunction with a robust handover process could mitigate this miss. In addition, a change in the organisational culture would be necessary to abolish unsafe practices in relation to established 'norms' outside the standard policies and procedures.

Scenario 7 ***The technician does not have the required time or attitude to attempt to find the missing key, thus he/she decides not to perform the assigned maintenance task and, for example, to move onto a different task. He/she forgets about the missing FCD key or gets distracted and does not report that. This shall cause delay in the work of the personnel who are then assigned to the maintenance task in the FCD-accessed area (as they will have to search for the missing key).***	
Communication factor identified	As with Scenario 2, 3, 5 and 6, not performing a proper handover, makes the ideal precondition for errors. This deviation from accurate reporting can result in lack of effective communication between colleagues and can prevent from the proper actions taken to mitigate the errors. Therefore, the communication problems identified here are in relation to items: D19, D2, C3, D8, D6, D17, C7, D15, D12, D3 and D6.
Possible Prevention Measures	Dual sign off and in-shift/inter-shift handover would be an effective solution to avoid such situations.

5.3.3 Results and Discussion

The seven scenarios presented (Scenario 1 to 7) refer to seven different causal situations in which safety issues, related to the fan cowl doors of modified aircraft of the Airbus 320 family, may arise. These scenarios were investigated against the items of the Communication and Trust Question Set. As shown in Table 5.1, many different trust and/or communication issues corresponded to each one of the scenarios, therefore all scenarios showed communication and trust preconditions. Trust was found present in five scenarios, while communication was found present in three. One scenario had communication and trust preconditions present at the same time, while the rest six had solely one precondition present (either trust or communication).

More specifically, the issues identified in relation to trust were about interpersonal trust. The Communication and Trust Question Set items are grouped in different constructs, each one indicating specific attributes of trust. Therefore, the specific characteristics identified here were trust towards colleagues' competence and benevolence. Concerning the communication satisfaction, issues were identified in relation to the satisfaction with the organisation's communication climate, with the superiors, with the organisation's integration, with the media quality, the general organisational perspective and with the horizontal informal communication. These are

Table 5.1 Communication and trust items, of the Communication and Trust Question Set, identified in Scenarios 1 to 7.

Scenario	Trust Factor Items	Communication Factor Items
Scenario 1	F2, F3, F5	
Scenario 2		D19, D2, C3, D8, D6, D17, C7, D15, D12, D3, D6
Scenario 3		D19, D2, C3, D8, D6, D17, C7, D15, D12, D3, D6
Scenario 4	F2, F3, F5	
Scenario 5		D19, D2, C3, D8, D6, D17, C7, D15, D12, D3, D6
Scenario 6	F2, F3, F4, F5	D19, D2, C3, D8, D6, D17, C7, D15, D12, D3, D6
Scenario 7		D19, D2, C3, D8, D6, D17, C7, D15, D12, D3, D6

the wider groups of the Communication Satisfaction Questionnaire items, that were initially introduced by Downs and Hazen (1977) and can describe categorically the specific issues with communication satisfaction identified in these scenarios.

The communication and trust items identified (listed in Table 5.1) are not factors that have to exist in combination to contribute to the hypothetical scenario. At least one of these factors (namely, one of the possible items) could suffice in the occurrence of the relevant scenario. The mean value of each item corresponds to the level of communication satisfaction and trust exhibited by the surveyed population. Namely, a high mean score is a positive indicator of high levels of communication satisfaction or trust. For this reason, an item's lower mean score of each scenario was selected as the criterion for the hierarchical categorisation of the scenarios relative to the possibility of occurrence. For example, a scenario with an item having a higher mean is less probable than that of a scenario with an item of a lower mean. Lower mean scores reveal lower communication satisfaction and trust, which subsequently include issues with communication and trust (yielding higher probability of occurrence).

Table 5.2 Means of the trust and communication factors as identified in Scenarios 1 to 7.

		Scenario						
		1	**2**	**3**	**4**	**5**	**6**	**7**
Trust Factor identified	**F2**	5.66	-	-	5.66	-	5.66	-
	F3	5.89	-	-	5.89	-	5.89	-
	F4	-	-	-	-	-	5.56	-
	F5	**5.54**	-	-	**5.54**	-	**5.54**	-
Communication Factor identified	**D19**	-	4.45	4.45	-	4.45	4.45	4.45
	D2	-	**4.15**	**4.15**	-	**4.15**	**4.15**	**4.15**
	C3	-	4.73	4.73	-	4.73	4.73	4.73
	D8	-	4.83	4.83	-	4.83	4.83	4.83
	D6	-	4.51	4.51	-	4.51	4.51	4.51
	D17	-	4.65	4.65	-	4.65	4.65	4.65
	C7	-	4.71	4.71	-	4.71	4.71	4.71
	D15	-	4.55	4.55	-	4.55	4.55	4.55
	D12	-	5.27	5.27	-	5.27	5.27	5.27
	D3	-	5.09	5.09	-	5.09	5.09	5.09
	D6	-	4.51	4.51	-	4.51	4.51	4.51

The identification of more probable and less probable scenarios involves the comparison of the means for all scenarios, listed in Table 5.2. The lower mean score is accounted as to have a higher occurrence probability of the scenario tabulated to this mean score. The least mean score in each scenario, that determined the ranking of the relevant scenario, is shown in Table 5.2 in bold font and highlighted in yellow colour. This process identified two items; whose mean scores categorised the seven scenarios. Therefore, the two mean scores categorised the seven scenarios into two groups: Group A, corresponding to more possible to occur, and Group B, to less possible to occur scenarios.

The output of this exercise summarised the results presented in Table 5.3, with a two-tier ranking obtained (Group A and B). Based on this ranking, Scenarios 2, 3, 5,6 and 7 are more possible to occur that Scenarios 1 and 4.

Table 5.3 Ranking of Scenarios 1 to 7 based on the possibility of occurrence.

Possibility of Occurrence	***Scenario***	***M***	***Trust / Communication Item***
A. More Possible	**Scenario 2**	4.15	D2
	Scenario 3	4.15	D2
	Scenario 5	4.15	D2
	Scenario 6	4.15	D2
	Scenario 7	4.15	D2
B. Less Possible	**Scenario 1**	5.54	F5
	Scenario 4	5.54	F5

5.4 The DiCTAM Model in Safety Management Systems

In aviation maintenance, the anticipation of safety is of major importance; therefore, the examination of communication and trust as causal preconditions to maintenance error can be proven valuable. The importance of this examination lays not only at the investigation and deeper understanding of these preconditions but also at their prediction, which is examined next. The structured approach offered by the DiCTAM model can be beneficial towards enhancing safety in the aircraft maintenance industry, or causal factors related directly or indirectly to communication and trust. Safety Management Systems (SMS) have been attracting increasing attention from the aircraft maintenance industry, both for regulatory compliance reasons but also for their capability to systemise approaches around safety. In that regards, the possible interconnection of the DiCTAM model with Safety Management Systems (SMS) within aviation maintenance organisations is examined here. This examination can yield useful conclusions on the applicability of this model within the existing SMSs.

5.4.1 Background and Objectives of Safety Management Systems

Aviation is one of the most complex and regulated industries around the world. From its early years, while its operations were growing rapidly, and tragic accidents with great loss of life and cost had started to occur, safety arose as a major factor in its operations. International Civil Aviation Organisation (ICAO) is the United Nation's specialised agency which works with 191 member States and industry groups to set common Standards and Recommended Practices (SARPs) and policies to implement safe, efficient, financially and ecologically sustainable activity in civil aviation.

Since 1944, when the Chicago Convention took place, the first 52 attending Nations signed the International Convention for Civil Aviation, setting the regulations and principles for all National Aviation Authorities (NAAs) (Purton, Clothier, & Kourousis, 2014). These policies and guidelines are used by Member States to ensure that their civil aviation authorities include them in their legislations content to the State's harmonisation with the global standards and safety procedures set by ICAO (Gerede, 2015; Purton & Kourousis, 2014). From the 1960s the quality management system term (QMS) appeared on the aviation field to pave the way to occupational health and safety management system (SMS) (Stolzer, Goglia, & Stolzer, 2015). Safety management systems have evolved gradually with the influence of other management systems and disciplines until they finally took their most current form (Stolzer et al., 2015). SMS and QMS are closely related to each other as they both promote safety. They are the most basic and complementary systems in managing safety in aviation (International Civil Aviation Organisation, 2013).

All sectors in aviation regardless if they are maintenance, operators, air traffic management, airport operations etc. operate under the same regulatory framework. SMSs are applied across the different sectors ensuring their safe operation. However, these different sectors have different operational circumstances and requirements that might affect the way the SMSs are applied and even affect their activities. The globalisation of operations dictated the standardisation of SMSs as well, to the harmonisation and efficient collaboration of different aviation organisations, as their international character grew bigger and more complicated. More than 20 years ago, the first standardisation of quality assurance was a reality (Stolzer et al., 2015). Today, aviation regulatory bodies around the world have institutionalised safety management systems, that follow the standardisation requirements, and aviation companies are obliged to have them in place.

5.4.2 Safety Management Systems Components

According to the 3rd edition of the ICAO's Safety Management Manual (SMM) (2013) "SMS is a systematic approach to managing safety, including the necessary organisational structures, accountabilities, policies and procedures" (International Civil Aviation Organisation, 2013, p. xii). In the same document ICAO states the significance of the implementation of SMSs by the NAAs internationally in order to:

- Locate the potential threats to safety,
- Make certain to enforce all corrective actions necessary to keep the agreed safety performance,
- Contribute to continuous monitoring and orderly assessment of safety performance, and
- Target a higher quality of performance of the safety management system.

To meet these criteria, a set of four components were proposed to form the SMS's framework. It is understandable that the size of each organisation and the complexity of the services provided defines the form of the frame in which the SMS is implemented. These four components include twelve elements and they are the minimum requirement for an aviation company to implement an SMS. The four components of SMS, according to ICAO's Safety Management Manual (SMM) (2013) are safety policy and objective, safety risk management, safety assurance and safety promotion (illustrated in Figure 5.10). Moreover, each of the components' elements that categorise its activities as shown in Table 5.4.

In the development of the components of SMS, safety culture emerged as a critical element is an ultimate goal for every management in aviation. Within the frame of a well-established safety culture, staff are fully aware of safety requirements and willing to promote safety.

Figure 5.10 Schematic representation of the four SMS components.

Table 5.4 SMS individual elements and corresponding activities.

Safety policy and objectives	• Management commitment and responsibility; • Safety accountabilities; • Appointment of key safety personnel; • Coordination of emergency response planning; • SMS documentation.
Safety risk management	• Hazard identification; • Safety risk assessment.
Safety assurance	• Safety performance monitoring and measurement; • The management of change; • Continuous improvement of the SMS.
Safety promotion	• Training and education; • Safety communication.

These components and their elements are set by ICAO's Safety Management Manual (SMM) (2013) as the minimum requirements each aviation organisation should have, after each National Aviation Authority's (NAA) approval. This approval reflects on each of the NAA guidance materials and requirements available to the aviation companies within their jurisdiction. Aviation regulatory bodies such as the Federal Aviation Administration (FAA) and European Aviation Safety Agency (EASA) have developed themselves SMS structures under the direction of ICAO's guidelines. As a result, NAAs around the globe are designing their SMSs following either FAA's or EASA's policies or directly ICAO's guidelines to ensure their compliance with ICAO's directions (Figure 5.11).

Figure 5.11 Schematic representation of the policymaking process.

In the Federal Aviation Administration's (FAA) Advisory Circular AC 120-92B (2015), the four components of SMS, as they are introduced by ICAO, are presented. Aviation companies are obliged to follow this structure in order to ensure their successful implementation of an SMS programme within their operational activities. These four components, as they are retrieved from the FAA's AC 120-92B, are explained, examined and mapped against the components and functions of the DiCTAM model.

5.4.2.1 Component 1 - Safety Policy and Objectives

The core of every organisational structure is its policies and procedures. In order for safety to be established as a fundamental part of this core, it needs to be dominated by relevant guidelines and to be included in the policies and the organisational structure. Under this framework, safety is organisationally in the company's goals to set objectives, assign responsibilities and set standards. The implementation of this stage depends highly on the commitment of the upper management to safety.

The management's role is critical, regarding the safety policy and objectives, as it is the management's active support and anticipation that keeps all employees focused and motivated to this direction. It is clearly the management's responsibility to oversee the accurate implementation of all policies and procedures as well as to ensure that safety is one of the primary goals of the company. This means that safety is included in the strategic plans of the company and is being assessed regularly along with the company's SMS. This assessment is a very critical phase for every aviation organisation. It includes feedback from the implementation of the safety risk management component and the risk assurance component of the SMS. This assessment and feedback give the opportunity to ensure that all policies and procedures are realised in the way they were designed to be, and all standards are accurately held.

From the examination of the 'Safety Policy and Objectives' Component of SMS (and its constituent activities), it stems that the DiCTAM model cannot have any role or direct/indirect contribution.

5.4.2.2 Component 2 - Safety Risk Management

The safety risk management component consists of decision-making processes, such as identifying hazards and mitigating risks, by carefully evaluating the organisation's systems and their operating environment. Evidently, the most important element in this component is the risk management system that is in place and its effectiveness. It is of high importance in each aviation organisation to successfully measure risk and to develop efficient strategies to manage it. This is particularly important for military aviation, due to the nature of operations, both in peace and wartime.

Acceptable risk is a value that each aviation organisation has to set for itself, following specific procedures, and then making decisions on ways to reduce that risk. This process requires a thorough understanding of the operational systems, which includes the structures, the procedures and the policies of the company along with the staff, equipment and the artefacts of the company. This means risk experts are called to use all available tools to process risk management by identifying the hazard in the company's activities and calculate the associated risk accordingly. Once the risk is analysed, its assessment comes next and eventually follows the reducing of the risk to conclude the process. Reducing the risk is a realistic term as elimination is rarely accomplished, either in civil or military aviation. In reality, reduction of risk to an acceptable level of risk is doable, with risk experts evaluating this acceptable level after thorough investigations and analyses.

From the examination of the 'Safety Risk Management' Component of it stems that the DiCTAM model can direct and indirect role and contribution in the following activities:

- Hazard identification, both the qualitative and quantitative function of the DiCTAM model can assist in identifying hazard areas related to communication and trust. In particular, it is the recognition and diagnostic functions of the DiCTAM model that can be employed in this direction.
- Safety risk assessment, the DiCTAM model can feed in the risk minimisation/elimination loop, as part of assessing hypothetical scenarios in relation to causation factors attributable to communication and trust.

5.4.2.3 Component 3 - Safety Assurance

Safety assurance is the stage in which the safety risk management process is evaluated. It means that this is the reassuring component which gives an aviation organisation the reassurance that their SMS is meeting their strategically set safety objectives and that all risk controls and mitigations, that took place during the safety risk management component, had a positive impact and were effective. Thus, in safety assurance procedure, detailed monitoring is of primary importance in measuring safety performance in the company's operations and in improving their level of safety constantly.

A robust safety assurance process uses as many resources as possible to preserve the integrity of risk controls. These resources may stem from information gained through the staff reporting system, audits (external or internal), experts' investigations and analyses. The key element at this stage is again the management's commitment to safety. Management is the organisational factor that is responsible for the realisation of all necessary changes in order to proceed to the desired level of safety. Therefore, safety assurance is the framework that enhances the safety performance of the organisation, makes corrections whenever it is necessary and pointing out existing processes that need to be under consideration. The DiCTAM model has a direct and indirect role and contribution to the safety performance monitoring and measurement. In particular, both the qualitative and quantitative function of the DiCTAM model can assist in identifying areas related to communication and trust. It is the recognition and diagnostic functions of the DiCTAM model that can be employed towards safety reporting, audits, investigations and analyses.

5.4.2.4 Component 4 - Safety Promotion

Safety promotion is the last component of SMS and is designed to promote safety among the organisation's employees. All staff from the upper management to the newly hired have to acknowledge their responsibility in safety by familiarising themselves with the safety policies and procedures, the reporting procedures that are in place and the risk controls. For a safety promotion to be effective, the creation and application of a robust safety culture are of high importance.

A safety culture within the organisation enables all staff to comprehend and maintain their part in safety operations of the company by following all the relevant policies and procedures while empowering the company's reporting culture and the just culture (Stolzer et al., 2015). An efficient reporting culture comprises of a system that enables safety-related issues to be reported freely among employees having as a goal their correction. A healthy just culture is the culture "in which individuals are both held accountable for their actions and treated fairly by the organization" (Stolzer et al., 2015, pp. 33).

In these regards, training and communication are essential elements of safety promotion. Continuous staff training ensures that all individuals involved are updated with all the requirements for their roles in the company and the properly certified qualifications have been provided to them. Training can be helpful; however, fundamental education is also very important for aviation staff. Thus, several companies are placing emphasis on the combination of training with education. Moreover, every organisation should have an efficient communications system in place, for staff to have untrammelled access to all safety regulations and policies. At the same time, this access should be unrestricted to qualified safety personnel for help and guidance.

From the examination of the ‘Safety Risk Management’ Component of it stems that the DiCTAM model can direct and indirect role and contribution in the following activities:

- ‘Training and Education’, the DiCTAM model is a tool having the capability to identify training needs gaps concerning communication and trust. This function can be used both in the assessment and development of training material (and curriculum where necessary) related to communication and trust matters.
- ‘Safety communication’, the outreach and impact of safety communication can be enhanced indirectly by developing a series of effective communications based on the construct of the Communication and Trust Question Set (acting as a guide for the development of such material).

5.4.3 Conclusion

From this examination and analysis of the SMS components and constituent activities, it is concluded that the DiCTAM model can have a contribution (direct/indirect) in SMS Component 2 ‘Safety Risk Management’, Component 3 'Safety Assurance' and Component 4 ‘Safety Promotion’. These findings highlight again the practical value of the developed model, also considering its capacity to accommodate various human factors traits, in addition to the ones for which it was originally developed for (communication and trust).

CHAPTER 6 DISCUSSION

6.1 Content Analysis of Accident and Incident Investigation Reports

As there was no direct mention of the word 'trust' and as the word 'communication' was mentioned at only one distinct occurrence, Research Question 1 had a negative answer. Then, the items of the questionnaire, which were developed to be used at the survey phase of this study, the Communication and Trust Question Set, were used. The Communication and Trust Question Set (Tables 3.2 and 3.4) helped to identify indirectly the preconditions of communication and trust in the maintenance errors, that were presented in these reports, and provided Research Question 1 with a positive answer.

During the indirect investigation phase of Research Question 1, indeed, the concealed elements of communication and trust were identified but not all items of the Communication and Trust Question Set were present in the reports. A comprehensive list of all items (found and not found in the reports) is provided in Table 6.1. Even though the items, not used in the content analysis, describe widely the two traits of communication and trust as well, there were no relevant references in the reports by the investigators, and consequently these items could not be linked to the reports' maintenance errors.

After a thorough examination of the fifteen accident and incident investigation reports, the following observations were made:

- The reports originate from various sources, and there were differences in their structure, content and methodologies. This means that these reports were not prepared in a standardised or consistent way. However, even though the investigators were not specifically investigating for communication and trust causal preconditions, the accident/incident content analysis revealed that both traits (communication and trust) might have contributed to all maintenance occurrences.
- None of the fifteen reports examined the supervisor/manager's perspective and therefore no item from the supervisor/manager's sections G and E of the Communication and Trust Question Set could be used in the content analysis. Since the aviation maintenance environment is a complicated, multilayer environment, as maintenance employees perform their duties mostly in teams

and in shifts, a reference about the supervisor/manager's perspective would be expected to be covered in at least some of these reports.

- Furthermore, some additional aspects of the association between communication and trust, in the examined maintenance errors in subchapter 4.1 'Content Analysis of Accident and Incident Investigation Reports', were not identified in any of the analysed reports. This is of major importance as these specific elements could be present but undetected and therefore, an opportunity to be examined might have been lost. The relevant questionnaire's items that reflected these aspects and were not used (Table 6.1) are:
    - ***Communication:*** these questionnaire's items are about: maintenance employees' personal feedback on the quality of their job, efforts, their personal judgement by colleagues, personnel news, financial and regulatory information in relation to their organisation and their personal situation, information on emergencies and problem handling, information on how superiors see and handle issues from bellow and information on informal communication (Table 6.1);
    - ***Trust:*** these questionnaire's items are about: keeping verbal commitments, assist colleagues when it is required, and reliability, dependence and predictability of the software used for maintenance tasks (Table 6.1).

Considering the above, the content analysis of the accident and incident investigation reports indicate that communication and trust are present preconditions in aviation maintenance errors. In particular, 48% of the Communication Satisfaction Questionnaire items (sections C and D) were used to identify the communication preconditions, as they were presented in the accidents/incidents' reports, and 71% of the Trust Constructs and Measures Questionnaire items (section F) were used to identify the trust preconditions (as summarised in Table 6.2). This is considered important in identifying and defining the conditions, under which, maintenance errors occur. These strong indications, that stem from the accident and incident investigation reports' content analysis, helped this study in understanding better the relationship between these two traits.

Table 6.1 Questionnaire's items that were identified as communication and trust preconditions in the accident and incident investigation reports in subchapter 4.1 'Content Analysis'.

Items found in the accidents/incidents' reports			***Items not found in the accidents/incidents' reports***		
Item	***Mean***	***SD***	***Item***	***Mean***	***SD***
C1	5.01	1.57	**C2**	4.99	1.40
C3	4.99	1.40	**C4**	4.80	1.57
C7	4.71	1.59	**C5**	4.71	1.62
C8	5.26	1.46	**C6**	4.81	1.73
C10	4.43	1.52	**C9**	4.26	1.58
D2	4.15	1.67	**C11**	4.35	1.60
D3	5.09	1.77	**C12**	4.51	1.79
D4	5.10	1.62	**C13**	4.53	1.78
D6	4.51	1.55	**C14**	4.76	1.39
D8	4.83	1.58	**D1**	4.55	1.68
D12	5.27	1.43	**D5**	4.56	1.67
D13	5.14	1.38	**D7**	5.89	1.29
D15	4.55	1.61	**D9**	4.62	1.58
D16	5.30	1.43	**D11**	5.08	1.69
D17	4.65	1.55	**D14**	5.45	1.24
D19	4.45	1.54	**D18**	4.75	1.44
F1	5.48	1.17	**E1**	5.52	1.13
F2	5.66	1.06	**E2**	5.40	1.24
F3	5.89	0.97	**E3**	5.06	1.38
F4	5.56	0.98	**E4**	5.34	1.19
F5	5.54	1.13	**E5**	5.27	1.30
F7	5.13	1.42	**F6**	6.05	1.06
F8	5.45	1.31	**F10**	5.56	1.09
F9	5.67	1.14	**F15**	4.48	1.77
F11	5.54	1.15	**F16**	4.76	1.67
F14	5.46	1.77	**F17**	4.89	1.51
			G1	5.66	0.90
			G2	5.81	0.96
			G3	6.00	0.86
			G4	5.48	0.97
			G5	5.77	0.97
			G6	5.97	0.96
			G7	5.25	1.23
			G8	5.55	1.14
			G9	5.69	1.05
			G10	5.65	0.99
			G11	5.68	0.99

Note: The items highlighted in green (left-hand side), are those that were identified as communication and trust preconditions in the accident and incident investigation reports. The items highlighted in orange (right-hand side), are the items that were not identified as communication and trust preconditions in the accident and incident investigation reports.

Table 6.2 Descriptive statistics of the questionnaire's items used in the content analysis performed on the selected accident and incident investigation reports.

	Number of items		Percentage
	Total in the questionnaire	Used in content analysis	Used in content analysis
Communication for all employees	33	16	48%
Communication for supervisors/managers	5	0	0
Trust for all employees	17	12	71%
Trust for supervisors/managers	9	0	0

6.2 Content Analysis of Human Factors Training Curriculum and Material

Human factors training promotes safety in aviation maintenance practice. This is signified by the following facts:

- EASA, one of the most influential regulatory authorities around the world, has introduced this element in regulated training;
- Investigators from accident/incident investigation boards consider training to be an important element in the occurrence investigation and provide feedback on it in their reports.

The aviation authorities selected to investigate the coverage of this relationship between communication and trust, are responsible for the regulation of aviation maintenance training in countries having a total registered carrier departure of 48.6% of the world (Table 6.3). This is a significant proportion of the global departures, including countries having very mature aviation regulatory frameworks and high volumes of air transport traffic. In their approved aviation maintenance training, the three regulatory agencies (EASA, DGCA and CASA), that include human factors training in their regulated training programmes, do not refer directly to trust. On the other hand, concealed communication and trust elements were indirectly identified in the EASA approved training material. In the accident and incident investigation reports' content analysis, there were references to whether aviation maintenance personnel had undergone human factors training and investigators appeared to highlight this issue (Air Accidents Investigation Branch, 2015).

The answer to the Research Question 2, by conducting the aviation maintenance training content analysis, was negative in the direct identification of trust, and positive to the indirect identification of communication and trust in the aviation maintenance human factors basic training. The concealed elements of trust into the aviation maintenance training contribute to the evaluation of the training material and further research may be necessary.

Table 6.3 Regulatory authorities and their registered carrier departures worldwide.

Regulatory Agency	Year 2018 Air transport, registered carrier departures worldwide	Percentage
FAA	9,879,630	26.7%
EASA	6,252,643	16.9%
DGCA	1,200,111	3.2%
CASA	665,384	1.8%
Total	17,997,768	48.6%
World	36,999,575	

6.3 Survey

The scatterplots in Figures 4.2 to 4.8 present the correlation between the variables of trust and communication satisfaction. In particular, it was found that 57% of the variation in managers' communication satisfaction towards their subordinates can be explained by the variation in their interpersonal trust towards them, with a supporting very high correlation between these two traits. This is the strongest association found in this study and could be due to the high interaction and interrelation between the two groups (managers and subordinates). In comparison in the subordinates' group, 37% of that group's variation in communication satisfaction can be explained by variation in interpersonal trust which is lower than that of the managers. Next, 31% in variation in overall communication satisfaction for all employees can be explained by variation in interpersonal trust, with a supporting high correlation between these two traits as well. The association, even though it is not as strong as that of the managers, is strong enough to support a statistically significant positive association.

Conversely, trust towards the company's software and communication satisfaction (especially for the managers towards their subordinates) indicate a very weak association (r = 0.33) (the weakest association found in this study). This could be partly due to other uses of the company's software, apart from the communication between managers and their subordinates. The use of the company's software could explain why the association between the subordinates' communication satisfaction and their software trust is only slightly greater (r = 0.45), while the association of the managers communication satisfaction towards their company and peers and their trust towards the company's software (r = 0.57), is slightly higher than the previous two, but still considered weak.

After finding the mean scores of all measures for all aviation maintenance employees and the differences between the managers and the subordinates in their communication satisfaction and the different types of trust, t-tests were performed to identify if any of the differences between these groups regarding communication satisfaction and trust were statistically significant. The results indicated that there is not enough evidence to show that differences between the managers and the subordinates' levels of communication satisfaction, interpersonal trust and software trust were statistically significant. However, a t-test to identify differences between the military and civil aviation personnel on these measures, while indicating no difference between them in the levels of interpersonal trust, did identify statistically significant differences in their levels of communication satisfaction and software trust, with the civil employees having larger means for both these traits.

Aviation maintenance employees were separated into six groups according to their license status (no license, EASA, FAA, CASA, multiple licenses, military) and were investigated to determine the differences in their communication satisfaction and the various types of trust. A one-way ANOVA was performed for these groups, and it revealed that there were no differences for the different groups in their interpersonal and software trust but, there were significant differences in the communication satisfaction for two of the pairs of the groups (FAA-CASA and FAA-military). It is noted here that due to the small size of some of the license groups, they were not proportionally correspondent to the population sample, so they cannot be characterised as representative and further research is recommended. However, these results imply the existence of important differences among these groups and further investigation would be very beneficial.

In the exploration of the two traits (communication satisfaction and trust) in the span of the employees' experience, there were differences in the levels of the communication satisfaction between the less experienced and more experienced employees. More specifically, between the two less experienced groups (0 to 9.5 and 10 to 19.5 years) there is no difference in their communication satisfaction and the same happens with the two more experienced groups (20 to 29.5 and 30 years and more). The significant differences in the levels of communication satisfaction appear when any one of the less experienced groups is compared with any one of the more experienced groups. So, it seems that communication satisfaction is a trait that changes, as the level of experience increases, and since the mean scores of communication satisfaction are larger for the more experienced groups, it seems reasonable to infer that communication satisfaction levels get higher as experience grows.

Furthermore, in an attempt to identify the formation of the initial trust levels theory (McKnight et al., 1998), the aviation maintenance employees formed two groups according to the length of employment with their current employer. The newly hired employees formed one group, and the other more experienced employees formed the second group. The newly hired group's communication satisfaction, interpersonal and software trust mean scores were calculated and compared to the means of the more experienced group, for the same traits. All three mean scores for interpersonal trust, software trust and communication satisfaction were found to be larger for the newly hired employees. As the newly hired group is a very small group, these results cannot be characterised as representative; however, they are consistent with the initial trust levels theory and further investigation is recommended.

Moreover, the aviation maintenance participants were able to be compared, in terms of their communication satisfaction, to other three professional groups (nurses, teachers and administrative employees). The limitation of this process did not allow an in-depth analysis. The results, though, indicated that aviation employees have higher satisfaction in most of the dimensions examined, compared to the other three categories. These results highlight the need for further research in the deeper investigation and analysis in the validation and exploration of the contributing factors. A further examination of the existence and association of trust across different professional groups could contribute greatly to the research community as well.

6.4 DiCTAM Model

The synthesis of the methodology followed in this research project led to the formation of the proposed Conceptual Investigation Process (Figure 5.1). This process provides a comprehensive, structured process in the investigation of the identification/association of communication and trust. This process is cyclical, with four consecutive phases, which are used in the:

- Identification of communication and trust in the real aviation maintenance environment,
- Examination of the aviation maintenance training about communication and trust,
- Investigation of the association of communication and trust in the aviation maintenance perception and the prediction of communication and
- Exploration of trust as error precondition in possible future occurrences.

The tool that was used in the implementation of this process is the Communication and Trust Question Set and was formed by the items of the questionnaire used in the survey phase of this study. The multifunctional nature of this tool and its different uses are described and discussed in subchapter 5.2.1 ‘Development’ (Figure 5.2). This multifunctional tool, when matched on the Conceptual Investigation Process, takes the form of a complete model capable of extracting methodically useful results towards aviation safety practice. The novelty of (DiCTAM) model not only lies in its methodological sequence, namely its capability in investigating and synthesising results about communication and trust towards deviation prediction in aviation maintenance practice. It also lies in the ability to predict hypothetical deviations during aviation maintenance practice and in the advancement of the research in the area of aviation maintenance safety promotion. Especially in the aviation Safety Management Systems, the usability of the DiCTAM model in Component 2 ‘Safety Risk Management’, Component 3 'Safety Assurance' and Component 4 ‘Safety Promotion’, can enhance the outreach of these two elements of communication and trust. This usability can provide researchers and human factors practitioners with a very useful and effective tool for the advancement of these areas of safety. Furthermore, following the same methodology, directed towards different human factors traits, it is possible to obtain useful results in these domains. This suggests the Conceptual Investigation Process's transferability to an extended area of the human factors domain.

The A320 family FCD safety issue cannot be considered as a trivial issue since it has concerned the aviation industry over the past 18 years. It is anticipated that the Airbus modification - EASA ADs shall be able to contribute positively to the error management regarding FCD losses. However, it is important to consider the associated human attitude elements brought in with this modification, as illustrated by this qualitative scenario analysis (Figure 5.9). To this end, communication and trust are identified as possible contributing preconditions, and a list of human factors centred procedures and actions are recommended. These stem from the various scenarios, described and discussed in subsection 5.3.2.2 ‘Scenarios’, and consist of all possible attitudes and responses of the technicians towards the new modifications.

In summary, the recommended actions are: provision of better time management training, enhancement of communication skills, focused training, encouraging a collaborative attitude, implementation of a dual sign off procedure for the opening/closing of the FCDs, thorough verbal/written shift handover and facilitation of changes in the airline/maintenance organisation culture (where necessary). These measures can achieve efficiencies in procedures associated with troubleshooting in the area enclosed by the key-accessed FCD, reduce the likelihood of errors, and, most importantly, identify and suppress any safety-infringing ‘norms’ within operators and maintenance organisations. All recommendations are related to the communication and trust preconditions identified through this analysis.

These seven scenarios, presented in section 5.3.2.2, refer to seven different causal situations in which safety issues, related to the fan cowl doors of modified aircraft of the Airbus 320 family, may arise. The Communication and Trust Question Set tool was used to identify the traits of Communication and Trust in the hypothetical scenarios examined. As shown in Table 5.1, many different trust and/or communication issues corresponded to each one of the scenarios; therefore all scenarios showed communication and trust preconditions. Trust was found present in five scenarios, while communication was found present in three. One scenario had communication and trust preconditions present at the same time, while the other six had solely one precondition present (either trust or communication).

Next, the comparison of the mean scores of all items of the Communication and Trust Question Set, that were tabulated to the seven hypothetical scenarios, assisted in the categorisation of all seven scenarios into two categories:

- More possible scenarios and
- Less possible scenarios.

This categorisation can be indicative of the probability of the deviations, this study's sample of respondents might face, if they would come across one of these hypothetical scenarios. Therefore, the importance of this aspect of the process lies in the fact that if there are communication and trust data available from a group of respondents, a researcher can extract the probability of hypothetical deviation scenarios of the same group. The data used in this study were obtained from the Communication and trust Question Set.

CHAPTER 7 CONCLUSIONS

This study has identified the need for greater consideration of communication and trust as contributory factors in the causes of aviation maintenance accidents and incidents. It has unveiled a positive association between these two traits and human error in the aviation maintenance working environment. Also, a gap has been revealed in the aviation maintenance basic human factors training (certain aviation jurisdictions do not provide compulsory human factors training while the ones who do provide it do not directly explore trust). These findings may be used as a starting point for further research in aviation maintenance human factors.

This is the first time that a positive association between communication and trust in the aviation maintenance research sector has been reported. These findings can be very useful for a human factors approach to aviation maintenance safety management, given that both communication and trust are fundamental in aviation maintenance failure detection and analysis (Langer & Braithwaite, 2016). Past research has shown communication satisfaction associated with job satisfaction, organisational commitment and job performance (work values in general) which are important to the successful and profitable operation of the organisation and productivity (Carrière & Bourque, 2009; Jalalkamali et al., 2016), but to the safety-related practices of the employees as well (Dode et al., 2016; Evans et al., 2007; Glendon & Litherland, 2001; Luria & Yagil, 2010; O'Connor, 2011).

Furthermore, poor communication itself has been linked to accident causation and poor safe work practices (Flin et al., 2002; Karanikas et al., 2017; Weick, 1990). The content analysis conducted in this study was able to verify this connection. Both ineffective communication and trust were identified as an accident/incident causal condition. Also, utilising the content analysis method, a gap was identified in aviation maintenance basic human factors training, regarding the existence of trust and the association between communication and trust. There are indications that there is no relevant material available (about trust and the positive relationship between communication and trust) to the approved training curriculum and resources. This means that aircraft maintenance employees who get their basic human factors training, are not aware of the association of communication and trust and are not trained accordingly, jeopardising the quality of their training.

Therefore, since safety is the primary objective of all aviation regulatory authorities, it is the approved human factors training that should be initially examined and updated according to these new human factor research findings. EASA, which is the largest and most influential authority globally, could maximise the benefits of its Part-66 Module 9 Human Factors training, by implementing training on trust, and its positive association to communication, into their approved material. Also, managers should find a way to enhance their organisation's communication system in order to keep their employees' communication satisfaction at high levels. Since this study has shown a positive association between communication satisfaction and trust, management must take trust into consideration while implementing and/or improving their effective communication systems. Due to the nature of aviation maintenance work, trust (especially interpersonal trust) is built around co-workers' relationships and cooperation, which are structured in a way to reduce the likelihood of error.

A new process is introduced (Conceptual Investigation Process) which is able not only to predict possible maintenance practice deviations in a causal relationship with communication and trust but also with any other human factors traits under examination. This means that the methodology used in this study can be transferable to other human factors research projects with similar scope. The implementation of the Conceptual Investigation Process was made possible with the use of the Communication and Trust Question Set. The developed Diagnosis of Communication and Trust in Aviation Maintenance (DiCTAM) model introduces the diagnosis and recognition functions of this multifunctional tool that made this process possible. The DiCTAM model is formed by the methodology that was followed in this research study and is proposed to be used by other researchers that also work in the area of aviation maintenance human factors.

As the DiCTAM model was conceived and used for the first time in this research project, its implementation by other researchers and the comparisons of all results can be of scientific interest. Also, the aviation industry can make use and benefit from the implementation of this model, in the identification and investigation of communication and trust within their business activities. The Safety Management Systems (SMSs) used in various aviation organisations (including maintenance companies) can benefit greatly from this model, as it can contribute positively to the SMS' promotion and evolution.

Due to the discussed limitations of this study, further research may be necessary for the generalisation of the results obtained in the survey and the content analysis. In particular, the following limitations have been found:

- In the content analysis phase of this study, due to a large amount of material available and the restriction of the availability of this material in the English language, a representative sample was selected to investigate the two more general research questions;
- The sample of aviation maintenance employees in the survey phase of this study is not necessarily a representative sample of the total of these employees' population. More specifically, there were small numbers of participants from many different geographical areas, and this does not mean that they would be representative of the total population of these areas;

To conclude, an overall outline of this PhD study's research output is provided in Table 7.1, as a visual aid for the reader. This table presents the answers obtained from this study for all the Research Questions and Research Hypotheses examined.

Table 7.1 Summary of research output of this study.

Research question	**Answer to the Research Question**
1. Are trust and communication detectable in aviation maintenance?	**Positive** Both trust and communication are not directly but indirectly detectable in the aviation maintenance sector.
2. Are communication and trust covered in aviation maintenance human factors basic training?	**Negative** Trust is not directly covered in aviation maintenance human factors basic training. However, a concealed element of trust has been identified.
Research Hypothesis	**Research Hypothesis Results**
1. (a) Aviation maintenance employees' levels of interpersonal trust towards their colleagues has a positive association with their communication satisfaction and (b) supervisors/managers' levels of interpersonal trust towards their subordinates has a positive association with their communication satisfaction.	Hypothesis 1(a)(b) is **supported.** Interpersonal trust is positively linked to overall communication satisfaction among aircraft maintenance employees and between supervisors/managers and their subordinates.
2. (a) Employees' trust towards the company's software has a positive association with their communication satisfaction and (b) supervisors/managers' trust towards the company's software has a positive association with their communication satisfaction.	Hypothesis 2(a)(b) is **supported**. The correlations indicated the positive association between trust towards the company's software for employees and their overall communication satisfaction, as well as the managers' trust towards the company's software and their overall communication satisfaction.
3. (a) Subordinates' levels of interpersonal trust has a positive association with their communication satisfaction and (b) subordinates' trust towards the company's software has a positive association with their communication satisfaction.	Hypothesis 3(a)(b) is **supported.** For Hypothesis 3(a) the correlation between the subordinates' overall communication satisfaction and their interpersonal trust, indicated a moderate relationship between the two traits. For Hypothesis 3 (b) the correlation indicated some association of this form of trust with the subordinates' overall communication satisfaction.
4. High initial trust levels are detectable in (a) interpersonal trust and (b) company's software trust to newly recruited maintenance employees.	Hypothesis 4(a)(b) is **supported.** The newly hired group showed greater levels of trust in comparison to the experienced group while measuring interpersonal trust and trust towards the company's software.

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APPENDICES

Appendix A: Published Journal Paper 1

Chatzi, A., V., Martin, W., Bates, P., & Murray, P., (2019). The unexplored link between communication and trust in aviation maintenance practice". Aerospace, 6(6), 66 https://doi.org/10.3390/aerospace6060066.
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Review

The Unexplored Link between Communication and Trust in Aviation Maintenance Practice

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Abstract: Communication and trust are fundamental factors in the operation of complex and highly regulated industries like aviation maintenance. This article reviews two preconditions of human error: communication and trust, as well as the way these are linked as aviation researchers have only recently started to study factors not individually, but rather by combining their effects. Communication is essential in the exchange of information and knowledge in aviation maintenance. The conditions that make communication effective and miscommunication avoidable are explored. Next, ways of communication, like aircraft maintenance documentation, are discussed along with appreciation of how communication is valued in aviation maintenance. Trust within different aspects of maintenance practice (interpersonal trust, trust towards technology, initial levels of trust) is presented and analysed, as well as examined as a prerequisite of effective communication. The characteristics of trust, its forms and results are identified in the literature with limited sources from the aviation bibliography, as it is a domain barely explored. Therefore, a gap has been identified in the study of trust and the exploration of the combined traits of communication and trust in aviation maintenance. Recommendations for additional research in this field is provided.

Keywords: human factors; communication; trust; safety; aviation maintenance; error

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1. Introduction

To err is within human nature. However, it is primarily over the last 50 years that human error has become a field of scientific research, as errors started to have a great global impact in the economy, health, environment and communities. In the US alone, from over $300 billion spent on maintenance and operations every year, 80% was spent repairing damage caused by human error in equipment, systems and dealing with harm caused to people [1,2]. In 2014 alone, there were 648 fatalities in 14 fatal accidents caused by human error. This number was

1.5% higher than the previous 10 years average. This increase was the result of larger airplanes, with larger passenger capacity which has led to an increase of fatalities in the occurrence of an accident [3], therefore, since human error led to higher numbers of human loss, there is a necessity within the aviation community to address this issue even more urgently.

A greater understanding of human factors became imperative within aviation, and a large number of models and systems have been introduced and implemented in the continuous attempt to predict and reduce human error. In aviation maintenance, there are twelve principal preconditions or conditions that contribute to human errors, widely known as the Dupont's *Dirty Dozen* [4–9]. These elements (shown in Figure 1) are dissimilar in nature and appear either on personal, group or organizational performance levels [10].

The *Dirty Dozen* is still used in training, accident, and human error analysis in aviation maintenance worldwide [4,5,7,8,11]. These 12 factors are of a different nature and quantifiability, nevertheless each one of them represents a precondition/condition to failure in the user's judgement and as such they are treated either individually or in groups of similar items [8]. As shown in Figure 1 lack of communication is among these 12 most frequent conditions/preconditions of human error.

Researchers still investigate elements similar to the ones of the *Dirty Dozen*, but also consider mutual interactions. As a most recent example, the Joint Research Program in the European Union (EU) 'Future Sky Safety', aims to study the concept of the Human Performance Envelope (HPE) in aviation. This research is investigating the interactions between nine human factors (stress, attention, situation awareness (SA), vigilance, teamwork, workload, communication, trust, fatigue) and the pilot's human performance, how they work individually or in combination, and how they affect or decline human performance [12].

Communication has been indicated by past research to have a strong association with trust [13]. Trust is an important element in human social life and therefore, has been researched extensively in the past by many different disciplines of science such as marketing, psychology, sociology, political science, economics, etc. [14]. Many researchers agree that trust is a very important element in employees' relations and it is associated with the quality of their communication [15–22]. Trust is under-investigated in aviation [19] and its association with communication is an unexplored area, especially in aviation maintenance.

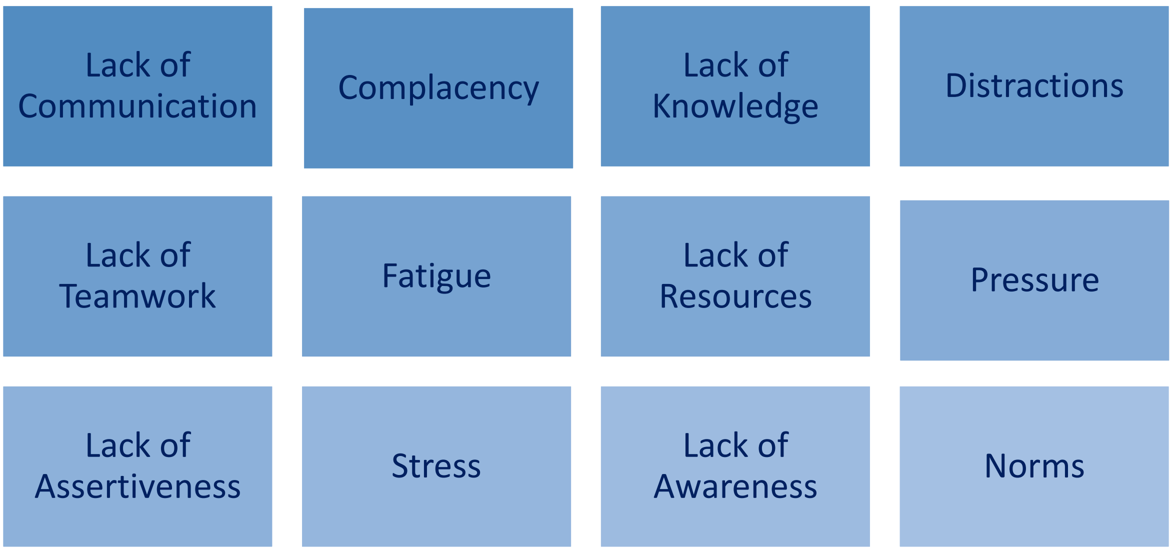

Figure 1. The Dirty Dozen [16].

2. Basic Communication Theory

Communication is a field of study that is of interest for many disciplines, such as marketing or computer science. Communication is a process that everyone uses in their everyday life. However, defining communication has proven to be challenging. There have been many definitions of communication in textbooks and different approaches through the years since Shannon and Weaver [23] saw communication as the transmission of messages [24].

There are various definitions of communication depending on the different approaches and discipline of each researcher. In some definitions there is emphasis on the significance of symbols, as in "the transmission of information, ideas, emotions and skills…by the use of symbols" (Page 527 in [25]), while others examine communication as a product, e.g., "We use the word 'communication' sometimes to refer to what is so transferred, sometimes to the means by which it is transferred, sometimes to the whole process" (Page 13 in [26]). In the study of communication there are two main streams. One stream considers communication as *the transmission of messages* and the other as *the production and exchange of meaning* [24].

At the *transmission of the message* stream, the member that sends the message is the sender, and the one who accepts it is the receiver. Communication, to be effective, must be an active process where both the sender and the receiver/s assure that the intended objectives are met. To achieve that, both the coding and the decoding process of the message along with the channel and/or medium of communication, are very important to success. If the result is not the anticipated, then the communication process is characterized as *failed* and the communication steps are investigated to identify the causes of this failure [24]. The second stream, the *production and exchange of meanings* deals with the interaction between messages and people and the meaning that comes out of this interaction. In this stream, connotation is a term that is usually met. Additionally, misunderstandings, besides being a result of failure in communication, may occur due to cultural differences between the sender and the receiver [24].

According to Schramm [27] important elements that should be added to the communication process are the sender's and receiver's experiences. The mode of communication chosen should be the appropriate one to meet the circumstances of both the sender and the receiver. The sender proceeds with the message coding based on his/her experience while the receiver understands the message by connecting it to his/her prior knowledge/cognitive level. Then the sender needs to ensure that the message has been transmitted correctly by evaluating the receiver's feedback [27] as shown in Figure 2.

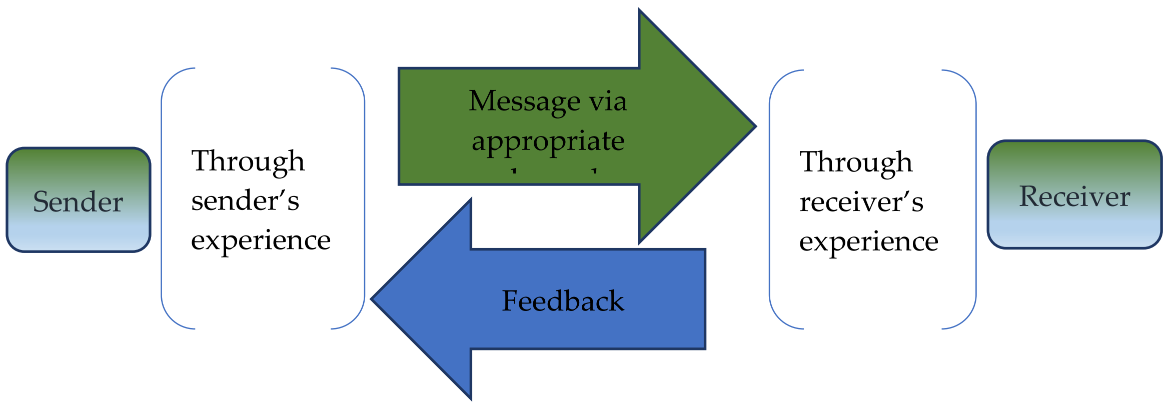

Figure 2. Schramm's [18] communication model with feedback.

To understand the communication theories fully the definitions of the terms: channel, code, and medium are necessary. Channel is the means through which information flows [28]. Examples of channels are: light waves, sound waves, radio waves. Medium is the material or mechanical way of transforming the message into a signal capable of being passed on along the channel. Coding is the sharing of mutual meaning between members of the same culture [24].

The basic features of the chosen channel determine the nature of the medium that will be selected. Next, this medium will determine the characteristics and the range of the codes that will be used to transmit the message. Fiske [24] further suggests that media can be divided into three categories as shown in Figure 3:

a. The presentational media. The body language, the oral speech, the facial expressions are providing communication. This requires the physical presence of the communicator as he/she is the medium and communication happens in real-time.
b. The representational media. Any medium that represents the above by the production of a text, picture, painting, piece of art. These media do not require the presence of the communicator as they can act independently.
c. The mechanical media. These media utilize technologically developed channels; therefore, they are transmitters of the presentation and representation media. Examples are: radio, television, computers, and telephones.

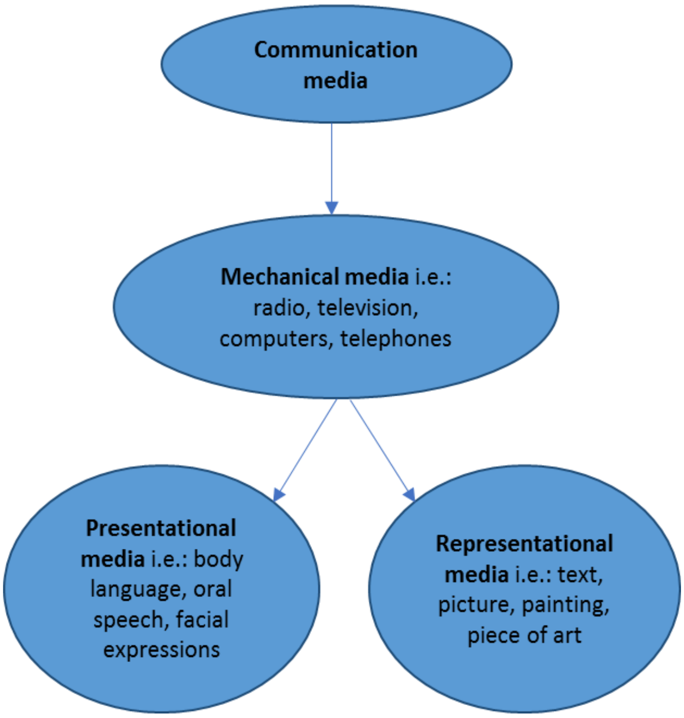

Figure 3. Concept map of communication media.

Given that communication is effective and complete it can a) be beneficial to staff's interpersonal and group relationships; b) guarantee that attitudes and expectations will be clear with no hidden agendas; c) retain focus on the task and situational awareness; and d) act as a managing tool [29].

2.1. Miscommunication

To understand and define communication, researchers needed to clarify miscommunication as well. Communication and miscommunication are strongly interrelated, and they present a difficulty in investigating them separately. Miscommunication is treated as a kind of communication with its own distinct patterns and characteristics [30]. In this context miscommunication can be defined as 'the dark side of interpersonal communication' [31] not being too far from its standard meaning of missing, flawed, and disrupted rules of communication [32].

Furthermore, miscommunication includes ‘mismatching interpretation’ and distortion of message [30]. This definition also includes the potential cultural differences between the sender and the receiver which are responsible for possible alternative interpretative models. Miscommunication, in the condition that if it is noticed and attempted to be repaired, has positive outcome to the communication process as well as it provides a chance for further interaction between the communicators. Miscommunication has been included in several communication theories, e.g., Shannon and Weaver [23], through the years as a deviation or a disruption, either important or less important, at any stage of the communication process [30].

In the aircraft maintenance environment, a model of communication fault was developed by Shukri, Millar, Gratton and Garner [33] that was inspired by Cushing’s [34] detailed overview of communication failures between pilot and a traffic controller. In this model there are six message characterisations: “a) A message that is unavailable; b) A message that is available but incomplete; c) A message that is available, complete but incorrect; d) A message that is available, complete, correct but not clear; e) A message that is available, complete, correct, clear but not understood; and f) A message that is available, complete, correct, clear, understood but mistakes still happen due to human factors” [33].

From this model, it is evident that even if the message is free from all the failure prone factors, there is still the possibility of mistakes. Subsequently, all the specialists’ efforts lead to the direction of the elimination of the known or predictable factors that can lead to fault and the constant attempt to identify and eliminate the uncharted ones. Therefore, in the case that communication for one or more reasons does not result in the correct exchange of the message, the beneficial effects are not fully realised.

The contribution of communication to the occurrence of human errors has been recorded in various reports. Human error can be tagged as ‘the human causal factor associated with aviation accidents’ [35] or ‘the failure of planned actions to achieve their desired ends—without the intervention of some unforeseeable events’ [2]. A study commissioned by the Dutch Aerospace Research Centre (NLR), identified various contributory factors to aircraft accidents, incidents, and errors. In seven ground service providers in the Netherlands both management and operational personnel named the ten most frequent factors that are involved in the cause of mistakes on the ramp (see Figure 4). Poor communication is the second most prevalent factor on that list [36].

Ineffective communication is a precondition for human error in all highly complex and regulated industries worldwide [34]. Extended research in aviation has shown that human factors cause 70–80% of aviation incidents and 15–20% of them relate to maintenance procedures [37,38]. The aviation sector was the first to identify that the implementation of standardised procedures has contributed to safety and teamwork efficiency, following the realisation that 70% of commercial flight accidents were caused due to communication errors between crew members [39].

Another large study in the aviation industry found that 70% of all accidents were caused due to crew coordination and communication issues [40]. These findings are supported by Wiegmann and Shappell [41] and Yacavone, [42] as they have recognized crew coordination to be a major contributing factor in military aviation (as cited by Wiegmann and Shappell, [43]). Failed communication has also been reported to be among the most frequent local factor in airworthiness events along with tools and equipment, perceived pressure or haste, environment and knowledge, skill, and experience [44]. As a comparison, in railway maintenance, it has been shown that 92% of incidents occurred due to communication failures [44,45]. In the healthcare industry communication is an extremely common element prone to flaws as well [39]. Subsequently, healthcare also had the need for standardization of the communication tools due to its complexity, the limitations of the human performance, and the different training among the medical professionals. For that purpose, tools like SBAR (Situation, Background, Assessment, and Recommendation) were introduced for all medical personnel as a means to establish common terminology and methodology to avoid communication failures [39].

In Figure 4 it is indicated that the management's awareness is at higher levels than the line personnel's, suggesting that the administration has recognised these factors to be preconditions of human errors. The European Commercial Aviation Safety Team (ECAST) has acknowledged the awareness of the potential risk of ineffective communication as a human factor and that further research is necessary towards that direction [36]. Moreover, various researchers have highlighted the problem of ineffective communication between maintenance staff, cabin crew, and flight crew, proposing different ways to mitigate this issue [46,47]. It is evident from the above that communication is a very important element within complex industries like aviation.

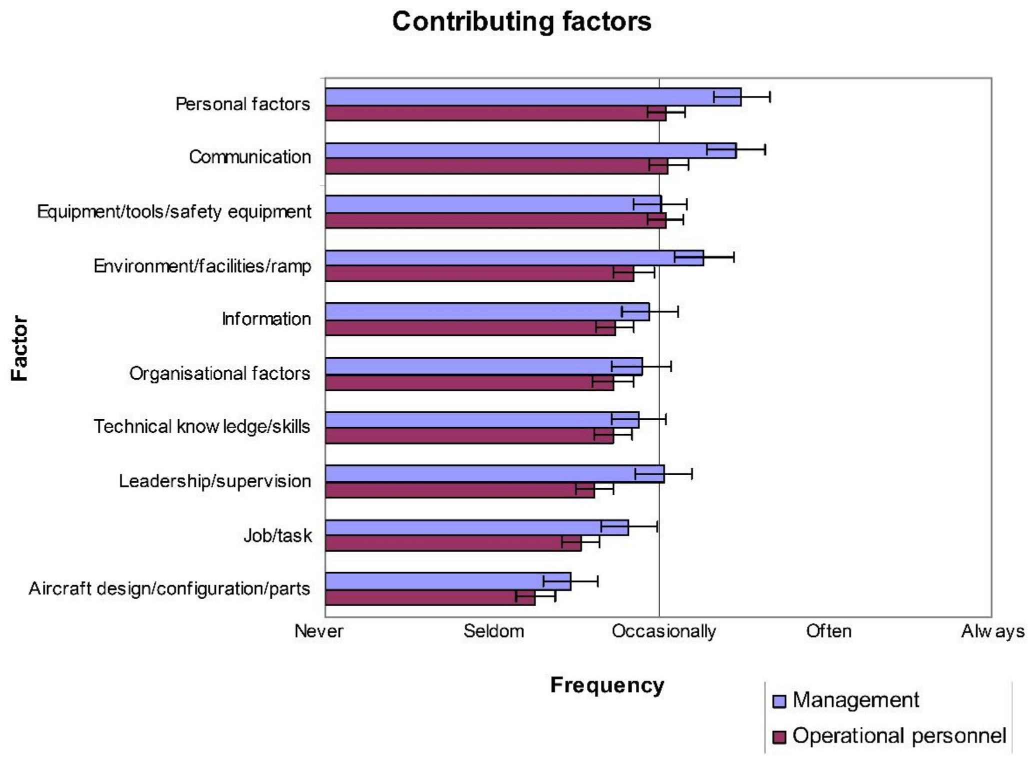

Figure 4. the most frequent causal factors involved in mistakes on the ramp [36].

An example, in which maintenance communication was involved in an airplane accident, is the Atlantic Southeast Airlines flight 529 in August 1995. The aircraft crashed in Georgia, USA, during an emergency landing, after the loss of a propeller blade, resulting in 9 fatalities and 20 injuries. The National Transportation Safety Board (NTSB) determined that "the probable cause of this accident was the in-flight fatigue fracture and separation of a propeller blade resulting in distortion of the left engine nacelle, causing excessive drag, loss of wing lift, and reduced directional control of the airplane. The fracture was caused by a fatigue crack from multiple corrosion pits that were not discovered by Hamilton Standard because of inadequate and ineffective corporate inspection and repair techniques, training, documentation, and communications." [48]. The NTSB in this report highlighted as a contributing factor the internal inadequate communication and documentation systems of the airplane parts' manufacturer that led maintenance personnel to confusion and faulty procedures.

Even though aviation was the first industry to regulate and implement human factors policies and guidelines, the need for further research and procedural improvement is continuous and arduous. In the occurrence of any new procedure introduced, new research over the possible reasons for failure of the system or its human element towards its failure must be conducted. Moreover, the continuous effort to make communication in aviation effective has led to the observation and understanding of all aspects of human expressions. Different modes of expression, such as politeness [49], are under review by human factors specialists, in their attempt to promote clarity and minimize miscommunication at all levels.

2.2. Areas in Aviation Maintenance Prone to Communication Failure

In aviation maintenance one critical aspect is documentation. The most common reason for accidents in aviation maintenance is insufficient documentation and procedures [50–52]. More recent studies indicate that written communication can be more prone to mistakes than oral communication during critical maintenance tasks. The reason is that in oral communication any clarification is easier to obtain, so more human errors, that affect aircraft safety, are detected [33].

The improvement of maintenance documentation can establish communication as an important factor that could have a positive contribution to the execution of maintenance tasks safely [50,53]. Written procedures govern every action in aircraft maintenance. These are manufacturers' Instructions for Continued Airworthiness (ICA's), Fault Isolation Manuals and all supporting documentation that are continually updated. Additionally, as aircraft design is evolving fast and becoming more sophisticated, maintenance-related information is expanding in volume. This immense amount of documentation amendments and novelty has to be adopted simultaneously by maintenance personnel around the world, even if their first language is not the one the documentation was produced in [54,55].

Moreover, there is extended research in the development and improvement of online platforms, that aim to replace workcards, targeting lower cost along with a positive impact on the engineers' situational awareness, error probability, job satisfaction, and adaptability [56,57]. Another example is that of a Federal Aviation Administration (FAA) three-phase sponsored study that dealt with an improved design of the manufacturer's maintenance documentation enabling the transfer of information to the maintenance personnel at a satisfactory level [58].

Many researchers have produced instructions and guidelines, following human factors principles, to help maintenance staff avoid mistakes. Their research has been successful in reducing human errors [55,59]. However, the people in charge do not always acknowledge this work by implementing it in the field [60]. They usually persist in following their own former good experience and the employees' perspective rather than adopt guidelines and instructions that stem from research [58].

Moreover, shift turnover is of great significance in highly complex and regulated business environments, such as aviation maintenance, the oil industry, and medicine. According to Parke and Kanki, from the 8% of the aircraft maintenance failures that were due to communication factors, 51% were related to the shift turnover while 41% had no relation to it [61]. The turnover related maintenance occurrences were classified, by the reporting system used for this research, to have more severe and dangerous consequences [61] whereas debriefs that are conducted according to human factors principles can enhance productivity by 20–25% [62]. While debriefs may appear to be cost effective and produce quick results in the organizations' improvement of performance, the study of such processes over the years is scattered across different disciplines, such as healthcare, education, psychology, and organizational fields with no conclusive results [62].

The literature highlights that communication in the aircraft maintenance environment provides several considerations: first, it is an element that underlies every phase of the aircraft maintenance process; next, it is a primary element of the maintenance process, as it is the framework upon which information transmission takes place; finally, the research community and the industry need to proceed with further investigation on documentation structure and shift turnover procedures.

2.3. Communication in Aviation Training

The training framework in aviation is designed to enhance communication skills and techniques, promote teamwork, accommodate human performance tools and develop situational awareness (SA) among maintenance personnel. This indicates of the way that the aviation industry values communication, acknowledges it as an important contributing factor of human performance and takes actions towards its successful application within the aviation various activities. This training is either called Crew Resource Management (CRM), Maintenance Resource Management (MRM), or Team Resource Management (TRM) [63–65].

As the literature indicates: a) training is essential in enhancing elements such as successful communication and indeed has good results, and b) the design of training, the delivery and its implementation is of great importance in achieving the required results in areas such as communication [50,66,67]. To define the success of training in promoting factors such as communication, more 'on the job' observation of the participants is needed, given that most of the research has been conducted in simulation [64,68,69].

In the European Union, there is a 30 mil. Euro program (Future Sky Safety 2015–2019) that explores all new tools and approaches to aviation safety. This research, among other issues, indicates that a significant gap has been recognized between the quality of the students' oral and written communication skills gained during their studies (especially in the aeronautical area) and the skills required by the aeronautical industry to perform the tasks safely [70]. Industry and academia do not work together as the communication between them is ineffective and discontinued [71,72]. This indicates that since there is no wide human factors training within the tertiary education curricula, there is a great need for it in newly recruited personnel.

3. Trust

First, trust is the belief of somebody else's benignant intentions. Second, none can impose these beliefs to come true, in other words trust means to be prepared for the possibility that the anticipated benignant outcome will not happen. Third, the meaning of trust includes a degree of interdependency as somebody's situation is linked to somebody else's actions [13]. Based on these three elements, trust is the attitude someone or a party adopts (trustor) towards somebody else or another party (trustee) [73]. This attitude, or even both parties' relationship, is influenced by the trustee's behaviour and it will form the trustor's understanding and receptiveness towards the trustee [13]. It is noted in the literature that the competence, benevolence and integrity of the trustee are the characteristics that trustor takes into consideration for the formation of his/her trust [74,75].

Trust, while it has been extensively researched by organizational researchers and more specifically by certain industries (e.g., web commerce) is understudied in high-reliability organisations, such as the aviation industry [76]. Trust usually stands in combination with other human characteristics and is difficult to be isolated and quantified. However, there is growing research indicating that trust and professionalism are fundamental factors in maintaining safety in the aviation industry. On the one hand, professionalism is the basis to exercise all the necessary steps towards safety, but on the other hand, personal trust is essential in the communication that is required [19,20,22,77,78].

Additionally, personal trust is associated with performance and cooperation [79–82], citizenship behavior [83], problem solving [84], and confidence in the skills and capabilities of aviation experts (trust in competence), to achieve the desired level of safety [85]. Maintenance personnel need to trust that their colleagues will act as safely as themselves. This is a process that needs to be inspired and enhanced rather than taken for granted [86].

Trust towards people, and especially towards individuals in the case of a risky situation, where an individual will do anything within his/her power to overcome the risk, aspires to be a solid factor in ensuring safety management [85]. However, Harvey and Stanton [85] and Reason [87] argue that this statement contradicts the modern systems approach to risk and human error, according to the human factors principles, as human error has been considered so far to be a systemic rather than an individual consequence [88,89]. Adaptation is inevitable where models include the social system and human error while organizations put pressure on their systems on the benefit of their cost effectiveness-productivity balance [90]

Apart from the trust between colleagues, there is the trust between maintenance personnel and management that has been rather low and makes staff feel sceptic and pessimistic whether positive results in safety can be achievable [65]. Management is responsible for building (establishing/taking the initiative towards the employees) and maintaining trust [13]. Apart from the interpersonal trust, there is the confidence towards technology and procedures. Additionally, another characteristic of trust is that it is bipolar: lingering between the two edges of trust and distrust [91,92].

Procedures are clusters of partial steps that, to be successful, need to meet different criteria and conditions (e.g., environment). Due to different reasons (e.g., lack of knowledge, norms) maintenance employees might not take these conditions under consideration in the case of failure. Situations like these might lead these professionals to lose trust in procedures, in the case of a failure, or show overreliance in the instance that the procedures were effective even if the right conditions were not met [92].

The benefits of trust have been well understood for some decades now since Zand proved in 1972 [84] that employees with higher levels of trust compared to the ones with lower levels: a) make information processing more cost-effective to the company; b) seem to have more contentment among them; and c) show certainty towards other counterparts [84]. Research has also shown that trust towards familiar individuals is far more easily achieved, especially when positive feedback indicates this person to be trustworthy. Obviously, the level of trust tends to differ amongst various organizations, depending on their size. In small organizations, the interpersonal trust seems to be at a higher level than in larger organizations and the army [93].

Technology, on the other hand, is a human construction and, as a product, it lacks human characteristics [94]. To focus on the technology, one should isolate it from the human element (users, developers) and examine the technology artifact itself. This approach enables the investigation of trust towards technology without being influenced by other surrounding human structures [95].

People depend on technological artifacts and rely on their anticipated abilities and capabilities to perform successfully. In this concept trust means to depend or rely on another [96]. Therefore, if someone believes he/she can depend on technology's performance in a time of need, then trust towards technology is the describing term for it [95].

Trust in technology is divided into initial trust and knowledge-based trust [95]. Initial trust refers to the expectations and beliefs of the anticipated operations of the technological application chosen by the user. Knowledge-based trust is the result after interaction and familiarization with a technological system. Trust in technology needs further investigation as limited research has been conducted in this area [95].

Furthermore, in modern times, more organisations have evolved into big impersonal enterprises where trust between groups is difficult to achieve [15]. To overcome this issue, organisations have to agree, adopt and utilise similar social rules to gain familiarity and work together efficiently [97]. Even though these sets of rules seem to prevent distrust among enterprises, some researchers insist that interpersonal relations are the ones that guarantee the formation of trust. This means that specific people need to represent organisations to form the needed familiarity [98].

Within business relations, trust is a fundamental factor that takes part in the orchestration of their expectations and mode of collaboration [99]. It appears to have an assistive role in establishing business relationships and it is crucial to re-establish the theory behind the organisational influences on the business behaviour. This will be of major help in attempts at building trust in interorganisational interactions [15]; “The more complex and dynamic social and economic relations and exchange arrangements are today, the more trust is needed as a lubricant to keep the motor running” [100].

Overreliance or excessive trust may have negative effects on interpersonal and organizational relations and there is no current research to describe it adequately [101]. To unfold the role that trust plays in organizations, one must explore the macrolevel and microlevel of theory and analysis. In the macro level, trust is studied regarding its interaction with the industry structure while in micro level trust is examined among people as seen in Figure 5 [102].

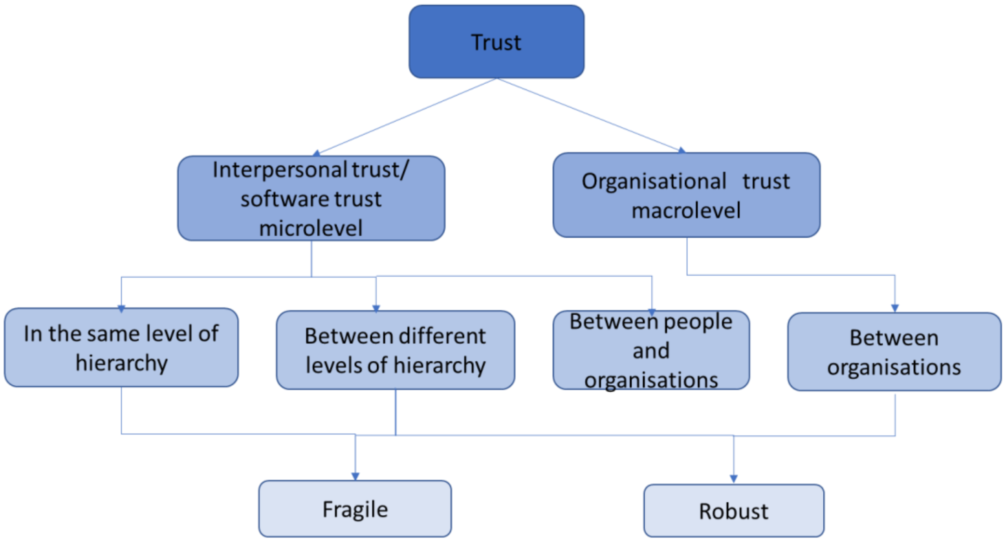

Figure 5. Schematic representation of the concept of trust [102].

3.1. Trust Dynamics within the Organization

When systems in organizations promote open and free communication (knowledge sharing, uninhibited information disclosure) their employees are more likely to develop trust towards the organization and each other [13,74,101]. From the very beginning, trust has been linked to safety in the aviation industry and there has been a significant effort through MRM training (5th generation) to implement and enhance safety culture and engage all personnel in that direction.

In the case that an organization proceeds with implementing all necessary actions to reduce human errors then learning from their mistakes would be one of them. In this case, it is crucial to the people involved to have sufficient trust that they will not be blamed if they report mistakes and that they can speak openly about them (commonly called a just culture [103,104]). Although there are mechanisms available to maintenance personnel to avoid or reduce human errors, they must trust their managers mutually to achieve that.

Studies have revealed that a big proportion of engineers do not trust that their managers’ actions will be solely aimed at enhancing safety [105]. The lack of trust, or distrust, acts as an obstacle to the formation and implementation of programs, such as the FAA’s Aviation Safety Action Program (ASAP), that provides maintenance personnel with a system to report failures and thereby contribute to the continuous effort to improve aviation safety.

3.2. Characteristics of Trust

Other extended research on trust indicates that trust is at high levels at the beginning of a professional relationship "*high initial trust levels*" [106]. New employees begin their employment with an intrinsic level of trust towards their colleagues and their organizations. Thereafter, it is the culture of each organization that will be responsible for maintaining or altering this level. Trust is also a multidimensional area that is highly influenced by other social features. As proposed in the Model of Trust by Mayer, Davis, and Schoorman (as cited by Mayer et.al. [75]) trustworthiness is perceived by factors like ability, benevolence and integrity. In a society that is trained to believe and rely on others, it is most probable that people will trust their organization initially at a high level [106,107].

Depending on the circumstances, trust levels can appear to develop as fragile or robust. Fragile is when it is subject to sudden changes during a given period either to a higher level, when the initial level is low or vice versa. Robust, on the other hand, is the opposite of fragile. It is used when the level of trust remains stable over a specified period [106]. Since the existence of the "*high initial trust levels*" is observed, it is of primary importance in the aviation industry to maintain it at those levels. It will only be successful by keeping in mind that the elements that make trust robust are: a) adequate precedent support, that is former good experience which forms a present behaviour in a similar manner; b) belief-confirming cognitive mechanisms, in which people's remarks that oppose their beliefs are overlooked; and c) social mechanisms, the personal contact among people enhances the positive attitude between them [106]. Moreover, research has identified legislative procedures, conflicts of power, stress, and liability to be factors that reduce trust within organisations [108,109].

Furthermore, research has confirmed the relationship between ASAPs and trust since organizations with ASAPs in place have demonstrated higher scores in trust than other companies in which ASAPs were not in their structure [110]. To evaluate the personal perception of maintenance personnel regarding human factors and safety in the workplace, specific tools had to be introduced. One tool that has been extensively used by FAA is the Maintenance Resource Management Technical Operations Questionnaire (MRM/TOQ). Among other questions that were used to measure different human factors, the following questions were used to measure the level of trust:

- "My supervisor can be trusted"
- "My safety ideas would be acted on if reported to supervisor"
- "My supervisor protects confidential information."
- "I know proper channels to report safety issues" [86,110].

These types of questionnaires evolve and adapt over time, and new data is accumulating through continuous research. The optimum result would be to obtain a large amount of data from the full range of aviation activities, which would enable researchers to analyse results comparatively, inferentially, and longitudinally [86].

4. The Relation between Trust and Communication

Literature has indicated that personal trust is an essential element that is associated with successful communication (see, for example, [15,16,18–20,22,77,78]). Experimental research has proven that face-to-face communication has been highly successful due to, among other reasons, the lifting of anonymity and the trust that the communicators show to each other. Face-to-face communication enhances verbal communication where trust elements, such as commitment and promises, are used along with body language, facial expressions, and visual cues to ensure a successful outcome [82]. Experimental evidence, regarding the relation between trust and communication, is scarce and more research in that field is needed [82].

When it comes to group communication, the group should establish common ground for the members to agree upon some basic ideas/concepts. This process depends on trust development among the members, towards their incentives and attitudes, for the group to create a functioning communication ([30] as adapted by [111,112]).

At the organizational level, when organizational culture supports open and free communication among all levels of employees, it is expected from them to enhance their trust levels towards each other and their organization [13,74,101]. Recent research in the aviation maintenance field indicated that communication and trust are two major factors that both can be used as tools for maintenance failure detection [113]. Additionally, according to the FAA, trust is an essential element for a successful safety program in the aviation industry. The different safety programs base their effectiveness on the successful communication among the different business partners and mutual trust or distrust can affect this communication.

5. Discussion and Conclusions

This review aimed to include mainly aviation maintenance literature relevant to communication and trust and this literature was found to be scarce. This suggests that, the factors of communication and trust, either individually or in combination, are understudied in aviation maintenance. To unfold this critical issue, communication and trust were explored in multidisciplinary literature and they were considered within the aviation maintenance framework. Some of the most important findings of the review are presented in Figure 6.

Most researchers have concluded that aviation has recognised miscommunication as a paramount human factor contributing to errors [36,114], but there is still much work to be done to eliminate this risk and provide the industry with error free communication. A gap has been identified in the issues that arise from the communication among different areas within aviation, and there is research underway mitigating these issues [46,47]. Every aspect of human nature and personality characteristics should be considered, to eliminate the factors that might lead the message to not be adequately delivered and understood in the communication process. To succeed in this, it is of high importance to place the mechanisms and models of miscommunication in the specific frame of aviation industry [30] as there is a great deal of potential in their implementation and development, especially in aviation maintenance [115].

Several decades ago, it became quite apparent that standard terminology and methodology would help reduce human errors related to aircraft procedures, especially in the written forms of communication, e.g., documentation, manuals, workcards, etc. [55,59]. Due to such endeavours, new technology and improved software are being used in the place of internal communication forms and workcards with encouraging results [56,57]. Extended research has still to be conducted in this direction to make novel technology more appealing and subsequently resolve both managers' and employees' negative attitude to similar platforms [58]. On the other hand, there is a lack of systemic study of maintenance debriefings that does not help in the comprehension and improvement of this crucial step in the maintenance procedure [62].

Training is the only vehicle that will introduce and facilitate all the required communication skills [63–65,116]. There has been considerable research during the past few decades in developing systems and the generation of effective programs. There is, however, potential for further research in the long-term effectiveness of these programs as trainees do not seem to acquire the desired level of knowledge and skill [50].

The framework within interorganisational trust has a lot of potential to be restructured, to enhance business interactions, and to achieve further development [15]. The literature found that deals with trust in the aviation industry is scarce. This alone indicates that there is a great deal of work that could be done in identifying and associating trust with other traits in the actual working environment in aviation maintenance [19]. The interesting element in trust is that the initial levels of trust (the levels of trust an individual or a company indicates at the beginning of a collaboration) are high, so human factors researchers could focus their research towards the direction of the mechanisms which will contribute to maintaining these levels high over time [106].

More extensive research is needed to standardize trust measuring methodologies, analyse results, and enable smaller-scale research to be compared safely, which, in turn, will lead to reliable results and interventions [86]. Only over recent years have researchers started trying to unveil the causal factors for maintenance errors [117].

Communication and Trust
Experimental evidence, regarding the relation between trust and communication, is scarce and more research on that field is needed [82].
More specifically the relationship between trust and communication (how they interact with each other) among colleagues, between subordinates and managers/supervisors and between maintenance staff and technology.

Communication	Trust
Most researchers have concluded that aviation has recognised miscommunication as a paramount human factor contributing to errors [36, 114], but there is still much work to be done to eliminate this risk and provide the industry with an error free communication	Trust, while it has been extensively researched by organizational researchers and more specifically by certain industries (e.g. web commerce) it is understudied in high-reliability organisations, as the aviation industry [76].
To succeed in this, it is of high importance to place the mechanisms and models of miscommunication in the specific frame of aviation industry [30] as there is a lot of potential in their implementation and development there, especially in aviation maintenance [115].	The optimum result would be to obtain a large amount of data from the full range of aviation activities, which would enable researchers to analyze results comparatively, inferentially, and longitudinally [86].
While debriefs may appear to be cost effective and produce quick results in the organizations' improvement of performance, the study of such processes over the years is scattered across different disciplines with no conclusive results [62].	The literature found that is dealing with trust in the aviation industry is scarce. This alone indicates that there is a lot of work that could be done in identifying and associating trust with other traits in the actual working environment in aviation maintenance [19].
This research, among other issues, indicates that a significant gap has been recognized between the quality of the students' oral and written communication skills gained during their studies (especially in the aeronautical area) and the skills required by the aeronautical industry to perform the tasks safely [71].	The interesting element in trust is that the *Initial levels of trust* (the levels of trust an individual or a company indicates at the beginning of a collaboration) are high, so human factors researchers could focus their research towards the direction of the mechanisms which will contribute to maintaining these levels high over time [106].
Extended research has still to be conducted in using new technologies to make them more appealing and subsequently resolve both managers' and employees' negative attitude to similar platforms [58].	More extensive research is needed to standardize trust measuring methodologies, in analyzing the results, and to enable smaller scale research to be compared safely, which in turn will lead to reliable results and interventions [86]. Only over recent years, have researchers started trying to unveil the causational factors for maintenance errors [117].
	Trust in technology and the negative effects of excessive interpersonal or organizational trust can be researched further, as again these are understudied fields, especially in aviation maintenance.

Figure 6. Tabular representation of the recognised future research potentials.

Following the example of 'Future Sky Safety' and trying to fill in the gap of the human factors research in aviation maintenance, the investigation of the interaction between two factors, such as communication and trust, is pioneering within the aviation maintenance context and of great importance. The research that has been conducted in aviation human factors so far is mainly a single factor research. Therefore, the study of two and more factors and their impact on human performance is a direction more researchers should follow in the future, given that human reaction is the result of different factors and conditions that interact with each other.

Under the scope of the investigation of factors in combinations, it would be interesting to see further combined research in communication and trust in aviation maintenance. More specifically the relationship between trust and communication (how they interact with each other) among colleagues, between subordinates and managers/supervisors, and between maintenance staff and technology. Furthermore, trust among aviation businesses and how they interact with each other would be a domain for further research, as new data could be exposed. Moreover, trust in technology has been under-researched in the aviation maintenance domain, which appears to be bereft of any significant research in this field. Additionally, the negative effects of excessive interpersonal or organizational trust can be researched further as, again, this is an understudied field, especially in aviation maintenance.

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Appendix B: Published Journal Paper 2

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Safety Management Systems: An Opportunity and a Challenge for Military Aviation Organisations

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Abstract

Purpose - Most military aviation organisations today have not evolved their safety management approach towards harmonising with civil aviation. Safety culture is the base for any civil aviation organisation, enabling employees to communicate effectively and be fully aware and extrovert on safety. Just culture and reporting culture both are related to safety culture. Both are parts of the awareness process, enhancing safety promotion. These distinct elements and the safety management systems (SMS) can serve well the military aviation. This viewpoint paper presents and discusses the SMS philosophy, structure and elements as a solution for military aviation organisations.

Design/methodology/approach – The feature of civil aviation SMSs are presented and discussed, with reference to the applicable frameworks and regulations governing the SMS operation. A discussion on the challenges faced within the military aviation organisations, with a brief examination of a European Union (EU) military aviation organisation, is presented.

Findings – The European Military Airworthiness Requirements (EMARs), which are based on the European Aviation Safety Agency (EASA) set of rules, can act the basis for establishing military aviation SMSs. A civil-based approach, blended, as necessary, with military culture is workable, as this is the case for many defence forces that have adopted such aviation safety systems.

Originality/value – This viewpoint paper discusses the opportunities and challenges associated with the adoption of SMS by military aviation organisations. This is the first time that this issue is openly discussed and presented to the wider aviation community, outside military aviation.

Keywords: Safety Management Systems, Safety Culture, Reporting Culture, Just Culture, Aviation.

Introduction

Aviation is one of the most complex and regulated industries around the world. From its early years, while its operations were growing rapidly, and tragic accidents with great loss of life and cost had started to occur, safety arose as a major factor in its operations. International Civil Aviation Organisation (ICAO) is the United Nation's specialised agency which works with 191-member States and industry groups to set common Standards and Recommended Practices (SARPs) and policies to implement safe, efficient, financially and ecologically sustainable activity in civil aviation. Since 1944, when the Chicago Convention took place, the first 52 attending Nations signed the International Convention for Civil Aviation, setting the regulations and principles for all National Aviation Authorities (NAAs) (Purton, Clothier, & Kourousis, 2014b). These policies and guidelines are used by Member States to ensure that their civil aviation authorities include them in their legislations content to the State's harmonisation with the global standards and safety procedures set by ICAO (Gerede, 2015; Purton & Kourousis, 2014). Recognising the effectiveness of these standards and regulations by mitigating the accident rate in civil aircraft, especially after the 1970s, efforts are driven at the moment in designing a relevant framework that concerns the state aircraft. The state aircraft (military, customs, police services) due to its diversity in technical and flight operations are in great need for SARPS, similar to the European Military Airworthiness Requirements (EMARs) (Purton, Clothier, & Kourousis, 2014a; Purton et al., 2014b; Purton & Kourousis, 2014; Purton, Kourousis, Clothier, & Massey, 2014c). However, transition to a modern civil-based aviation safety system has yet to be realised for most of the defence forces around the world, including the defence forces within the European Union (EU). Many EU defence forces share similar characteristics (size, homogenous population, diversity of the fleet) sharing similar goals. For that reason, the Hellenic Army's example is used in this paper as their representative. The Hellenic Army aviation is an operator utilising a very diverse fleet of approximately 160 helicopters (AH-64 Apache, CH-47 Chinook, NHI NH-90, Bell UH-1H/AB 205, Bell 206B, Bell AB212). Historically, the operation of military aviation helicopters in the Hellenic defence forces have been experiencing a relatively constant fatality rate, significantly higher than their Air Force counterparts (Fig. 1).

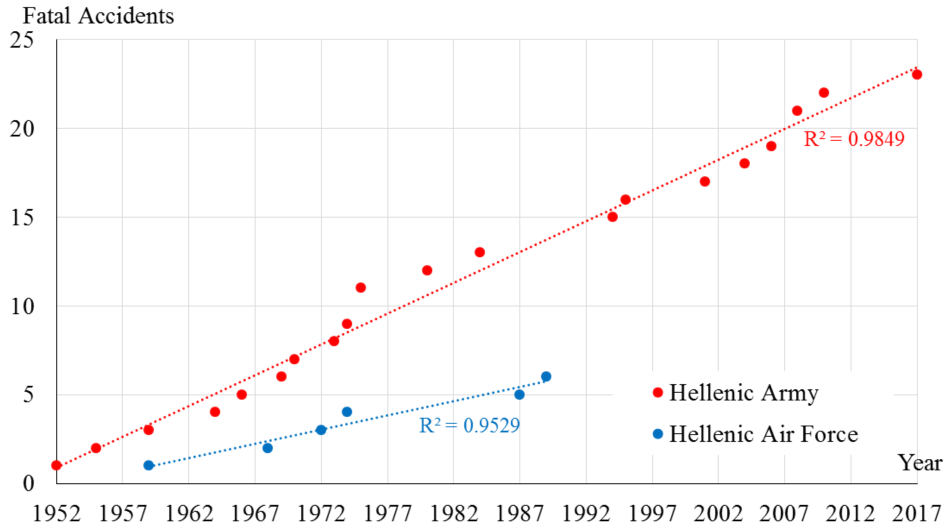


Figure 1. Hellenic Army – Hellenic Air Force helicopter fatal accidents (courtesy of K. I. Kourousis).

Without examining the operational and other organisation differences existing between the Hellenic Army aviation and the Hellenic Air Force, a key factor that could possibly contribute in improving safety performance in the Hellenic Army aviation is the establishment of a safety management system on the basis of the civil aviation safety management systems (SMS). This viewpoint article aims to analyse the elements of an SMS system that can be applicable to the Hellenic military aviation organisation and other defence forces that share similar characteristics. Moreover, it discusses the SMS main philosophy, structure and elements as a solution for military aviation organisations' safety management.

Safety Management Systems

From the 1960s the quality management system term (QMS) appeared on the aviation field to pave the way to occupational health and SMS (Stolzer, Goglia, & Stolzer, 2015). Safety management systems have evolved gradually with the influence of other management systems and disciplines until they finally took their most current form (Stolzer et al., 2015). SMS and QMS are closely related to each other as they both promote safety. They are the most basic and complementary systems in managing safety in aviation (ICAO, 2013).

General Framework

The globalisation of operations dictated the standardisation of SMSs as well, to the harmonisation and efficient collaboration of different aviation organisations, as their international character grew bigger and more complicated. More than 20 years ago, the first standardisation of quality assurance was a reality (Stolzer et al., 2015). Today, aviation regulatory bodies around the world have institutionalised safety management systems, that follow the standardisation requirements, and aviation companies are obliged to have them in place.

According to the 3rd edition of the ICAO's Safety Management Manual (SMM) (2013) "SMS is a systematic approach to managing safety, including the necessary organisational structures, accountabilities, policies and procedures" (ICAO, 2013, pxii). In the same document ICAO states the significance of the implementation of SMSs by the NAAs internationally in order to: a) locate the potential threats to safety, b) make certain to enforce all corrective actions necessary to keep the agreed safety performance, c) contribute to continuous monitoring and orderly assessment of safety performance, and d) to target a higher quality of performance of the safety management system.

To meet these criteria, a set of four components are proposed to form the SMS's framework. It is understandable that the size of each organisation and the complexity of the services provided, defines the form of the frame in which the SMS is implemented. These four components include twelve elements and they are the minimum requirement for an aviation company to implement an SMS. The four components of SMS, as shown in Fig. 2, according to ICAO's Safety Management Manual (SMM) (2013) are: safety policy and objectives, safety risk management, safety assurance and safety promotion.

Figure 2. Schematic representation of the four SMS components.

Each one of these components consists of different individual elements that categorise its activities as shown in Table 1.

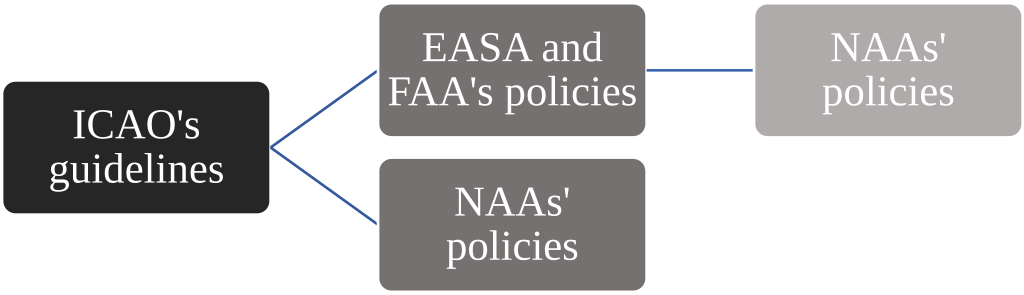
Table 1. SMS individual elements and corresponding activities.

Safety policy and objectives	• Management commitment and responsibility; • Safety accountabilities; • Appointment of key safety personnel; • Coordination of emergency response planning; • SMS documentation.
Safety risk management	• Hazard identification; • Safety risk assessment.
Safety assurance	• Safety performance monitoring and measurement; • The management of change; • Continuous improvement of the SMS.
Safety promotion	• Training and education;

- Safety communication.

These components and their elements are set by ICAO’s Safety Management Manual (SMM) (2013) as the minimum requirements each aviation organisation should have, after each National Aviation Authority’s (NAA) approval. This approval reflects on each of the NAA guidance materials and requirements available to the aviation companies within their jurisdiction. Aviation regulatory bodies such as the Federal Aviation Administration (FAA) and European Aviation Safety Agency (EASA) have developed themselves SMS structures under the direction of ICAO’s guidelines. As a result, NAAs around the globe are designing their SMSs following either FAA’s or EASA’s policies or directly ICAO’s guidelines to ensure their compliance with ICAO’s directions (Fig. 3).

Figure 3. Schematic representation of the policy making process.



SMS Components

In the FAA’s Advisory Circular AC 120-92B (2015), the four components of SMS, as they are introduced by ICAO, are presented and explained. Aviation companies are obliged to follow this structure in order to ensure their successful implementation of an SMS programme within their operational activities. These four components, as they are retrieved from the FAA’s AC 120-92B, are explained in more detail in the subsequent sections.

First Component - Safety Policy and Objectives

The core of every organisational structure is its policies and procedures. For safety to be established as a fundamental part of this core, it needs to be dominated by relevant guidelines and to be included in the policies and the organisational structure. Under this framework, safety is organisationally in the company’s goals to set objectives, assign responsibilities and set standards. The implementation of this stage depends highly on the commitment of the upper management to safety.

The management’s role is critical, in regard to the safety policy and objectives, as it is the management’s active support and anticipation that keeps all employees focused and motivated to this direction. It is clearly the management’s responsibility to oversee the accurate implementation of all policies and procedures as well as to ensure that safety is one of the primary goals of the company. This means that safety is included in the strategic plans of the company and is being assessed regularly along with the company’s SMS. This assessment is a very critical phase for every aviation organisation. It includes feedback from the implementation of the safety risk management component and the risk assurance component of the SMS. This assessment and feedback gives the opportunity to ensure that all policies and procedures are realised in the way they were designed to be, and all standards are accurately held.

In military aviation policy is described in Orders, of different hierarchy, and it is often very prescriptive, especially when compared to civil aviation policy documents. The level of inflexibility involved in military policy documents often presents challenges in the implementation of safety rules.

Second Component - Safety Risk Management

The safety risk management component consists of decision making processes, such as identifying hazards and mitigating risks, by carefully evaluating the organisation's systems and their operating environment. Evidently the most important element in this component is the risk management system that is in place and its effectiveness. It is of high importance in each aviation organisation to successfully measure risk and to develop efficient strategies to manage it. This particularly important for military aviation, due to the nature of operations, both in peace and war time.

Acceptable risk is a value that each aviation organisation must set for itself, following specific procedures, and then making decisions on ways to reduce that risk. This process requires a thorough understanding of the operational systems which includes the structures, the procedures and the policies of the company along with the staff, equipment and the artefacts of the company. This means risk experts are called to use all available tools to process risk management by identifying the hazard in the company's activities and calculate the associated risk accordingly. Once the risk is analysed, its assessment comes next and eventually follows the reducing of the risk to conclude the process. In military aviation, the commanding officer's role in deciding to accept or reject risk is of paramount importance. In practice, for most military aviation organisations, the safety system operates strictly under a single-point failure mechanism. This is considered a major drawback for the effective implementation of risk-management system. Reducing the risk is a realistic term as elimination is rarely accomplished, either in civil or military aviation. In reality, reduction of risk to an acceptable level of risk is doable, with risk experts evaluating this acceptable level after thorough investigations and analyses. Again, military aviation practice generally suffers from the chain-of-command effect and the lack of sufficient independence between the organisation's units comprising their safety system – e.g. the commander is the operator and the regulator in some cases, which presents a clear conflict of interest in civil aviation terms.

Third Component - Safety Assurance

Safety assurance is the stage in which the safety risk management process is evaluated. It means that this is the reassuring component which gives an aviation organisation the reassurance that their SMS is meeting their strategically set safety objectives and that all risk controls and mitigations, that took place during the safety risk management component, had positive impact and were effective. Thus, in safety assurance procedure, detailed monitoring is of primary importance in measuring safety performance in the company's operations and in improving their level of safety constantly. Safety performance is military aviation requires a far more dynamic monitoring approach, as opposed to civil aviation. The simple reason is that the inherent system safety of the aircraft, as well as the operational environment, have a profound effect on the evolution of safety performance. Effectively, trend analyses are a constant tool used to predict a degrading performance or assist in faster recovery of operations following incidents or accidents. In the military helicopter operations world, the situation is far more dramatic than in the fixed wing world (mainly due to the high-risk profile of the operations and the overall lower reliability of the technical systems).

A robust safety assurance process uses as many resources as possible to preserve the integrity of risk controls. These resources may stem from information gained through staff reporting system, audits (external or internal), experts' investigations and analyses. The key element at this stage is again the management's commitment to safety. Management staff in military aviation are governed not only by a chain of superior (commanding) officers but from a set of military rules. One odd situation that can be identified in the defence forces, is the regular disconnect existing between rules governing purely military discipline and those rules who dictate safe practice of the staff duties. This disconnect may lead to contradictory situations, which can have a negative impact on the military organisations aviation safety performance, especially in the Army (as opposed to the Air Force, which is a more technical service body). Management is the organisational factor that is responsible for the realisation of all necessary changes in order to proceed to the desired level of safety. Therefore, safety assurance is the framework that enhances the safety performance of the organisation, makes corrections whenever it is necessary and pointing out existing processes that need to be under consideration.

Fourth Component - Safety Promotion

Safety promotion is the last component of SMS and is designed to promote safety among the organisation's employees. All staff from the upper management to the newly hired have to acknowledge their responsibility in safety by familiarising themselves with the safety policies and procedures, the reporting procedures that are in place and the risk controls. For a safety promotion to be effective the creation and application of a robust safety culture in of high importance.

A safety culture within the organisation enables all staff to comprehend and maintain their part in safety operations of the company by following all the relevant policies and procedures while empowering the company's reporting culture and the just culture (Stolzer et al., 2015). An efficient reporting culture comprises of a system that enables safety related issues to be reported freely among employees having as a goal their correction. A healthy just culture is the culture''in which individuals are both held accountable for their actions and treated fairly by the organization'' (Stolzer et al., 2015, pp. 33). Promoting safety culture is another area of problematic implementation within military aviation, especially where a military aviation/airworthiness system is not established and operated. Moreover, a key characteristic of army aviation is the less robust education channel for their staff. In general, aviation staff (either pilots, technicians or engineers) may come from a common education system where the focus is on developing a culture geared around effective ground-battle practice. This staff is then moving to aviation roles and a new culture/behavioural attitude must be developed from scratch, that of having a focus on aviation safety. This transition is neither straightforward nor easy and has a negative impact on creating a safety culture within an army aviation organisation.

In these regards training and communication are essential elements of safety promotion. Continuous staff training ensures that all individuals involved are updated with all the requirements for their roles in the company and the proper certified qualifications have been provided to them. Training can be helpful, however fundamental education is also very important for military aviation staff. Thus, several defence forces are putting emphasis on the combination of training with education. Moreover, every organisation should have an efficient communications system in place for staff to have untrammelled access to all safety regulations and policies and at the same time unrestricted access to qualified safety personnel for help and guidance.

Safety Culture and its relation to Just and Reporting Culture

As mentioned, safety culture is a fundamental part of the fourth component of an SMS, the safety promotion. "Safety culture is defined as the shared values, beliefs, assumptions, and norms that may govern organizational decision making, as well as individual and group attitudes about safety" (Wiegmann, Zhang, Von Thaden, Sharma, & Gibbons, 2004, pp.122). Safety culture is a term that has been examined extensively through the different industries around the world. Researchers have proposed that safety culture includes different organisational indicators in these different industries (Wiegmann et al. 2004). There are at least five of them that are applicable globally to all industries and they include organizational commitment, management involvement, employee empowerment, reward systems, and reporting systems (Wiegmann et al. 2004), as shown in Fig. 4.

Figure 4. The five different organisational indicators that form safety culture

In any industry that its complexity and responsibility to their products or services dictates an efficient safety system in place, like aviation, reporting systems are their corner stones. Through these reporting systems any failure of safety management is detectible, by recognising the faults and omissions of the system. Therefore, their success, in order to be prepared and prevent any negative occurrence or even an accident, depend on the free reporting of all employees regarding any safety issue that arises while on duty (Wiegmann et al. 2004).

By the term free reporting, the aviation organisation has to take measures towards the protection of the status of their staff and assets while using the reporting system. This is the only warranty towards staff to persuade them to use the system effectively and to prevent accidents and incidents while they get feedback on how the issue has been resolved (Wiegmann et al. 2004).

An ongoing debate is in place for years in civil aviation regarding free reporting and more specifically how a blame-free reporting attitude can lead people away from their responsibilities, by blaming the system, even though every provision, to prevent mistakes, was in place (Sharpe, 2003). This means that staff should be accountable for their actions, thus being more responsible. On the other hand, it is of great importance to encourage staff into reporting their mistakes freely and contributing in their correction (Catino & Patriotta, 2013; Dekker & Breakey, 2016).

Just culture has been offered as a possible solution to this dilemma by researchers (Catino, 2008; Dekker, 2009; Dekker & Breakey, 2016). A just culture approach aims to keep all staff's obligations and expectations open and transparent. It also acknowledges that even experienced personnel are anticipated, at some point of their career, to err and to develop shortcuts or routine violations (Dekker & Breakey, 2016). Nevertheless, this does not mean that management tolerates deliberate or reckless mistakes. By this approach, just culture aims at perspicuous reporting and more efficient communication among staff (Dekker & Breakey, 2016). This system benefits itself from a transparent punitive matrix, in which every staff is aware of, to promote free reporting. This is a reassuring measure that staff won't be unfairly blamed in case of an incident and they are encouraged to honestly report any error or malfunction of the system and to mitigate any negative consequences (Dekker & Breakey, 2016). To be able to eliminate the risk it is of great importance that the right questions are asked. To address the problem properly at an incident, and find the right solution, it is important to investigate the conditions and examine the way the provocative systems worked and not only who was involved in it (Zehr & Gohar, 2002).

Again, the key role in just culture is played by upper management who is responsible in establishing a fair and just environment for all staff and empowering them in reporting all critical issues in safety. In a military aviation organisation, the role of the commanding officer, at the various levels of the chain-of-command, is instrumental in creating such a working environment. Upper management's role is critical in communicating all relevant to safety information and human factors initial and concurrent training to the whole of their staff. However, human factors' training (or even basic awareness) is very limited in most military aviation organisations. Moreover, there is often the misconception (especially among higher/mid-level management military staff) that generic health and safety rules can be adopted in lieu of aviation-specific human factors' considerations and rules. Literature has shown that there is a tendency that staff who are aware of the safety regulations and requirements, choose safety over productivity (Karanikas, Melis, & Kourousis, 2017). This is also a typical situation among less experienced army aviation staff operating or maintaining aircraft and who are frequently subject to transfers between different units/roles/aircraft types. To reach this desired state in which employees consciously prefer safety, effective safety communication is a prerequisite among all organisational and managerial levels reflecting the thorough safety training that has been provided to the staff (Geldart, Lohfeld, Shannon, & Smith, 2010; Hall, Oudyk, King, Naqvi, & Lewchuk, 2016). The role of a structured and well-defined education and training system in military aviation is of paramount importance, especially if the military organisation is experiencing regularly staff internal mobility or attrition.

Discussion

All sectors in aviation regardless if they are maintenance, operators, air traffic management, airport operations etc. operate under the same regulatory framework. SMSs are applied across the different sectors ensuring their safe operation. However, these different sectors have different operational circumstances and requirements that might affect the way the SMSs are applied and even affect their activities. The same situation, and in even greater extent, applies to military aviation, where (for example) the operations and maintenance units within the organisation have different needs and requirements, which also vary between training and wartime operations.

ICAO has already established the framework, which the Member States around the world, one by one, include into their regulatory repertoire and take part in the attempt for global standardisation and safety operations in aviation. Each national aviation authority is responsible for the implementation, alongside with the industry's active role. This model has proven to be successful in civil aviation, as the positive outcomes in safety have resulted in the mitigation of the rate of accidents which has led to: a) the expansion of these regulations globally to include the military aircraft (Purton, Clothier, & Kourousis, 2014a; Purton et al., 2014b; Purton & Kourousis, 2014; Purton, Kourousis, Clothier, & Massey, 2014c); b) other industries like healthcare to acknowledge the successful example of aviation and take steps in following its example (Pronovost et al., 2003; Ross, 2014;Sexton, Thomas, & Helmreich, 2000). However, for most military operators around the world, this harmonisation/adaptation has yet to be realised. The Hellenic Army aviation is one of these operators. It is highlighted that none of the Hellenic defence forces services, as well as several other European Union (EU) defence forces, have yet adopted the EU military airworthiness framework (EMARs). This is considered as a missed opportunity in moving towards a more effective and efficient aviation safety system.

In the development of the components of SMS, safety culture emerged as a critical element being the goal for every management in aviation. Within the frame of a well-established safety culture staff are fully aware of safety requirements and willing to promote safety. The structures that assist staff in gaining the desired level of awareness and collaboration towards safety are reporting culture and just culture (Stolzer et al., 2015). Research not only in aviation but in other highly complex and regulated industries dictate that a functional reporting system promotes safety as it enables free and accurate communication in safety issues and their successful resolution (Wiegmann et al. 2004). Communication in military organisations is an activity which is prescribed by a mixed set of generic military communication norms/rules and aviation-specific rules (the latter are not necessarily best adapted to the needs of an aviation organisation). Moreover, fragmentation of information and rules (especially legacy rules or standing orders established over a series of iterations throughout the years) present additional difficulties in establishing a robust reporting system. These are considered distinct challenges that a military aviation organisation, such as the

Hellenic Army aviation among other similar EU military aviation organisations, must manage in the process of setting up an SMS.

Just culture, on the other hand, warranties the transparency and the feeling of justice, the employees should experience in their workplace. This helps them to work undistracted and proceed in reporting any safety related issue without prejudice and fear (Dekker & Breakey, 2016). Evidently, it is obvious that reporting culture and just culture are two desirable qualities in aviation organisations that affect positively safety culture and safety promotion and contribute to a successful SMS. However, maintaining military discipline, which is part of the chain-of-command function of any military organisation, will surely obstruct the full deployment of a reporting and just culture. Responsibility is considered not only one of the virtues that all military staff should have and in most military organisations its promotion is linked with punishment of individuals (or even groups, to offer examples to others). This is perhaps one of the primary challenges (mental shift) that the commanding officers are going to face in any such change management process.

Research has shown that in aircraft maintenance, even though there are differences in the SMSs and the safety climate among different organisations, it does not affect the safety attitude of the staff or their dedication to their work, which is found to be high (McDonald, Corrigan, Daly, & Cromie, 2000). This led the research to acknowledge the similarities of the technical personnel sub-culture, while a difference in the climate between the different occupational groups of the organisation revealed the different understanding of safety by these groups (McDonald et al. 2000). This is an important consideration for military aviation staff, since the groups are generally not only more diverse (in terms of staff experience/expertise) but also more in number (as military aircraft require more technical specialties/trades and licences, when compared to the typical EASA or FAA licencing/type rating system).

The aviation example dominates the relevant healthcare research regarding safety (Pronovost et al., 2003; Ross, 2014; Sexton, Thomas, & Helmreich, 2000). In the literature it is stated that a good safety culture is associated with decreased error within pilots. Furthermore, the contribution of efficient communication, successful teamwork and decision making is highly appreciated in the reinforcement of safety culture in aviation (Pronovost et al., 2003). Especially among pilots, the values that are highly anticipated by their employers, are their ability in learning by errors, among other qualities and capabilities (Pronovost et al., 2003). For this ability i.e. learning by errors, a healthy reporting system is required to provide all pilots with all the near misses and incidences to inform and train them in avoiding a similar situation in the future. The highly procedural nature of the pilot’s activities exists in same, or even greater, extent in military aviation. The pilot of a military helicopter (or aircraft) must fly, navigate and operate the aircraft as means of transportation and a war vehicle. Therefore, the workload of a military pilot, especially in tactical missions (either in training or wartime operations), is a risk-multiplier factor that must be taken into consideration when developing and operating a SMS.

Moreover, recent research has unveiled that pilots have more contact with different types of management within the aircraft operators (e.g. airlines). As a result, they have noted that there is no consistency on behalf of the different layers of management towards safety resulting in giving contradicting messages to pilots (Gibbons, von Thaden, & Wiegmann, 2006). Therefore, the management’s important role is obvious in maintaining the same amount of awareness among the pilots of an airline. The same applies for pilots of military helicopters and aircraft, especially when the organisation operates a diverse fleet (such as the case of some of the EU military aviations).

Conclusion

As a result, it is obvious that just culture and reporting culture are influencing safety culture, and both are important when developing a military-specific SMS. Military aviation organisations, in all sectors/activities involved, should take cautious steps in maintaining and strengthening these elements (just-reporting culture) as they have been proven to be significant part of safety promotion and by extension they can influence the performance of an SMS. Military pilots, technical staff and other occupational groups (support staff working in logistics support, etc) have been proven to show inconsistences in their perception of safety in their organisation. Therefore, it is the military organisation management's responsibility to make sure that safety is an equal priority for every different occupational aviation group by maintaining a consequent attitude towards them all. The Hellenic Army aviation and other similar organisations can benefit largely by examining the structure of SMS and how elements of that could be gradually implemented within the organisation. A civil-based approach, blended, as necessary, with the military culture is workable, as this is the case for many defence forces that have adopted the EMARs and other (relevant) airworthiness/aviation safety systems. However, establishing the applicability of civil norms to military aviation is currently work-in-progress, as part of an ongoing research project. It is noted that this communication paper offers the research and military aviation professionals community with an outline of this ongoing project' aims and philosophy.

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Appendix C: Published Journal Paper 3

Kourousis K. I., Chatzi A. V., & Giannopoulos I. K., (2018). The airbus A320 family fan cowl door safety modification: a human factors scenario analysis", *Aircraft Engineering and Aerospace Technology*, 90(6),967-972, https://doi.org/10.1108/AEAT-08-2017-0191
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The Airbus A320 Family Fan Cowl Door Safety Modification: A Human Factors Scenario Analysis

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Abstract

Purpose – The Airbus A320 family engine fan cowl doors safety issue is known to the industry for almost 18 years, however it has not been addressed adequately by the aircraft manufacturer and the various operators and regulating authorities. This brief case study paper examines in a systematic way the possible operational and safety implications of a new modification on the engine fan cowl doors.

Design/methodology/approach – An array of error-prone scenarios are presented and analysed under the prism of human factors in a non-exhaustive qualitative scenario analysis.

Findings – All examined scenarios are considered more or less probable. A number of accident prevention solutions are proposed for each of the scenario examined, in view of the acceptance and implementation of this modification by operators.

Research limitations/implications – Since these scenarios are neither exhaustive, nor have been tested/validated in actual aircraft maintenance practice further analysis is necessary. A substantial follow up survey should take place, which should include a wider array of scenarios. This would allow obtaining the necessary data for a quantitative (statistical) analysis.

Practical implications – This case study identifies issues in relation to this modification, introduced by Airbus and the European Aviation Safety Agency (EASA), which may prove problematic from the point of view of safety effectiveness and disruption of operations.

Originality/value – This case study examines a long-standing aviation safety issue and the implications of a solution proposed by the aircraft manufacturer and adopted by EASA. This can be useful in increasing the awareness around these issues and

highlight the importance of a human-centric and scenario-based design of engineering modifications towards minimising error in aircraft technical operations.

Keywords

Human factors, aviation maintenance, safety, airworthiness, accident prevention

Introduction

Several Airbus A320 family engine fan cowl door (FCD) (Figure 1) losses have occurred in the past due to uninspected unlocked situations that have occurred in service (AAIB, 2015). This issue is known to the industry for almost 18 years, however it has not been addressed adequately by the aircraft manufacturer (Airbus) and the various operators and regulating authorities. Similar issues have been faced in the past with other aircraft types, such as the ATR-42 (AEAT, 2002).

Figure. 1 A British Airways Airbus A319-100, where the (blue-painted) fan cowl doors (FCDs) surrounding the engines are shown (photograph by Adrian Pingstone). [https://commons.wikimedia.org/wiki/File:Britaw.a319-100.g-eupu.arp.jpg. Public domain].

A historical overview offers an interesting insight on the FCD safety issue, by looking at the preceding modifications (manufacturers' SBs), issued EASA and Federal Aviation Authority (FAA) ADs and FAA proposed rulemaking documents (Notice for Proposed Rule Making, NPRM) (Figure 2). What stems from this brief examination is that following an activity in the early 2000's, the issue was practically silenced (from the standpoint of redesign and safety regulation) for 12 years, despite the ongoing incidents. Airbus, as the aircraft design approval holder, has re-opened the investigation and mitigation of this safety issue in reaction to an accident investigation report released in 2015 by the United Kingdom (UK) Air Accidents Investigation Branch (AAIB).

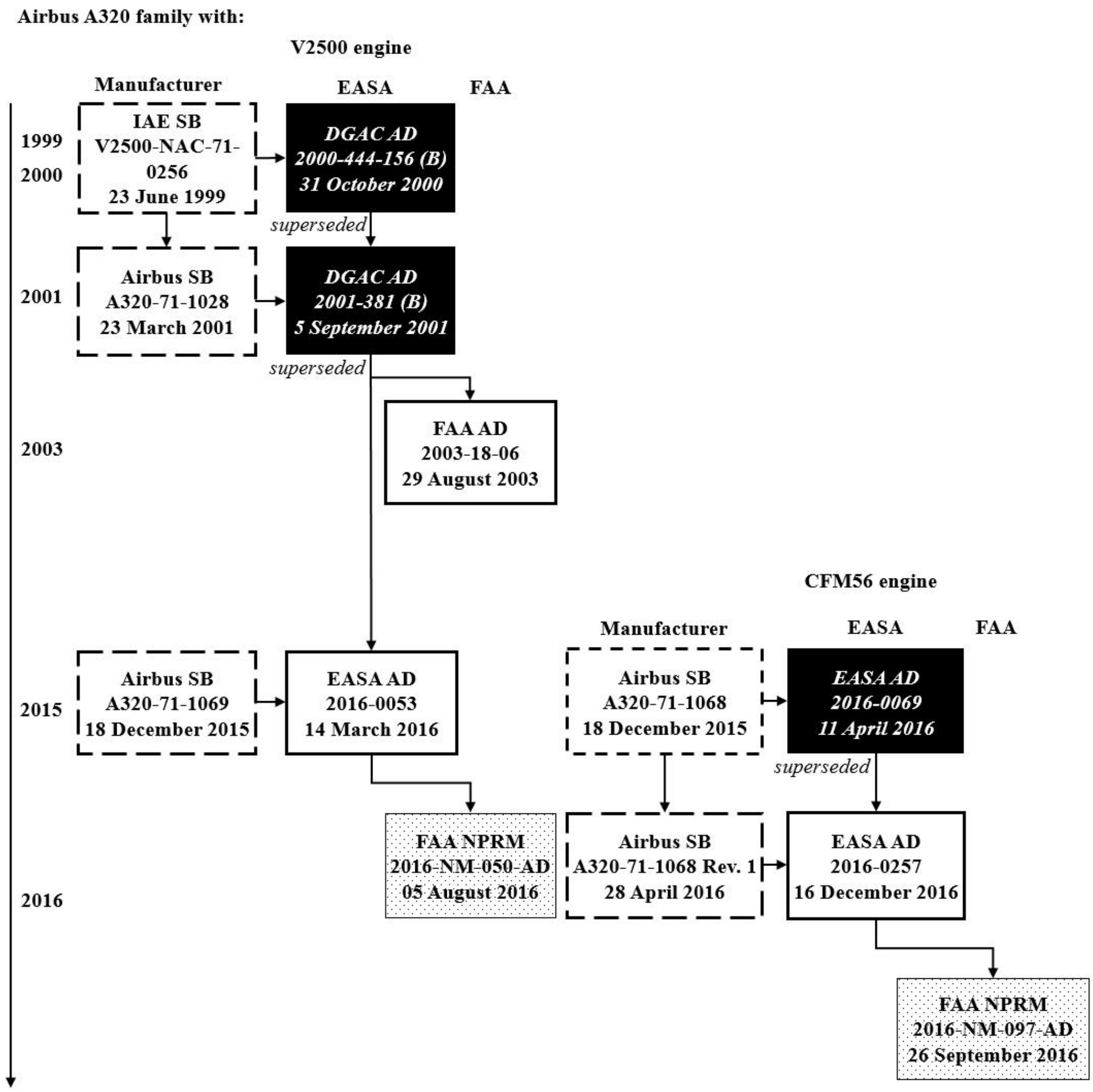

Figure 2. A historical overview of the manufacturers' and regulating authorities' (EASA, FAA) actions on the Airbus A320 family engine FCD safety issue. Note: DGAC refers to the French aviation regulator ('Direction Générale de l'Aviation Civile').

In particular, it was a double FCD loss from a British Airways Airbus A319 in 2013 (Figure 3) that has led to the escalation of this issue, following the release of the 2015 AIB accident investigation report (AAIB, 2015). Airbus, in an attempt to address the issue permanently, proceeded in redesigning the FCD locking arrangement and control philosophy (Airbus, 2015a; Airbus, 2015b), which were subsequently adopted by the European Aviation Safety Agency (EASA), in 2015 and 2016, as Airworthiness Directives (ADs) (EASA, 2016c; EASA, 2016d). Both EASA ADs are currently under consideration by FAA (FAA, 2016a; FAA, 2016b).

Figure 3. Remaining parts of the right-hand engine inboard FCD of the British Airways Airbus A319-131 G-EUOE following the 24 May 2013 accident (photograph reproduced from the AAIB Aircraft Accident Report 1/2015 (AAIB, 2015)).

The 2016 EASA ADs and the relevant Airbus Service Bulletins (SBs) describe the modification that the aircraft operators has to implement on all affected models of the Airbus A320 family (A318/319/320/321) fitted with the IAE V2500 and CFM56 engines. The main features introduced by this modification are (EASA, 2016c; EASA, 2016d):

- A new FCD front latch which locks/unlocks with a use of a specific key (the two other latches remain unchanged) (Figure 4). This key cannot be removed once the latch is unlocked.
- A new locking/unlocking key for the FCD front latch with a ('remove before flight') flag fitted on it (Figure 4). The flag increases the visibility-detectability of an unlatched condition, since the key-flag assembly is attached to the latch as long as it remains in the open position.
- A key keeper assembly at a designated storage area in the cockpit, where the key and the ('remove before flight') flag assembly are kept when once the FCD is closed.
- Aircraft Maintenance Manual (AMM) adaptation, to include provisions for a logbook entry requirement when opening/closing the FCDs is performed, as a way to assist communication and raise awareness over the matter.

Figure. 4 Modified A320 family engine FCD with new latch and key - ‘remove before flight’ flag assembly.

However, as part of the EASA ADs’ consultation process (conducted prior to their issue), a number of major operators (United Airlines, American Airlines, All Nippon Airways, Air Canada) have expressed reservations on the effectiveness of the Airbus redesign, on the basis of human factors issues, potential financial impact on operations and implementation cost (EASA, 2016a; EASA, 2016b). For example, United Airlines, in their comments to EASA (EASA, 2016a) argued that the implementation of another visual cue does not guarantee that the people involved will not miss it, unless they are careful and attentive. In the same response, United Airlines highlighted that dual sign-off for the FCD closure and other steps they have introduced in their operational procedures (towards increasing the awareness of the technical staff) have proved to be successful in addressing human factor related issues. In particular, United Airlines has not had any incidents occurring since the introduction of these, human factor focused, measures in 2006. Similarly, Air Canada supported the suitability and effectiveness of the dual sign procedure, expressing a strong negative view on the usefulness of the modification (EASA, 2016b). As Air Canada highlighted in their comments, a uniform solution approach is not likely to be effective, since each organisation should work towards changing the technical staff culture to address the safety issues around FCDs (EASA, 2016b). As also recorded in the (EASA, 2016a; EASA, 2016b), one may note that, in response to these comments, EASA did not make any changes in the final ADs, while they suggested that operators may apply for an Alternative Means of Compliance (AMC) to the AD, by providing data supporting their requests (for exemption from the AD).

The EASA’s reasoning behind the adoption of the Airbus FCD SB is not described in the ADs. Moreover, the design principles employed by Airbus, in the development of the SB, is not known (as the SB is not publicly available). The adopted solution is considered peculiar for aviation maintenance, from the point of view of human factors, since it is not usual practice to restrict access to aircraft compartments via specific keys, rather than standard or special tools. Extensive review has failed to identify similar solutions utilised in civil aviation.

This brief paper intends to examine and discuss in a systematic way the possible operational and safety implications that the FCD modification can have in aircraft maintenance practice.

Qualitative scenario analysis, results and discussion

Taking into account the aircraft modifications and the changes in the maintenance processes which occur from the EASA ADs, we have examined and identified steps in the new procedures that may prove problematic from the point of view of safety effectiveness (increase errors or lead to deviations from safe practice) and disruption of operations (create delays/obstructions in aircraft dispatch/maintenance). In particular, an array of error-prone scenarios are presented and analysed under the prism of the human element.

The scenarios were developed conceptually by utilising the authors' 10+ years' experience in aircraft maintenance practice (as certifying staff), design/certification of modifications and accident/incident investigation. The realism of the scenarios (steps, sequence, etc.) was also validated by consulting aircraft maintainers having prior experience on the A320 family aircraft. Thus, both the development and validation of the scenarios did not require any physical work on aircraft (or any interaction with an aircraft maintenance organisation).

Moreover, accident prevention solutions are proposed for each of the scenario examined. It is noted that within the EASA framework these recommendations are part of the existing Maintenance Resource Management (MRM) training and the EASA Part-66 and Part-145 human factors training requirements (EU, 2014). Errors related to handovers generally have more severe and dangerous consequences, as approximately half of the aircraft maintenance failures due to ineffective communication are related to the shift handover (Parke and Kanki, 2008). Debriefs which are based upon human factors considerations have the potential to enhance productivity by 20%–25% (Tannenbaum and Cerasoli, 2013). Effective teamwork is known to be essential in safer aviation maintenance practice (Leonard et al, 2004; Robertson, 2005; Sexton et al, 2000), mainly due to the nature of the profession (organisational structure of work, rather than individuals working in isolation). Time pressure, such as that experienced in the flight line environment, is a primer for errors (Goglia et al, 2002; Reason 2000) and, in this case, it is considered important to examine. Overall, teamwork, dual sign-offs, effective time management and request for assistance from colleagues and supervisors (whenever required) constitutes good practice in aviation MRM.

According to the FAA, MRM can also act as a training programme, as it aims to alter the technicians' attitude and perspectives in order to establish safety as their primary goal (Robertson 2005). As regularly reported in the literature, training in aviation is important and it acts beneficiary, while its design, delivery and implementation needs to be tailored to the needs of the organisation (Lappas and Kourousis, 2016; Salas et al, 2012; Taylor and Thomas, 2003). Consequently, aircraft maintenance managers should consider the training process as a proactive safety measure and actively support MRM training. It is of note that employees working within the highly regulated aviation industry, are inclined to practice more safely than in a more productive fashion (Karanikas et al, 2017). This is a strong indicator of how the 'safety over productivity' equilibrium can be positively influenced (towards safety) by regulation.

It is interesting to look at the definition of (Wiegmann,et al, 2004) on safety culture "as the shared values, beliefs, assumptions, and norms that may govern organisational decision making, as well as individual and group attitudes about safety". Focusing on the norms of an organisation, these set the framework within the employees are expected to think and operate (Wreathall, 1995). Therefore, if the norms contradict the organisation's safety policy, they should be revised or abolished. Any organisation, in order to action changes in culture, they have to establish effective safety communication between the various organisational and managerial levels. In aircraft maintenance training, this can include the establishment of a thorough safety training programme (Geldart et al, 2010; Hall et al, 2016).

The scenarios are not intended to be exhaustive, in terms presenting the full spectrum of combinations of actions. However, they represent a number of cases which are deemed likely to occur in service and that can have a considerable impact on safety and operations. All scenarios start from the case of a maintenance task requiring access to the area enclosed by the FCD (in the cases examined 'engine failure troubleshooting'), which is secured by the specific key (introduced with the Airbus modification/EASA ADs).

FCD key in designated area

The technician retrieves the FCD key from the designated storage area in the cockpit and inserts a logbook entry for the opening/closing of the FCD.

Scenario 1 The technician leaves the maintenance task (in the area enclosed by the FCD) for the end of the failure troubleshooting. He/she performs the maintenance task at the end of his/her shift. However, he/she does not dedicate adequate time for the maintenance task, as he/she inadvertently prioritised the FCD task [return of the key, closure of the logbook entry ('FCD closed')], in an effort to avoid the FCD is not left open. This poor practice may result in reduced maintenance quality, under stressful or very time constrained situations, since FCD-related tasks are added to the existing workload. Prevention measures may include: putting more focus on time management techniques and requesting assistance from peer-workers/team leader in stressful/time-pressing situations.

Scenario 2 The technician performs the maintenance task straight away but leaves the key return and logbook entry closure for later. Since these steps were left for a later time, the technician either forgets completely to return the key/close the logbook entry or gets distracted near that time, having the same result. As a consequence, the aircraft release to service can be delayed, since the involved personnel (flight crew, technical staff) will have to locate the missing key and complete the FCD sign-off in the logbook.

A dual sign off practice would offer the opportunity for a confirmation check and reduce the possibility of misses and errors.

Scenario 3 The technician does not perform the maintenance task and has to pass it over to the next shift. Since these steps were left for the next shift, he/she either forgets to return the key/close the logbook entry or gets distracted to do that. In case that the shift handover is not performed properly, the FCD tasks are not completed. As a consequence, similarly to Scenario 2, the aircraft release to service can be delayed, since the missing key has to be located and the logbook signed off.

As with Scenario 2, the dual sign off practice can mitigate this issue. Moreover, a thorough (verbal and written) shift handover would be helpful in avoiding communication gaps in relation to the FCD tasks (reducing the possibility for misses and errors).

Key missing from designated area

The technician does not find the FCD key in the designated storage area in the cockpit.

Scenario 4 The technician attempts to find the FCD key. He/she prioritises this task over the maintenance task itself. In the case that he/she finds the key, the amount of time spent on the search does not allow him/her to focus on the maintenance task, thus this is not performed adequately.

Similarly, to Scenario 1, it would be beneficial if better time management techniques were practiced, as well as if the technician requested assistance.

Scenario 5 The technician attempts to find the FCD key, prioritising the search over the maintenance task (same as in Scenario 4). He/she does not manage to find the key, leaving the maintenance task unaccomplished. In the case that the technician is forgetful or distracted, he/she will not report the missing key, causing more delay, as other personnel in later time will repeat the search process.

Similarly to other scenarios, the dual sign off in conjunction with a robust handover process could mitigate this miss.

Scenario 6 The technician attempts to find the FCD key, prioritising the search over the maintenance task (same as in Scenario 4 and 5). He/she does not manage to find the key, therefore deciding to use his/her own key or the spare key as per the organisation's 'norm', and fills in the logbook entry ('open FCD'). After completing the maintenance task the technician is forgetful/omits or gets distracted and does not report the missing key. As with Scenario 5, this may cause a delay in the future. Moreover, using his/her own key means that this may not have the 'remove before flight' flag attached, increasing the probability of leaving the cowl door open (since this modified visual cue will be missing).

Similarly to previous scenarios, the dual sign off in conjunction with a robust handover process could mitigate this miss. In addition, a change in the organisational culture would be necessary to abolish unsafe practices in relation to established 'norms' outside the standard policies and procedures.

Scenario 7 The technician does not have the required time or attitude to attempt to find the missing key, thus he/she decides not to perform the assigned maintenance task and, for example, to move onto a different task. He/she forgets about the missing FCD key or gets distracted and does not report that. This shall cause delay in the work of the personnel who are then assigned to the maintenance task in the FCD-accessed area (as they will have to search for the missing key).

Dual sign off and in-shift/inter-shift handover would be an effective solution to avoid such situations.

Graphical Representation of the Scenarios

The sequence of the events and causes described in each of the Scenarios (1 to 7) is graphically represented in Figure 5, where all interconnections are shown. The graph illustrates characteristically the complexity of the various problematic situations that may arise out of the subject matter FCD safety modification.

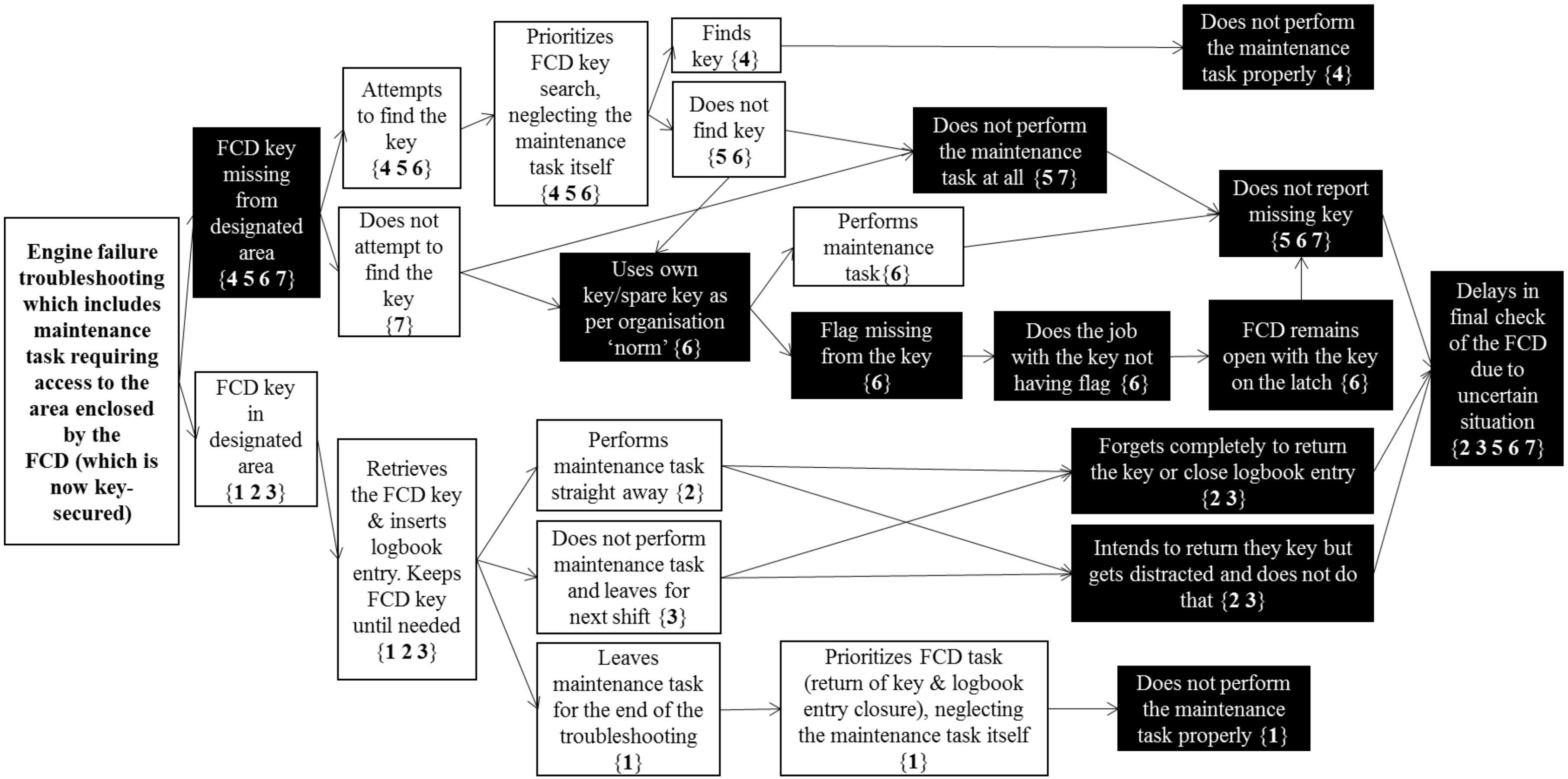

Figure 5 Graphical representation of the sequence of the events and causes described in each of the Scenarios examined (1 to 7). In { } the relevant Scenario number(s) is (are) indicated.

Since all scenarios are realistic they are considered more or less probable. Typically, these may be encountered by technicians working both in the line and base level aircraft maintenance environment. However, since these scenarios are neither exhaustive, nor have been tested/validated in actual aircraft maintenance practice further analysis is necessary. For that purpose, a substantial survey, which should include a wider array of scenarios, would be necessary to obtain the necessary data for a quantitative (statistical) analysis.

Conclusion

The A320 family FCD safety issue cannot be considered as a trivial issue, since it has been concerning the aviation industry over the past 18 years. It is anticipated that the Airbus modification - EASA ADs shall be able to contribute positively to the error management regarding FCD losses. However, it is important to consider the associated human attitude elements brought in with this modification, as illustrated by this qualitative scenario analysis. To this end, a list of human factors centred procedures and actions are recommended. These stem from the various scenarios, described and discussed in the previous section, and consist of all possible attitudes and responses of the technicians towards the new modifications. In summary, the recommended actions are: provision of better time management training, enhancement of communication skills, focused training, encouraging a collaborative attitude, implementation of a dual sign off procedure for the opening/closing of the FCDs, thorough verbal/written shift handover and facilitation of changes in the airline/maintenance organisation culture (where necessary). These measures are able to achieve efficiencies in procedures associated with troubleshooting in the area enclosed by the key-accessed FCD, reduce the likelihood of errors, and, most importantly, identify and suppress any safety-infringing ‘norms’ within operators and maintenance organisations.

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Appendix D: Accepted for publication Journal Paper 4

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Article

The Diagnosis of Communication and Trust in Aviation Maintenance (DiCTAM) model

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Abstract: In this research paper a new conceptual model is introduced, the Diagnosis of Communication and Trust in Aviation Maintenance (DiCTAM) model. The purpose of this model is to recognise, measure and predict the relationship between communication and trust in the aviation maintenance field. This model was formed by combining a conceptual cyclical process and two established survey tools adapted and incorporated in a single question set. The implementation of each phase of the DiCTAM model is performed with the use of qualitative and quantitative research methods. This includes the use of content analyses of accident/incident investigation reports and training material, a survey, and a hypothetical case study. The predictive functionality of the DiCTAM model has been investigated through the hypothetical case study. The obtained results indicate a positive relationship between communication and trust according to the aviation maintenance employees' perception and accidents/incidents reports, even though basic training includes communication without direct mention to trust.

Keywords: Aviation; Communication; Trust; Aviation maintenance; Prevention; Human factors.

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1. Introduction

Communication can be defined as the transmission of information from one person to another while trust is the openness to another party, based on the concept of its reliability and competence [1]. Trust is associated with and can contribute to successful communication [2,3]. Thus, a minimum level of trust should be present along with effective communication between two or more counterparts. Past research has shown that effective communication techniques are part of the employees' initial and recurrent training and are linked to their on-job safety-related practices [4]. Furthermore, organisational commitment and employees' level of organisational satisfaction is associated with employees' safety-related practices [5-9].

Both communication and trust are fundamental concepts that can influence safe practice in aviation maintenance, especially in the regions exhibiting fast growth [10]. It is well recognised that poor communication is a paramount human factor contributing to errors [11,12]. More specifically, researchers have identified the gap in effective communication between maintenance staff, cabin crew and flight crew, proposing some ways to mitigate this issue [13-16]. Some researchers have acknowledged the need for error-free communication within aviation [14,16], while others have identified poor communication to be an accident causal factor [17-19]. Tools have been developed to proactively detect maintenance failures, such as the Maintenance Operations Safety Survey (MOSS), in which communication and trust are major factors [20]. The relationship between trust and communication, including initial trust levels, among technical staff, have not been adequately investigated and further research could play an important role in aviation maintenance and the advancement of aviation safety [21].

The recognition and measurement of perceptions around communication and trust has been studied extensively in various industries. Various survey-based research tools has been used for that purpose, including the Communication Satisfaction Questionnaire (CSQ) and the Trust Constructs and Measures Questionnaire (TCMQ). These are briefly discussed in the following paragraphs.

The CSQ is a tool that was incepted in 1977 [22] and widely used since then in research projects dealing with communication satisfaction in various industries [22-34]. The CSQ has been an efficient tool to extract employees' perceptions of the communication within their organisation [33,35,36]. This is a 40-questions questionnaire, with items categorized in eight communicative themes (dimensions). These dimensions vary from interpersonal communication (e.g. an employee's evaluation of the communication with his/her supervisor), to the organization-wide communication climate [32]. This construct has been found to have a test-retest reliability of 0.94 [22]. It has been characterised as "arguably the best measure of communication satisfaction in the organizational arena" [27, p. 6] while Rubin et al. [34, p. 116] agree that "The thoroughness of the construction of this satisfaction measure is apparent. The strategies employed in this study are exemplary".

The TCMQ has been developed by Li, Rong, & Thatcher, [37] and it is in practice a synthesis of various questionnaires developed and used in past research studies [38-44]. The studies performed with the constituent questionnaires have yielded valid and reliable research data and findings, which informed their adoption and adaption from Li et al. [37]. Moreover, the measurement model (reliability scores, construct validity, convergent and discriminant validity) was found to produce statistically significant results [37]. The measurement model results verified that the measurement scales adapted by Li et al., [37] were valid and reliable in their study. Specifically, web capability and reliability were found to be powerfully belief constituent in assessing trust in website. This outcome confirmed that the Information Technology-specific scales, which were adopted by Li et al., [37] were valid in technology trust measurement [37].

This paper introduces a conceptual model, built upon the CSQ and TCMQ tools, which aims to explore and understand the relationship between trust and communication in aviation maintenance. In particular, the objectives of the proposed model are summarised as following:

1. Detect the existence of communication and trust in aviation maintenance practice;
2. Recognise if communication and trust are covered in the aviation maintenance basic training curriculum;
3. Detect and measure the perception of aviation maintenance employees on communication and trust within their working environment;
4. Predict deviations in maintenance practice that can be attributed to communication and trust preconditions.

2. Model Formulation

2.1. Model Foundation: Cyclical Process

The foundation of the proposed conceptual model is a four-phase cyclical process used for the diagnosis of communication and trust issues in various facets of aviation maintenance.

Each phase has been chosen to align with the objectives of the model, as outlined in the Introduction section of this paper. The cyclic process transforms the individual objectives of the model to a structured-interconnected process, following a systems approach. Each phase's tasks are provided below, with the cyclical process illustrated schematically in Fig. 1:

1. **Phase 1:** The two traits, communication and trust, are examined whether they exist or not in aviation maintenance;
2. **Phase 2:** Aviation maintenance training material is examined to recognise if the aviation maintenance employees are trained for communication and trust, and consequently if they have developed awareness and relevant good practices in their work;
3. **Phase 3:** The aviation maintenance sector is investigated for the detection and measurement of the relation between the communication and trust;
4. **Phase 4:** Having completed phase 1, 2 and 3, with all information and data available, one can predict any communication and trust precondition (positive associations), as a possible cause of error in any already established or new maintenance procedure/process/task in the workplace.

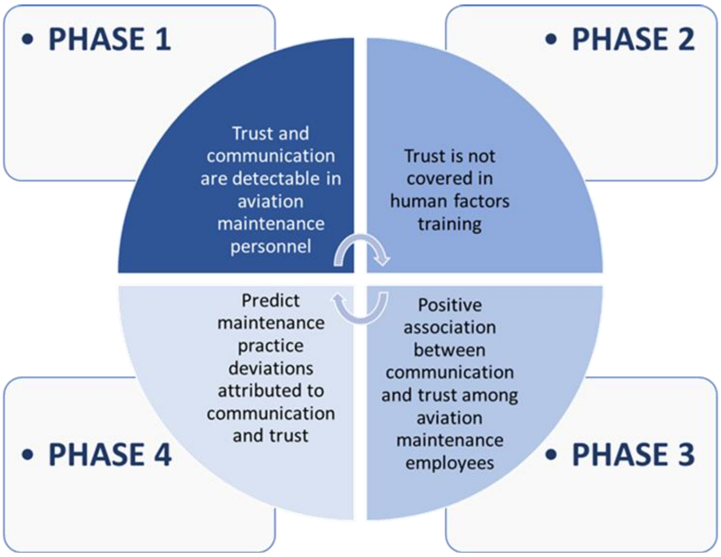

Figure 1. The foundation cyclic process of the proposed conceptual model used.

2.2. Model Tool: Communication and Trust Question Set

In order to accompish the tasks involved in each of the four phases, and by extention the objectives of the model, it is necessary to introduce a new tool. For this reason, a dual-use question set is introduced, consisting primarily of the :

- Communication Satisfaction Questionnaire (CSQ) [22];
- Trust Constructs and Measures Questionnaire (TCMQ) [37].

Both the original CSQ and TCMQ [27, 38] have been adapted to research communication and trust in an aviation maintenance context. Details on the adaptation of the CSQ and TCMQ are provided in a separate paper currently under review [69]. These two questionnaires are complemented with demographics and general questions' sections. The complete set is denoted as the Communication and Trust Question Set (CTQS) (Appendix A) and it is comprised of the following sections:

- Section A: ‘Demographic information of the participants ‘;
- Section B: ‘General Questions’;
- Sections C, D and E: ‘Communication Satisfaction Questionnaire’ (section E is limited to managers);
- Sections F and G: ‘Trust Constructs and Measures Questionnaire’ (section G is limited to managers).

The CTQS is common across all phases of the conceptual process (Fig. 1) and it is used both as a qualitative tool (having a recognition function) and a quantitative tool (having a diagnosis function). In both cases, the CTQS questions serve either as survey questions for human participants or desk research on primary/secondary data (i.e. when employing content analysis/case study methodologies). For example, as a quantitative tool, the CTQS diagnosis function can be used to explore the perceptions of aviation maintenance professionals about their work (phase 3 shown in Figure 1). As a qualitative tool, its recognition function can be used to conduct content analysis of accident and incident investigation reports, audit reports, etc (phase 1 and 2 shown in Fig. 1). Depending on the nature and amount of the body of material available, a quantitative analysis of these data through this function is possible. The same approach can be followed for actual or hypothetical scenarios for prediction purposes (phase 4 shown in Figure 1).

The overall construct and functionalities of the CTQS are illustrated in Figure 2.

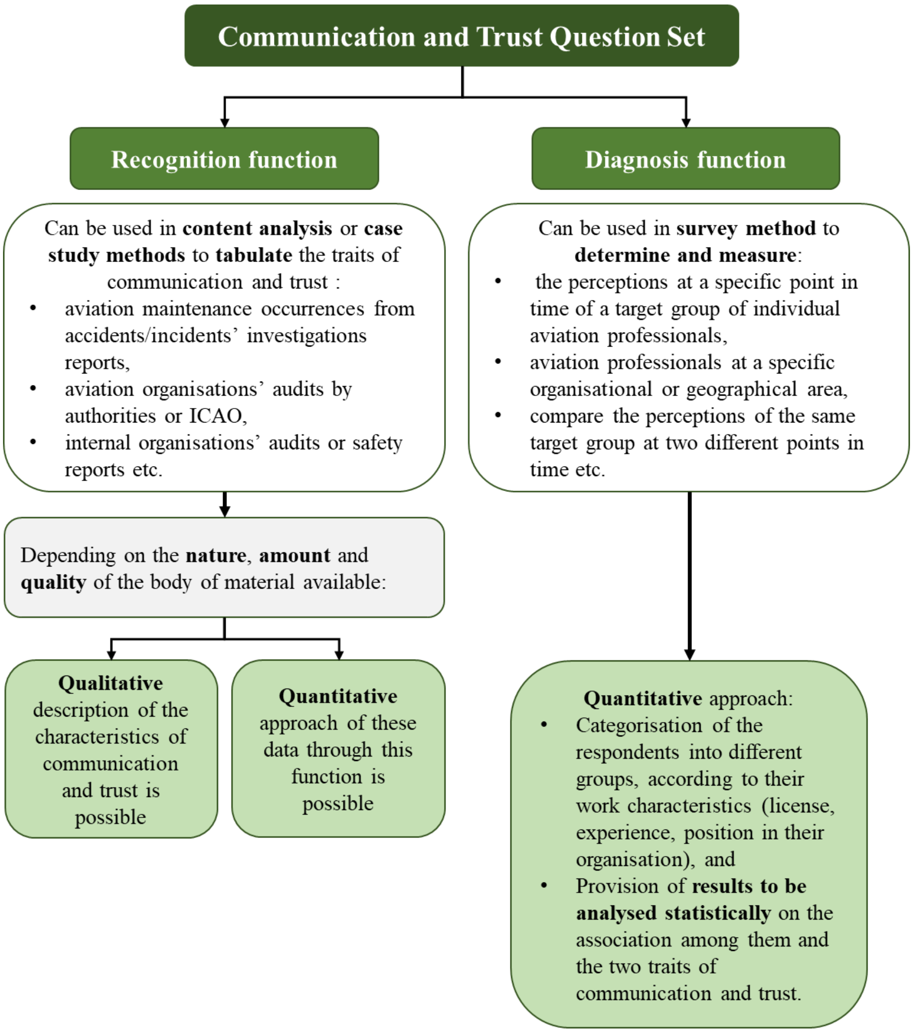

Figure 2. Multifunctional uses of the CTQS.

2.3. Complete Model: Diagnosis of Communication and Trust in Aviation Maintenance (DiCTAM)

The merging of the foundation cyclical process with the CTQS (described in sections 2.1 and 2.2 correspondingly) constitutes the complete model, denoted as the Diagnosis of Communication and Trust in Aviation Maintenance (DiCTAM) model. This is represented schematically in Fig. 3, where the different functionalities for each phase are also shown. The implementation of the model and the results obtained is presented in the next section of this paper.

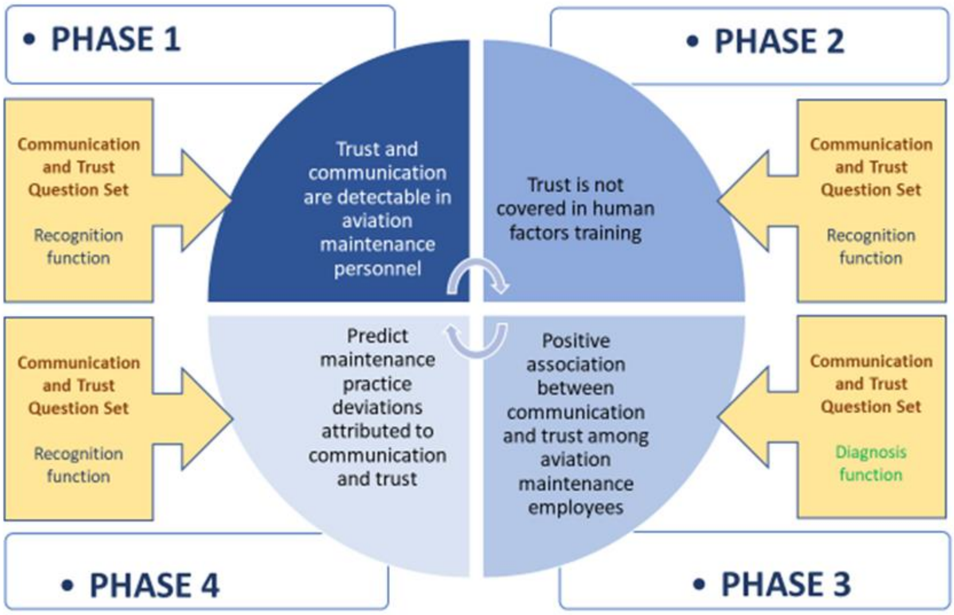

Figure 3. The complete Diagnosis of Communication and Trust in Aviation Maintenance (DiCTAM) model.

3. Results and Discussion

The implementation of the DiCTAM model is performed via a selection of different types of data and cases, in order to present its features, operation and the results that can be obtained when used for communication and trust analyses within an aviation maintenance context. Each section corresponds to the phases of the model, discussing in detail in the findings.

3.1. Phase 1

The content analysis technique was used in phase 1 of DiCTAM, chosen for its capability for a thorough investigation of the existence of both communication and trust in real occurrences within aviation maintenance. A selection of accident and incident investigation reports was performed by applying criteria in relation to the language, origin and recency of the report. When applying these criteria, accident and incident investigation authorities/bodies from Indonesia, Ireland, Australia, Netherlands, UK, USA, India Japan, Portugal and Hong Kong were shortlisted. Initial filtering of the databases of these authorities/bodies was performed with the term 'maintenance', producing an extensive list of (100+) accidents/incidents. Thus, further shortlisting was necessary, in this case performed by searching in the internet for incidents/accidents considered as 'high profile' (based on their order of appearance in the google search engine results) and for reports containing substantial information (in terms of volume and detail) on the maintenance related causal factors. This shortlisting exercise identified the fifteen representative (for the purposes of this study) accidents/incidents selected for the content analysis. It is noted that further investigation (involving a higher volume of reports) would not add more to the scope of this analysis, as the reports selected were able to reveal the existence of these two traits (communication and trust), reaching their saturation point [45].

Each report was manually scanned for the keywords: 'communication' and 'trust' by the author as a Subject Matter Expert (SME) (approved EASA Part 147 maintenance training instructor in Human Factors). In the case that a keyword was found in the report this was mentioned accordingly. From the previous keywords, the only found was 'communication' ('trust' was not found in any report). In this case, the items of the CTQS were used to identify any underlying communication or trust factor. The CSQ items were used to identify underlying communication issues while the TCMQ items to locate trust issues. The preconditions for errors identified were mapped against the questionnaire items, with a detailed justification provided.

The summarised results from the analysis of all (fifteen) accident and incident investigation reports are presented in Appendix B. This table offers a quick view of the items of the CTQS identified in these reports. Considering all data obtained from the content analysis (as summarised in Appendix B), it is indicated that both trust and communication are detectable in the aviation maintenance sector. In particular, trust and communication, as they are reported in the accident and incident investigation reports, are identified as distinct preconditions in the vast majority (78%) of the distinct maintenance errors. In six of the examined distinct maintenance errors (accounting to 14% of the total 42) trust only can be identified as a precondition to maintenance error, while communication is identified in just four distinct maintenance errors (corresponding to 8% of the errors analysed) (Table 1).

Table 1. Absolute number and percentage (%) of maintenance errors where trust, communication and combination of both identified as preconditions within the accident and incident investigation reports analysed.

Total Number of Distinct Maintenance Errors Analysed	**Number of Distinct Maintenance Errors that were identified with Precondition(s) of:**		
	Trust only	**Communication only**	**Trust and Communication**
42	**6**	**4**	**31**
	14%	8%	78%

Only 22% (out of the total forty-two errors analysed) included solely one (communication or trust) as an error precondition and not both. It is, however, noted that these numerical results are not conclusive, as the investigation reports reflect the accident/incident investigators' exposition of evidence. This means that the investigators were not necessarily looking for 'communication' or 'trust' evidence; therefore, both factors may have not been exhaustively investigated (and subsequently reported).

More specifically about trust, the two types that were investigated in this research were about interpersonal trust and trust towards the company's software used for aviation maintenance purposes. The TCMQ, which includes all trust items, is devided in smaller groups of items, constructs. Each group indicates specific attributes of trust. Therefore, the specific characteristics identified here were trust towards colleagues' competence, integrity and benevolence and trust towards the company software's capability. Regarding the communication satisfaction, there is a similar grouping of items, depending on the theme of each item. Therefore, the groups of items, in relation to satisfaction, are: with the organisation's communication climate, with their superiors, with the organisation's integration, with the media quality, with the general organisational perspective and with the horizontal informal communication. These are the wider groups of the CSQ items, that were initially introduced by Downs and Hazen [22] and can describe categorically the specific issues with communication satisfaction identified in the analysed reports. Nonetheless, the aim of the content analysis here is to identify qualitatively the co-existence of these two factors as maintenance error preconditions.

3.2. Phase 2

For the implementation of phase 2 of the DiCTAM, the data were obtained directly from official/approved aviation maintenance training sources. It is noted that the Federal Aviation Administration (FAA) does not include a distinct module of human factors training in its curriculum (as presented in Appendix B to Part 147—General Curriculum Subjects). Therefore it is the European Union Aviation Safety Agency (EASA), Directorate General of Civil Aviation, Government of India (DGCA) and the Civil Aviation Safety Authority of Australia (CASA) from which approved training material can be obtained for review. All three regulatory authorities practically share the same curriculum for their maintenance human factors training; thus, the analysis is performed on the EASA Part-66 Category A and B Module 9 'Human Factors' curriculum (Table 2).

Aircraft maintenance training under the EASA framework is highly regulated with provisions of consistency and high quality in the delivered course material by all approved maintenance training organisations (commonly referred as EASA Part-147 organisations, reflecting the applicable regulatory set). Two coursebooks were selected for the content analysis, as very few published and publicly available EASA Part-66 Module 9 'Human Factors' course material exists. These coursebooks were:

- **Coursebook 1:** 'Module 9-Human Factors' (by C. Strike), published in 2018 by Cardiff and Vale College in the UK [61];
- **Coursebook 2:** 'Human factors for A level Certification, module 9' by N. Gold, published in 2015 by Aircraft Technical Book Company in the USA [62].

Table 2. Curriculum of the EASA [62] Part-66 Category A and B Module 9 'Human Factors'.

Chapter	Title	Content
9.1	**General**	The need to take human factors into account; Incidents attributable to human factors/human error; 'Murphy's' law.
9.2	**Human Performance and Limitations**	Vision; Hearing; Information processing; Attention and perception; Memory; Claustrophobia and physical access.
9.3	**Social Psychology**	Responsibility: individual and group; Motivation and de-motivation; Peer pressure; 'Culture' issues; Team working; Management, supervision and leadership.
9.4	**Factors Affecting Performance**	Fitness/health; Stress: domestic and work related; Time pressure and deadlines; Workload: overload and underload; Sleep and fatigue, shift work; Alcohol, medication, drug abuse.
9.5	**Physical Environment**	Noise and fumes; Illumination; Climate and temperature; Motion and vibration; Working environment.
9.6	**Tasks**	Physical work; Repetitive tasks; Visual inspection; Complex systems.
9.7	**Communication**	Within and between teams; Work logging and recording; Keeping up to date, currency; Dissemination of information.
9.8	**Human Error**	Error models and theories; Types of error in maintenance tasks; Implications of errors (i.e. accidents); Avoiding and managing errors.
9.9	**Hazards in the Workplace**	Recognising and avoiding hazards; Dealing with emergencies.

The first examination of these coursebooks determined that both followed the EASA curriculum, as expected. Furthermore, the content of both books was found to cover the curriculum in a similar way, having a comparable structure and content. Therefore, these two coursebooks were the adequate required body of material for using the content analysis technique in phase 2 of DiCTAM.

The EASA curriculum and the two coursebooks were examined manually by the author as a SME, to locate the words 'communication' and 'trust'. The EASA Part-66 Module 9 'Human Factors' curriculum covers only the chapters and subchapters of the material approved to be taught. In the curriculum, the word 'trust' is not used while the word 'communication' is solely used in chapter seven (Communication) one time in the title of the chapter. The next step was to scan the two EASA Part-66 Module 9 coursebooks for the same words. The results were as follows:

- In Coursebook 1 [61], the word count in Chapter Seven-Communication, for the word 'communication' is 52, while for the word 'trust' is 0. It is noted that in the whole Chapter Seven-Communication, there is no reference to trust, even though communication is analysed and different communication techniques are presented there.
- In Coursebook 2 [62], the word count in Sub-module 07, Communication, for the word 'communication' is 63 while for the word 'trust' is 1. Trust towards a message sender is referred one time, in the communication chapter, as a precondition in the effective receipt of a message.

The summary of findings in the curriculum and the coursebooks are shown in Table 3.

Table 3. Word count of 'communication' and 'trust' in the EASA Part-66 Module 9 curriculum and the two coursebooks.

EASA Part 66 Module 9 'Human Factors' Curriculum and Training Material Examined	Word count	
	Communication	Trust
Curriculum	1	0
Coursebook 1	52	0
Coursebook 2	63	1

The second stage of this examination continued into the in-depth analysis to identify any concealed elements of communication and trust into the twelve elements of the Dirty Dozen tool. A better understanding of human factors has become imperative within aviation, and several models and systems have been introduced and implemented in the continuous attempt to predict and reduce human error. In aviation maintenance, there are twelve factors identified as the principal preconditions or conditions, that contribute to human error, widely known as the Dupont's *Dirty Dozen* [17,18,64-67]. These elements are dissimilar in nature and appear either on personal, group or organizational performance levels [68]. Communication is among these 12 most frequent causes of human error. These twelve factors are:

13. **Lack of communication;**
14. **Complacency;**
15. **Lack of knowledge;**
16. **Distractions;**
17. **Lack of teamwork;**
18. **Fatigue;**

19. **Lack of resources;**
20. **Pressure;**
21. **Lack of assertiveness;**
22. **Stress;**
23. **Lack of awareness;**
24. **Norms.**

The *Dirty Dozen* is one of the most used human factors typologies in aviation maintenance, as it is still used in training and accident and human error analysis in aviation worldwide [18,64-66,69]. These 12 factors are of different nature and quantifiability; nevertheless, each one of them represents a causal failure in the user's judgement, and as such, they are treated either individually or in homogeneous groups [66]. In particular, the results of this analysis were obtained by the mapping of the twelve elements of the Dirty Dozen with the use of the CTQS. All Dirty Dozen elements refer to the total population of the aviation maintenance professionals; therefore, all levels of management are included (sections E and G of the CTQS which are only for supervisors/managers). Ten factors appear to have either the communication or trust elements concealed into their meaning. Two of them, the lack of communication and lack of teamwork, appear to have both communication and trust concealed. For illustrative purposes, the overall mapping of the CTQS items against the Dirty Dozen elements are provided in appendix C.

The third stage included the manual tabulation of the elements of the Dirty Dozen against the EASA Part-66 Module 9 'Human Factors' course material. This tabulation (using the mapping of the CTQS items against the Dirty Dozen elements) revealed the concealed elements of communication and trust in Coursebook 1 and 2. The summary of the findings is presented in Table 4. From this analysis, it stems that both coursebooks include all factors of the Dirty Dozen and consequently include indirectly and concealed both communication and trust elements in their content.

Table 4. Dirty Dozen elements found in the examined EASA Part-66 Module 9 'Human Factors' coursebooks in relation to communication and trust elements.

Coursebook	**Dirty Dozen Element included in the Coursebook**	**Preconditions identified based on the Dirty Dozen mapping**	
		Communication	**Trust**
Coursebook 1 (Strike, 2018)	1. Lack of Communication	X	X
	2. Complacency	X	
	3. Lack of knowledge		X
	4. Distraction		X
	5. Lack of teamwork	X	X
	6. Fatigue	X	
	7. Lack of resources	X	
	8. Pressure	X	
	9. Lack of assertiveness	X	
	10. Stress	X	
	11. Lack of awareness	X	
	12. Norms		X
	1. Lack of Communication	X	X

Coursebook 2 (Gold, 2015)	2. Complacency	X	
	3. Lack of knowledge		X
	4. Distraction		X
	5. Lack of teamwork	X	X
	6. Fatigue	X	
	7. Lack of resources	X	
	8. Pressure	X	
	9. Lack of assertiveness	X	
	10. Stress	X	
	11. Lack of awareness	X	
	12. Norms		X

Considering all data from the content analysis (presented in Table 3) it stems that trust is not considered to be covered sufficiently in the aviation maintenance human factors basic training. In particular, the EASA curriculum has no mention of trust, neither as a separate chapter nor in any other chapters (and most importantly in the communication chapter). In the two examined coursebooks' chapters covering communication, there was only one mention to trust. Therefore, there is neither direct mention nor further explanation/discussion on trust. However, with the assistance of the mapping of the Dirty Dozen factors with the items of CTQS, concealed communication and trust elements were identified into the material of the two coursebooks. The direct absence of the trust factor in the training material may be partially covered by these concealed elements, although this has limited pedagogic value and effectiveness.

3.3. Phase 3

In phase 3 of the DiCTAM model the association among three factors was explored: communication satisfaction, interpersonal trust and trust towards maintenance software used by aviation maintenance companies. To serve this purpose, the CTQS was distributed to diverse set of aviation maintenance professionals working in civil and military organisations. The participants were sent an invitation to participate online (on the web-based tool Limesurvey) through emails. Over the two phases for the recruitment of participants, 501 aviation maintenance professionals were contacted and 259 answered fully to the questionnaire. A quantitative analysis was performed on the data collected, to identify possible interrelations between the three factors examined. For this analysis, a correlational research design was used to prevent any suggestion in any causal relationship among them. For the purposed of this research design, the specific statistical methods used were: Cronbach's alpha, descriptive statistics, correlations between variables, t-tests and analyses of variance (ANOVA), Harman's one factor with the help of SPSS Statistics 25.0.0. Further details are provided in a separate paper currently under review [70]

The survey results indicated, for managers and subordinates as well as for all employees, that a substantial proportion of their communication satisfaction was explained by their levels of interpersonal trust, giving statistically significant results. Differences in the communication satisfaction and software trust between military and civil aviation maintenance company employees were also observed. The results of civil aviation employees exhibit higher mean scores than that of military for all three factors. Overall, communication satisfaction was found to have a stronger association with interpersonal trust than with software trust. The mean scores of communication satisfaction and interpersonal trust increased across various levels of experience, with the differences between less and more experienced employees being statistically significant. An interesting finding of this research is that aviation maintenance professionals have relatively high levels of trust and communication satisfaction at the start of their current employment. This finding is also consistent with the initial trust levels theory, examined in the past for other industries. The descriptive statistics indicated that the participants of this survey came from many different geographical areas in small numbers. This can limit the results of this survey to be generalised to the global aviation maintenance professionals' population [70].

3.4. Phase 4

Following the confirmation of the positive association among those three aspects of the two traits (communication satisfaction, interpersonal trust and software trust), in phase 4 of the DiCTAM model prediction is attempted. Prediction can form different hypothetical occurrences (possible events and scenarios) by using the survey's results as a guide and can, therefore, contribute to the process of the examination of the two traits. More specifically, phase 4 includes hypothetical scenarios about possible aviation maintenance deviations that can take place in real life with the use of the case study method. For this purpose, the case study presented next is selected to present the operation of the DiCTAM model, as well as exemplifying its use. A well-known case has been selected, that of the engine fan cowl door losses experienced in the Airbus A320 family fleet in worldwide level [71]. The method of the case study is considered to be suitable method to examine hypothetical scenarios. A suitable application for the prediction exercise is deemed the use of the Fan Cowl Doors (FCDs) maintenance occurrences (after the implementation of the new procedures, provisioned by the latest EASA Airworthiness Directives (ADs)) [71]. The case study methodology assists in the holistic examination of these hypothetical occurrences to unveil concealed elements and identify or even predict future trends or patterns [72].

At this stage the aim is to examine these hypothetical scenarios for the identification of communication and trust elements and then, based on these findings, to predict the possibility of occurrence of each scenario. Seven scenarios, as they were introduced and discussed by Kourousis et al. [71], are examined below for the identification of trust and communication elements. Each scenario is scrutinised against the items of the CTQS by the author as SME, for the identification of question set's items within the scenario. The seven scenarios are divided in two broader groups, those which are occurring from two different situations:

- The technician retrieves the FCD key from the designated storage area in the cockpit and inserts a logbook entry for the opening/closing of the FCD (Scenarios 1, 2 and 3), presented in subsection 3.4.1;
- The technician does not find the FCD key in the designated storage area in the cockpit (Scenarios 4, 5, 6 and 7), presented subsection 3.4.2.

3.4.1 FCD Key in Designated Area

Scenario 1 ***'The technician leaves the maintenance task (in the area enclosed by the FCD) for the end of the failure troubleshooting. He/she performs the maintenance task at the end of his/her shift. However, he/she does not dedicate adequate time for the maintenance task, as he/she inadvertently prioritised the FCD task [return of the key, closure of the logbook entry ('FCD closed')], in an effort to avoid the FCD is not left open. This poor practice may result in reduced maintenance quality, under stressful or very time constrained situations, since FCD-related tasks are added to the existing workload.'***	
Trust factor identified	Maintenance personnel failed to dedicate the time required for this task, risking the quality of this work. This indicates that the maintenance personnel deviated from an expected good practice in their duties. Specifically, by using the CTQS, the following three items are identified in this failure: F2 'My colleagues perform their duties very well', F3 'Overall, my colleagues are capable and proficient technical staff' and F5 'My colleagues act in the best interest of the project'.

	Items F2 and F3 correspond to the 'construct of trust in colleagues' competence' category while item F5 in the 'construct of trust in colleagues' benevolence' category.
Possible Prevention Measures	Putting more focus on time management techniques and requesting assistance from peer-workers/team leader in stressful/time-pressing situations.

Scenario 2 ***'The technician performs the maintenance task straight away but leaves the key return and logbook entry closure for later. Since these steps were left for a later time, the technician either forgets completely to return the key/close the logbook entry or gets distracted near that time, having the same result. As a consequence, the aircraft release to service can be delayed, since the involved personnel (flight crew, technical staff) will have to locate the missing key and complete the FCD sign-off in the logbook.'***	
Communication factor identified	Not performing a proper handover, makes the ideal preconditions for errors. This deviation from accurate reporting can result in lack of effective communication between colleagues and can prevent from the proper actions taken to mitigate the errors. Therefore, the communication problems identified here are in relation to items: D19 'The amount of communication was not about right', D2 'The organisation's communication motivates and stimulates an enthusiasm for meeting its goals', C3 'Information about organisational policies and goals', D8 'Personnel receive in time the information needed to do their job', D6 'The organisation's communications are interesting and helpful, item', D17 'Issues whether the attitudes towards communication in the organisation are healthy', C7 'Information about departmental policies and goals, item C7', D15 'Meetings are well organised', D12 'Communication with colleagues within the organisation is accurate and free flowing', D3' Supervisor listens and pays attention to personnel' and D6 'The organisation's communications are interesting and helpful, item D6'.
Possible Prevention Measures	A dual sign off practice would offer the opportunity for a confirmation check and reduce the possibility of misses and errors.

Scenario 3	
'The technician does not perform the maintenance task and has to pass it over to the next shift. Since these steps were left for the next shift, he/she either forgets to return the key/close the logbook entry or gets distracted to do that. In case that the shift handover is not performed properly, the FCD tasks are not completed. As a consequence, similarly to Scenario 2, the aircraft release to service can be delayed, since the missing key has to be located and the logbook signed off.'	
Communication factor identified	As with Scenario 2, not performing a proper handover, makes the ideal precondition for errors. This deviation from accurate reporting can result in lack of effective communication between colleagues and can prevent from the proper actions taken to mitigate the errors. Therefore, the communication problems identified here are in relation to items: D19, D2, C3, D8, D6, D17, C7, D15, D12, D3 and D6.
Possible Prevention Measures	As with Scenario 2, the dual sign off practice can mitigate this issue. Moreover, a thorough (verbal and written) shift handover would be helpful in avoiding communication gaps in relation to the FCD tasks (reducing the possibility for misses and errors).

3.4.2 FCD Missing from Designated Area

Scenario 4	
'The technician attempts to find the FCD key. He/she prioritises this task over the maintenance task itself. In the case that he/she finds the key, the amount of time spent on the search does not allow him/her to focus on the maintenance task, thus this is not performed adequately.'	
Trust factor identified	Similarly to Scenario 1, maintenance personnel, failed to dedicate the time required for this task, risking the quality of this work. This indicates that the maintenance personnel deviated from an expected good practice in their duties. Specifically, following three items are identified in this failure: F2, F3 and F5.
Possible Prevention Measures	Similarly, to Scenario 1, it would be beneficial if better time management techniques were practiced, as well as if the technician requested assistance.

Scenario 5	
'The technician attempts to find the FCD key, prioritising the search over the maintenance task (same as in Scenario 4). He/she does not manage to find the key, leaving the maintenance task unaccomplished. In the case that the technician is forgetful or distracted, he/she will not report the missing key, causing more delay, as other personnel in later time will repeat the search process.'	
Communication factor identified	As with Scenario 2 and 3, not performing a proper handover, makes the ideal precondition for errors. This deviation from accurate reporting can result in lack of effective communication between colleagues and can prevent from the proper actions taken to mitigate the errors. Therefore, the communication problems identified here are in relation to items: D19, D2, C3, D8, D6, D17, C7, D15, D12, D3 and D6.
Possible Prevention Measures	Similarly to other scenarios, the dual sign off in conjunction with a robust handover process could mitigate this miss.

Scenario 6 ***'The technician attempts to find the FCD key, prioritising the search over the maintenance task (same as in Scenario 4 and 5). He/she does not manage to find the key, therefore deciding to use his/her own key or the spare key as per the organisation's 'norm and fills in the logbook entry ('open FCD'). After completing the maintenance task, the technician is forgetful/omits or gets distracted and does not report the missing key. As with Scenario 5, this may cause a delay in the future. Moreover, using his/her own key means that this may not have the 'remove before flight' flag attached, increasing the probability of leaving the cowl door open (since this modified visual cue will be missing).'***	
Trust factor identified	Maintenance personnel deliberately chooses to use own key, opposite to the company's policies, which might not include the dedicated visual cue. This indicates that the maintenance personnel deviated from an expected good practice in their duties. Specifically, by using the CTQS, the following four items are identified in this failure: F2 'My colleagues perform their duties very well', F3 'Overall, my colleagues are capable and proficient technical staff', F4 'In general, my colleagues are knowledgeable about our organisation' and F5 'My colleagues act in the best interest of the project'. Items F2, F3 and F4 fall in the construct of trust in colleagues' competence while item F5 falls in the construct of trust in colleagues' benevolence.
Communication factor identified	As with Scenario 2, 3 and 5, not performing a proper handover, makes the ideal precondition for errors. This deviation from accurate reporting can result in lack of effective communication between colleagues and can prevent from the proper actions taken to mitigate the errors. Therefore, the communication problems identified here are in relation to items: D19, D2, C3, D8, D6, D17, C7, D15, D12, D3 and D6.
Possible Prevention Measures	Similarly to previous scenarios, the dual sign off in conjunction with a robust handover process could mitigate this miss. In addition, a change in the organisational culture would be necessary to abolish unsafe practices in relation to established 'norms' outside the standard policies and procedures.

Scenario 7 ***'The technician does not have the required time or attitude to attempt to find the missing key, thus he/she decides not to perform the assigned maintenance task and, for example, to move onto a different task. He/she forgets about the missing FCD key or gets distracted and does not report that. This shall cause delay in the work of the personnel who are then assigned to the maintenance task in the FCD-accessed area (as they will have to search for the missing key).'***	
Communication factor identified	As with Scenario 2, 3, 5 and 6, not performing a proper handover, makes the ideal precondition for errors. This deviation from accurate reporting can result in lack of effective communication between colleagues and can prevent from the proper actions taken to mitigate the errors. Therefore, the communication problems identified here are in relation to items: D19, D2, C3, D8, D6, D17, C7, D15, D12, D3 and D6.
Possible Prevention Measures	Dual sign off and in-shift/inter-shift handover would be an effective solution to avoid such situations.

3.4.3 Analysis of Scenarios

The seven scenarios presented (Scenario 1 to 7) refer to seven different causal situations in which safety issues, related to the fan cowl doors of modified aircraft of the Airbus 320 family, may arise. These scenarios were investigated against the items of the CTQS. As shown in Table 5, many different trust and/or communication issues corresponded to each one of the scenarios, therefore all scenarios showed communication and trust preconditions. Trust was found present in five scenarios while communication was found present in three. One scenario had communication and trust preconditions present at the same time, while the rest six had solely one precondition present (either trust or communication).

Table 5. Communication and trust items, of the CTQS, identified in Scenarios 1 to 7.

Scenario	Trust Factor Items	Communication Factor Items
Scenario 1	F2, F3, F5	
Scenario 2		D19, D2, C3, D8, D6, D17, C7, D15, D12, D3, D6
Scenario 3		D19, D2, C3, D8, D6, D17, C7, D15, D12, D3, D6
Scenario 4	F2, F3, F5	
Scenario 5		D19, D2, C3, D8, D6, D17, C7, D15, D12, D3, D6
Scenario 6	F2, F3, F4, F5	D19, D2, C3, D8, D6, D17, C7, D15, D12, D3, D6
Scenario 7		D19, D2, C3, D8, D6, D17, C7, D15, D12, D3, D6

More specifically, the issues identified in relation to trust were about interpersonal trust. The CTQS items are grouped in different constructs, each one indicating specific attributes of trust. Therefore, the specific characteristics identified here were trust towards colleagues' competence and benevolence. In relation to the communication satisfaction, issues were identified in relation to the satisfaction with the organisation's communication climate, with the superiors, with the organisation's integration, with the media quality, the general organisational perspective and with the horizontal informal communication. These are the wider groups of the CSQ items, that were initially introduced by Downs and Hazen [22] and can describe categorically the specific issues with communication satisfaction identified in these scenarios.

The communication and trust items identified (listed in Table 5) are not factors that have to exist in combination to contribute to the hypothetical scenario. At least one of these factors (namely, one of the possible items) could suffice in the occurrence of the relevant scenario. The mean value of each item corresponds to the level of communication satisfaction and trust exhibited by the surveyed population. Namely, a high mean score is a positive indicator of high levels of communication satisfaction or trust. For this reason, an item's lower mean score of each scenario was selected as the criterion for the hierarchical categorisation of the scenarios relative to the possibility of occurrence. For example, a scenario with an item having a higher mean is less probable than that of a scenario with an item of a lower mean. Lower mean scores reveal lower communication satisfaction and trust, which subsequently include issues with communication and trust (yielding higher probability of occurrence).

The identification of more probable and less probable scenarios involves the comparison of the means for all scenarios, listed in Table 6. The lower mean score is accounted as to have the higher occurrence probability of the scenario tabulated to this mean score. The least mean score in each scenario, that determined the ranking of the relevant scenario, is shown in Table 6 in bold font and highlighted in grey shade. This process identified two items; whose mean scores categorised the seven scenarios. Therefore, the two mean scores categorised the seven scenarios into two groups: Group A, corresponding to more possible to occur, and Group B, to less possible to occur scenarios.

Table 6. Means of the trust and communication factors as identified in Scenarios 1 to 7.

		Scenario						
		1	**2**	**3**	**4**	**5**	**6**	**7**
Trust Factor identified	**F2**	5.66	-	-	5.66	-	5.66	-
	F3	5.89	-	-	5.89	-	5.89	-
	F4	-	-	-	-	-	5.56	-
	F5	**5.54**	-	-	**5.54**	-	**5.54**	-
Communication Factor identified	**D19**	-	4.45	4.45	-	4.45	4.45	4.45
	D2	-	**4.15**	**4.15**	-	**4.15**	**4.15**	**4.15**
	C3	-	4.73	4.73	-	4.73	4.73	4.73
	D8	-	4.83	4.83	-	4.83	4.83	4.83
	D6	-	4.51	4.51	-	4.51	4.51	4.51
	D17	-	4.65	4.65	-	4.65	4.65	4.65
	C7	-	4.71	4.71	-	4.71	4.71	4.71
	D15	-	4.55	4.55	-	4.55	4.55	4.55
	D12	-	5.27	5.27	-	5.27	5.27	5.27
	D3	-	5.09	5.09	-	5.09	5.09	5.09
	D6	-	4.51	4.51	-	4.51	4.51	4.51

Table 7. Ranking of Scenarios 1 to 7 based on the possibility of occurrence.

Possibility of Occurrence	*Scenario*	*M*	*Trust / Communication Item*
A. More Possible	**Scenario 2**	4.15	D2
	Scenario 3	4.15	D2
	Scenario 5	4.15	D2
	Scenario 6	4.15	D2
	Scenario 7	4.15	D2
B. Less Possible	**Scenario 1**	5.54	F5
	Scenario 4	5.54	F5

The output of this exercise summarised the results presented in Table 7, with a two-tier ranking obtained (Group A and B). Based on this ranking, Scenarios 2, 3, 5, 6 and 7 are more possible to occur that Scenarios 1 and 4.

4. Conclusions

The novelty of this model lies in the development and utilisation of a dedicated (CTQS) survey/question tool for aviation maintenance, which addresses methodically, for the first time, the association between communication and trust in aviation maintenance. The model can predict hypothetical deviations during maintenance practice attributed to communication and trust preconditions. These preconditions are identified (and can be quantified) based on the target group's perceptions on communication and trust. This model is expected to contribute to the advancement of research in this area, having, in turn, a positive contribution to the promotion of aviation maintenance safety.
In summary, the DiCTAM model is capable to:

1. Detect the traits of communication and trust;
2. Identify, investigating and associating the perceptions of the people involved;

3. Examine in depth the extent of the aviation maintenance employees' exposure to them, through their training;
4. Predict their actions regarding communication and trust preconditions in aviation maintenance.

This process can be expanded to include more preconditions and offer a structured approach applicable to other similar research projects. Thus, the construct of the DiCTAM model would be transferable to other human factors preconditions, which, similarly to communication and trust, are present in aviation maintenance and affect safety.

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APPENDIX A

The items of the distributed questionnaire in this research study

Section A: Demographic information of the participants (Based on Downs & Hazen 1977)

A1. My current post and duties require me to exercise my aircraft maintenance license privileges.

A2. My company is approved by .... to perform and certify maintenance.

A3. My experience with my current company is

A4. I have a total of .... years of experience in aviation maintenance.

Section B: General Questions (Based on Downs & Hazen 1977)

B1. How satisfied are you with your job?

B2. In the past 6 months, what has happened to your level of satisfaction?

Section C: Communication - My job (Based on Downs & Hazen 1977)

C1. Information about my progress in my job.

C2. Personnel news.

C3. Information about organisational policies and goals.

C4. Information about how my job compares with others.

C5. Information about how I am being judged.

C6. Recognition of my efforts.

C7. Information about departmental policies and goals.

C8. Information about the requirements of my job.

C9. Information about government action affecting my organisation.

C10. Information about changes in our organisation.

C11. Reports on how problems in my job are being handled.

C12. Information about benefits and pay.

C13. Information about our organisation's financial standing.

C14. Information about accomplishments and/or failures of the organisation.

Section D: Communication - My job and the people I work with (Based on Downs & Hazen 1977)

D1. My superiors know and understand the problems faced by subordinates.

D2. The organisation's communication motivates and stimulates an enthusiasm for meeting its goals.

D3. My supervisor listens and pays attention to me.

D4. My supervisor offers guidance for solving job related problems.

D5. The organisation's communication makes me identify with it or feel a vital part of it.

D6. The organisation's communications are interesting and helpful.

D7. My supervisor trusts me.

D8. I receive in time the information needed to do my job.

D9. Conflicts are handled appropriately through proper communication channels.

D10. The grapevine (person to person informal communication / gossip) is active in our organisation.

D11. My supervisor is open to new ideas.

D12. Communication with my colleagues within the organisation is accurate and free flowing.

D13. Communication practices are adaptable to emergencies.

D14. My work group is compatible.

D15. Our meetings are well organised.

D16. The amount of supervision given me is about right.

D17. The attitudes towards communication in the organisation are basically healthy.

D18. Informal communication is active and accurate.

D19. The amount of communication in the organisation is about right.

D20. Are you a supervisor / manager?

Section E: Communication - Only for managers / supervisors (Based on Downs & Hazen 1977)

E1. My subordinates are responsive to downward directive communication.

E2. My subordinates anticipate my needs for information.

E3. I do not have a communication overload.

E4. My subordinates are receptive to evaluation, suggestions, and criticism.

E5. My subordinates feel responsible for initiating accurate upward communication.

Section F: Trust (Adapted from Li et al. 2012)

F1. My colleagues fulfil my expectations in our collaboration.

F2. My colleagues perform their duties very well.

F3. Overall, my colleagues are capable and proficient technical staff.

F4. In general, my colleagues are knowledgeable about our organisation.

F5. My colleagues act in the best interest of the project.

F6. If I required assistance, my colleagues would do their best to help me.

F7. My colleagues are interested in my professional well-being, not just their own.

F8. My colleagues are truthful in their contact with me by actively exposing the whole truth on any work-related matter.

F9. I would characterize my colleagues as honest by not telling lies.

F10. My colleagues would keep their verbal commitments.

F11. My colleagues are sincere and genuine.

F12. My company's software has the functionality I need.

F13. My company's software has the ability to do what I want it to do.

F14. Overall, my company's software has the capabilities I need.

F15. My company's software is very reliable.

F16. I can depend on the software when I perform/certify maintenance tasks.

F17. This software performs in a predictable way.

F18. Are you a supervisor / manager?

Section G: Trust - Only for managers / supervisors (Adapted from Li et al. 2012)

G1. My subordinates are effective in assisting and fulfilling my expectations in our collaboration.

G2. My subordinates perform their duties very well.

G3. Overall, my subordinates are capable and proficient technical staff.

G4. In general, my subordinates are knowledgeable about our organisation.

G5. My subordinates act in the best interest of the project.

G6. If I required assistance, my subordinates would do their best to help me.

G7. My subordinates are interested in my professional well-being, not just their own.

G8. My subordinates are truthful in their contact with me by actively exposing the whole truth on a matter.

G9. I would characterize my subordinates as honest by not telling lies.

APPENDIX B Tabulation of the accident and incident investigation reports analysed.

No	Aircraft, Registration, Date, Accident Investigation Authority, Country (Type of Occurrence)	Preconditions for Maintenance Errors	Trust Factor: Survey items indicating trust issues existence	Communication Factor: Survey items indicating communication issues existence
R1	Airbus A320-214, EI-GAL, 07/05/2019, Air Accident Investigation, Ireland (Serious Incident) [46]	R1.1	F2, F3, F5	
		R1.2		C3
		R1.3	F2, F3, F5	
R2	Airbus A320-216, PK-AXC, 30/11/2015, Komite National Keselamatan Transportasi, Republic of Indonesia (Accident) [47]	R2.1	F2, F3, F5	
		R2.2		D19, D8, C7
R3	de Havilland Canada DHC 6-300, C-GSGF, 18/02/2016, Air Accident Investigation Unit, Ireland (Serious Incident) [48]	R3.1		C3
		R3.2	F2, F3, F5	
		R3.3	F2, F3, F5	D19, D12, D17
		R3.4		D19, D12
		R3.5	F2, F3, F5	
		R3.6	F2, F3, F5	
R4	Airbus A320, VH-VGZ, 22/03/2019, Australian Transport Safety Bureau, Australia (Incident) [49]	R4.1	F2, F3, F5	D19, D12, D17
		R4.2	F2, F3, F5	D17
		R4.3	F2, F3, F5	D19, D17, D8, C7
		R4.4	F2, F3, F5	D19, D17, D8, C7
R5	Bombardier DHC-8-Q402, G-JECP, 23/02/2017, Dutch Safety Board, Netherlands (Accident) [50]	R5.1	F2, F3, F5	
		R5.2	F2, F3, F5	
		R5.3		D19, D17, D8, C7
R6	Boeing 747-443, G-VROM, 01/10/2015, Air Accidents Investigation Board, UK (Serious Incident) [51]	R6.1	F4	C8
		R6.2	F2, F3, F5	
		R6.3		C8, D19
R7	Airbus A330-243, A6-EYJ, 06/05/2016, Australian Transport Safety Bureau, Australia (Serious Incident) [52]	R7.1	F2, F3, F5	C7, C8, D19
		R7.2	F1, F2, F3, F5	
		R7.3		C7, C8, D19
R8	Boeing 767, N360AA, 07/12/2012, NTSB, USA (incident) [53]	R8.1	F2, F3, F5	
		R8.2		C8, D19
R9	Boeing 767, N669US, 28/09/2016, NTSB, USA (Incident) [54]	R9.1	F2, F3, F5	
		R9.2		C8, D19, D8
R10	Airbus A319, VT-SCQ, 16/09/2016, Directorate General of Civil Aviation, India (Accident) [55]	R10.1	F2, F3, F5	
		R10.2		C8, D19, D8
R11	Boeing 737-800, B 18616, 21/08/2009, Japan Transport Safety Board, Japan (Accident) [56]	R11.1	F2, F3, F5, F8, F9, F11	D19, D17, D8, D12
		R11.2		D19, C10, D8, C8
R12	Airbus A319-131, G-EUOE, 14/07/2015, Air Accident Investigation Branch, UK (Accident) [57]	R12.1	F2, F3, F5	
		R12.2		D19, D17, D8, C7
		R12.3	F2, F3, F5	D19, D17, D8, D6
		R12.4	F2, F3, F5	
		R12.5		D19, D17, D6, D8
		R12.6		D19, D15, D17, D12, D3, D6
		R12.7		D19, D6, D17, D12, D3, D6
		R12.8	F1, F2, F4, F5, F7	
		R12.9	F1, F2, F4, F5, F7, F8, F11	D19, D2, C3, D8, D6, D17, C7, D15, D12, D3, D6
		R12.10	F12, F13, F14	
R13	Embraer 190-100LR, P4-KCJ, 02/05/2019, Gabinete de Precenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviarios, Portugal (Accident) [58]	R13.1	F2, F3, F5	
		R13.2		D19, C8, D17, C3, D6, D8
		R13.3	F1, F2, F3, F5	D19, D17, D16, D12, D13, D15, D6
		R13.4	F1, F2, F3, F4, F5	D19, D17, C3, D6, D8, D12, D15, D2, D6, C7, D3
R14	Airbus A330-342, B-HLL, 03/07/2013, Accident Investigation Division, Hong Kong (Accident) [59]	R14.1	F1, F2, F3, F4, F5	D19, D2, C3, D8, D6, D17, C7, D15, D12, D3, D6
		R14.2	F1, F2, F3, F4, F5	D19, D2, C3, D8, D6, D17, C7, D15, D12, D3, D6
		R14.3	F1, F2, F3, F4	D19, D2, C3, D8, D6, D17, C7, D15, D12, D3, D6
R15	Lockheed WC-130H, 65-0968, 09/10/2018, United States Air Force Accident Investigation Board, USA (Accident) [60]	R15.1	F1, F2, F3, F4, F5	D19, D2, C3, D8, D6, D17, C7, D15, D12, D16, C1, C8, D3, D4, D6
		R15.2	F1, F2, F3, F4, F5, F8, F9, F11	D19, D2, C3, D8, D6, D17, C7, D15, D12, D16, C1, C8, D3, D4, D6
		R15.3	F1	D19, D17, D16, D12, D13, D15, D6
		R15.4	F1, F2, F3, F4	D19, D2, C3, D8, D6, D17, C7, D16, D15, D12, D3, D6

APPENDIX C Mapping of CTQS items against the Dirty Dozen elements.

	DIRTY DOZEN ELEMENT											
Communication and Trust Question Set Items	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
C1	X	X			X	X	X	X	X	X	X	
C2	X	X			X	X	X	X	X	X	X	
C3	X	X			X	X	X	X	X	X	X	
C4	X	X			X	X	X	X	X	X	X	
C5	X	X			X	X	X	X	X	X	X	
C6	X	X			X	X	X	X	X	X	X	
C7	X	X			X	X	X	X	X	X	X	
C8	X	X			X	X	X	X	X	X	X	
C9	X	X			X	X	X	X	X	X	X	
C10	X	X			X	X	X	X	X	X	X	
C11	X	X			X	X	X	X	X	X	X	
C12	X	X			X	X	X	X	X	X	X	
C13	X	X			X	X	X	X	X	X	X	
C14	X	X			X	X	X	X	X	X	X	
D1	X	X			X	X	X	X	X	X	X	
D2	X	X			X	X	X	X	X	X	X	
D3	X	X			X	X	X	X	X	X	X	
D4	X	X			X	X	X	X	X	X	X	
D5	X	X			X	X	X	X	X	X	X	
D6	X	X			X	X	X	X	X	X	X	
D7	X	X			X	X	X	X	X	X	X	
D8	X	X			X	X	X	X	X	X	X	
D9	X	X			X	X	X	X	X	X	X	
D11	X	X			X	X	X	X	X	X	X	
D12	X	X			X	X	X	X	X	X	X	
D13	X	X			X	X	X	X	X	X	X	
D14	X	X			X	X	X	X	X	X	X	
D15	X	X			X	X	X	X	X	X	X	
D16	X	X			X	X	X	X	X	X	X	
D17	X	X			X	X	X	X	X	X	X	
D18	X	X			X	X	X	X	X	X	X	
D19	X	X			X	X	X	X	X	X	X	
E1	X	X			X	X	X	X	X	X	X	
E2	X	X			X	X	X	X	X	X	X	
E3	X	X			X	X	X	X	X	X	X	
E4	X	X			X	X	X	X	X	X	X	
E5	X	X			X	X	X	X	X	X	X	
F1	X		X	X	X							X
F2	X		X	X	X							X
F3	X		X	X	X							X
F4	X		X	X	X							X
F5	X		X	X	X							X
F6	X		X	X	X							X
F7	X		X	X	X							X
F8	X		X	X	X							X
F9	X		X	X	X							X
F10	X		X	X	X							X
F11	X		X	X	X							X
F14	X		X	X	X							X
F15	X		X	X	X							X
F16	X		X	X	X							X
F17	X		X	X	X							X
G1	X		X	X	X							X
G2	X		X	X	X							X
G3	X		X	X	X							X
G4	X		X	X	X							X
G5	X		X	X	X							X
G6	X		X	X	X							X
G7	X		X	X	X							X
G8	X		X	X	X							X
G9	X		X	X	X							X

	G10	X		X	X	X							X
	G11	X		X	X	X							X

Appendix E: Under Review Journal Paper 5

Chatzi, A., V., Bates, P., & Martin, W. Exploring the Association Between Communication Satisfaction and Trust in the Aviation Maintenance Environment: An International Study. Manuscript submitted for publication and is currently under review at the Journal of Air Transport management.

Submitted Version under Review

Exploring the Association Between Communication Satisfaction and Trust in the Aviation Maintenance Environment: An International Study

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Abstract

This study explores the association among communication satisfaction, interpersonal trust and trust towards maintenance software used by aviation maintenance companies. A survey was conducted to a diverse set of civil and military aviation maintenance professionals. 259 fully answered questionnaires were quantitatively analysed. Results showed managers and subordinates' communication satisfaction to be substantially explained by their levels of interpersonal trust. Differences in the communication satisfaction and software trust between military and civil employees were also observed. The results of civil employees exhibit higher mean scores for all three factors. Overall, communication satisfaction was found to have a stronger association with interpersonal trust than with software trust. The mean scores of communication satisfaction and interpersonal trust increased across various levels of experience being statistically significant. Recommendations are made for management to take into consideration trust along with communication, when improving communication processes in the wider attempt of aviation maintenance productivity enhancement.

Keywords: Communication Satisfaction; Interpersonal Trust; Technology Trust; Organizational Research; Aviation Maintenance.

Introduction

In the aviation industry it is well recognised that poor communication is a paramount human factor contributing to errors (Balk & Bossenbroek, 2010; Investigation, 1997). Researchers have acknowledged the need for error free communication within aviation (Caldwell, 2005; Mattson, Petrin, & Young, 2001) while others have identified poor communication to be an accident causal factor (Dupont, 1997; Flin, O'Connor, & Mearns, 2002; Weick, 1990). Recently, researchers have developed tools to proactively detect maintenance failures, such as the maintenance operations safety survey (MOSS), in which communication and trust are major factors (Langer & Braithwaite, 2016).

Communication is an important aspect of business as information gathering on different professional matters takes up a large proportion of employees' time (Mount & Back, 1999). Communication satisfaction (CS) is the perception of employees regarding the communication practices followed by their organisation (Carrière & Bourque, 2009). CS is very important in identifying a healthy and functioning organisation (Downs & Adrian, 2004; Downs & Hazen, 1977). Many researchers believe that satisfactory and effective communication is a sign of an organisation's successful operation, in regard of its productivity, efficiency and its sales and customers approach (Zwijze-Koning & De Menno, 2007).

CS has been associated positively with job satisfaction (Appelbaum et al., 2012; Carrière & Bourque, 2009; Downs & Hazen, 1977; Muchinsky, 1977; Pincus, 1986), employment situation satisfaction (Goris, 2007), organisational commitment (Ng, Butts, Vandenberg, DeJoy, & Wilson, 2006; Varona, 1996), productivity (Hargie, Tourish, & Wilson, 2002) work value, and job performance (Jalalkamali, Ali, Hyun, & Nikbin, 2016). CS research has been conducted so far in business areas such as: hospitality (Mount & Back, 1999), manufacturing (Downs & Hazen, 1977), private and public sector (Brunetto & Farr-Wharton, 2004), Information Technology (Appelbaum et al., 2012), nursing (Pincus, 1986), automotive (Jalalkamali et al., 2016), financial services (Clampitt & Downs, 1993), and the ambulance service (Carrière & Bourque, 2009).

In the aviation sector, research so far has shown that effective communication techniques are part of the employees' initial and recurrent training and are linked to their on job safety-related practices (Karanikas, Melis, & Kourousis, 2017). Also, organisational commitment and employees' level of organisational satisfaction is associated with employees' safety-related practices (Dode, Greig, Zolfaghari, & Neumann, 2016; Evans, Glendon, & Creed, 2007; Glendon & Litherland, 2001; Luria & Yagil, 2010; O'Connor, 2011) (figure 1). In figure 1 is shown a schematic representation of the summary of the interrelationship between communication and trust, and the effect of communication in organisational commitment and safety. However, in the literature there is no link between the other four organisational traits and safety, even though these four are affected by communication as well. However, no research in aviation maintenance has been conducted to identify the association between employees' CS and trust.

Figure 1: Interrelationships between communication, trust, safety and other organisational traits.

Whitener et al. (1998) found that there are three factors in communication that have been found to have a strong association with trust: precise information, explanations and justifications of decisions and openness. Trust, as a fundamental trait in human social life, has been the focus of many different disciplines of science, and each one has dealt with it and defined it according to each discipline's scope and interest (Hernandez & Santos, 2010). Trust has not been investigated as a trait in the aviation sector (Flin, 2007). However, it is a very important element of the interrelationships of co-workers in all industries and warrants further research, as it is linked to the quality of communication (Bachmann, 2003; Carrière & Bourque, 2009; Cascio, 2000; Cho & Park, 2011; Flin, 2007; Muchinsky, 1977; Shapiro, Sheppard, & Cheraskin, 1992; Yeager, 1978).

Interpersonal trust is among other organisational variables that have an interrelationship with communication. While these other variables are not the focus of this study, they include: performance, citizenship behaviour, problem solving, cooperation and cooperative relationships. These variables can be defined through three distinct dimensions (Whitener, Brodt, Korsgaard, & Werner, 1998). The first dimension is the confidence of the element of benevolence in the other party's acts. The second dimension is that there is no control over the other party's actions, therefore there is no warranty in the deliverable outcome and the third dimension is that the individual's performance has some reliance on the performance of another individual (Whitener et al., 1998). Also, research has indicated that the character of trust can change, depending on the stage of the relationship between the different parties involved (Hernandez & Santos, 2010). Moreover, the interaction between the two parties i.e. the knowledge and evaluation of previous successful collaboration which can lead to successful prediction of potential future collaboration, enhances trust. This is called the knowledge-based trust (Hernandez & Santos, 2010).

In this study, both interpersonal trust and company software trust is investigated. In correspondence with the technology trust (Li, Rong, & Thatcher, 2012), software trust is the aviation maintenance employees' beliefs of the trustworthiness towards their company software's performance.

The purpose of this study is to investigate the association between CS and trust of the aviation maintenance employees. This population is chosen for this study for its critical characteristics. These characteristics are mainly influenced by its global nature, yet it is governed by different laws in different geographical areas. The aviation maintenance profession is a highly complex, highly skilled and highly regulated around the world. Aviation maintenance employees, after multiyear training to get their qualifications, can work autonomously in a busy, constantly physically challenging working environment. Their work requires high pace, long hours, overtime due to shortages in staffing, shift work, and ongoing training as new technology and legislation are constantly introduced. Additionally, full attention and situational awareness can be limited due to the physical restrictions of their immediate working environment. Considering that managers' posts do not require the same hours as the rest of the employees (morning shifts) and the same locations (offices rather than ramps or painting shops etc), it is obvious that communication and trust between them could influence safety. Therefore, ongoing research of human factors, and especially the investigation of traits such as communication and trust, will continue to contribute to aviation maintenance safety and more efficient performance.

More specifically, the following hypotheses were tested and analysed in the aviation maintenance sector.

1.1 Research hypotheses

1. (a) Employees' levels of interpersonal trust towards their colleagues and (b) supervisors/managers' levels of interpersonal trust towards their subordinates have a positive association with their CS.
2. (a) Employees' trust towards the company's software and (b) supervisors/managers' trust towards the company's software have a positive association with their CS.
3. (a) Subordinates' levels of interpersonal trust and (b) subordinates' trust towards the company's software have a positive association with their CS.
4. *High initial trust levels* are detectible in (a) interpersonal trust and (b) company's software trust to newly recruited maintenance employees.

2. Material and methods

2.1 Instrument

A questionnaire, consisted of two parts, was used for this research: One part was based on the he Communication Satisfaction Questionnaire (CSQ) and the other one on the Trust Constructs and Measures Questionnaire (TCMQ). The CSQ is a tool that was incepted in 1977 and widely used since then in research projects dealing with CS in various industries (Appelbaum et al., 2012; Brunetto & Farr-Wharton, 2004; Carrière & Bourque, 2009; Chan & Lai, 2017; Clampitt & Downs, 1993; Downs & Hazen, 1977; Gochhayat, Giri, & Suar, 2017; Jalalkamali et al., 2016; Mount & Back, 1999; Pincus, 1986; Zwijze-Koning & De Menno, 2007; Zwijze-Koning, 2016). CSQ has proven to be an efficient tool to extract employees' perceptions of the communication within their organisation (Gray & Laidlaw, 2004; Zwijze-Koning & De Menno, 2007;

Zwijze-Koning, 2016). The CSQ is a 40-item questionnaire, with items categorized in eight communicative themes (dimensions). These dimensions vary from interpersonal communication (e.g. an employee's evaluation of the communication with his/her supervisor), to the organization-wide communication climate (Zwijze-Koning & De Menno, 2007). This construct has a test-retest reliability of 0.94 (Downs & Hazen, 1977).

The CSQ can expose employees' beliefs on important matters affecting communication within an organisation. CSQ's convergent validity has been compared in the past with other questionnaires, e.g. the Communication Incident Technique (CIT), and was considered to be a very reliable, up to date tool in investigating an organisation's CS (Zwijze-Koning, 2016). Several researchers have evaluated the reliability and concurrent and construct validity of the CSQ (DeWine & James, 1988; Lee, Strong, Kahn, & Wang, 2002; Rubin, Palmgreen, & Sypher, 1994; Zwijze-Koning, 2016).

It is noted that CSQ has been the primary research tool for various research studies conducted in many different countries and institutions (Rubin et al., 1994). It has been characterised as "*arguably the best measure of communication satisfaction in the organizational arena*" (Clampitt & Downs, 1993), p. 6) while Rubin et al. (1994, p. 116) agree "*The thoroughness of the construction of this satisfaction measure is apparent. The strategies employed in this study are exemplary*".

The items of the CSQ part of the questionnaire made its C, D and E sections (Appendix A) and all items were used as they were initially developed by Downs and Hazen (1977). Sections C and D were addressed to all participants while section E was addressed to supervisors/managers only. The question: D10 'The grapevine (person to person informal communication / gossip) is active in our organisation' was included in the questionnaire that was given to the participants, however it proved to be inconsistent with the other items' (based on reliability measures) and was therefore excluded from the analysis. Furthermore, other researchers have excluded the same question from their research projects as it was found to be blurry to the participants (Chan & Lai, 2017; Mount & Back, 1999).

TCMQ was again adapted in this research to measure interpersonal trust (among colleagues and between employees-managers) and trust towards the software package utilised for the purposes of aircraft maintenance certification and management. The original questionnaire, which was adapted by Li et al. (2012), has proven to be valid and reliable in past research (Gefen, 2004; Li et al., 2012; Lowry, Vance, Moody, & Beckman, 2008; McKnight, Carter, Thatcher, & Clay, 2011; McKnight, Choudhury, & Kacmar, 2002; Nicolaou & McKnight, 2006; Stewart & Malaga, 2009; Vance, Elie-dit-cosaque, & Straub, 2008). Moreover, the measurement model (reliability scores, construct validity, convergent and discriminant validity) was found to produce statistically significant results (Li et al., 2012). The measurement model results verified that the measurement scales adapted by Li et al., (2012) were valid and reliable in their study. Specifically, web capability and reliability were found to be powerfully belief constituent in assessing trust in website. This outcome confirmed that the IT-specific scales, that were adopted by Li et al., (2012) were valid in technology trust measurement (Li et al., 2012).

In this study, The F and G sections of the questionnaire were formed by the items of the TCMQ (Appendix A). Section F was addressed to all participants while section G was addressed to supervisors/managers only. This questionnaire was adapted by Li et al. (Li et al., 2012) and the items were adjusted again for the purposes of this research. Prior to the administration of TCMQ, an experts' evaluation process was conducted to examine the appropriateness of the adaptations (modifications) made. The need for this stage was derived from the fact that the items of the questionnaire were adapted again to suit the context of this study and therefore they had to be tested for the content validity of scores and if any improvement was possible on the questions and the format (Creswell, 2014). For this purpose, three aviation maintenance engineers were selected. Their background included many years of experience in the field, experience in training and in the academic sector. Their recommendations for the improvement of the questions were thoroughly assessed and implemented in the questionnaire, as they were found to be constructive.

Two questions: F12 'My company's software has the functionality I need' and F13 'My company's software has the ability to do what I want it to do' were included in the questionnaire that was distributed to the participants, however they showed problematically high correlations to F14: 'Overall, my company's software has the capabilities I need'. As a result, they were not included in the statistical analysis for this reason.

In the TCMQ, the items were grouped together, forming 8 constructs, as were introduced by Li et al. (2012). These constructs are: trust in colleagues' competence, trust in colleagues' benevolence, trust in colleagues' integrity, trust in company's software capability, trust in company's software reliability, trust in managers-subordinates' competence, trust in managers-subordinates' benevolence, managers-subordinates' integrity. However, since two of the three items forming the construct: trust in company's software reliability, were not used in the statistical analysis, a new single construct was formed with the four remaining questions about software: trust in company's software capability. All items in sections C, D, E, F, G of the combined questionnaire used a 7-point Likert scale. Sections C, D and E used the coding 1 = Very Dissatisfied to 7 = Very Satisfied and sections F and G 1 = Strongly Disagree to 7 = Strongly Agree.

Demographic and general questions formed section A and B of the questionnaire. These questions gathered information on the length of the participants' longevity of employment with current organisation, type of license and regulative authority under current employment, position. Sample items are: 'How satisfied are you with your job?' and 'I have a total of .... years of experience in aviation maintenance.'

The longevity of employment question was expected to separate the sample in two groups regarding their experience:

• The experienced group (6 months of experience and more with current employer);

• The newly recruited (less than 6 months with current employer).

The comparison of the results that stem from items from the TCMQ are essential in any observation of the *high initial trust levels* formation within the newly recruited group (Hernandez & Santos, 2010; McKnight, Cummings, & Chervany, 1998). According to McKnight et al. '…*initial trust*, because the parties have not worked together long enough to develop an interaction history' therefore, for the scope of this research the group of employees with experience up to 6 months was selected to measure the initial levels of trust. A maximum period of six months' experience enables a sufficient sample size to be used effectively in statistical analysis as well as set an amount of time that employees would not be yet familiar with all their company's systems.

2.2 Sample

The respondents were aircraft maintenance employees working in aircraft maintenance organisations operating under the Australian Civil Aviation Safety Agency (CASA), the European Aviation Safety Agency (EASA), the Federal Aviation Administration (FAA) system or in military organisations. The questionnaire was distributed in English and no respondent required its translation into a different language. Respondents were recruited in two different phases:

- phase 1. contacted through their managers as their company agreed to participate in the survey and
- phase 2. contacted directly by the principal investigator.

In phase one, 11 aircraft maintenance organisations were contacted initially for participation and five accepted the invitation. The questionnaire was sent to 121 aircraft maintenance employees, with full responses from 62 giving a response rate at 51%, which is consistent with past research (Chan & Lai, 2017; Leedy & Ormrod, 2013). In phase two another 380 aircraft maintenance employees were contacted directly by the principal investigator, with full responses from 197 giving a response rate of 52%. In total 259 fully answered questionnaires were collected.

The participants received the invitation to participate by email, which included an information sheet in which the scope of this research, the survey content, the value of each participant's input, anonymity reassurance, information on ethics approval, assurance of confidentiality of the data obtained, and a commitment of feedback were included. Participants received two weekly reminders in case they had not responded within a week of the initial invitation email. For the questionnaire's distribution the web-based tool Limesurvey (Faul, Erdfeldfer, Lang, & Buchner, 2007) was used. Limesurvey helped to augment the response rate to the questionnaire by providing a professional appearance, privacy and anonymity to the participants.

2.3 Data analysis

Quantitative analysis of responses to the questionnaire was conducted using SPSS Statistics 25.0.0. In this research study a correlational research design was used to investigate the relationship between the two traits (CS and trust) and avoid implying any causational relationship in any way (Fraenkel & Wallen, 2003). Following data screening to address any anomalies, the reliability of each construct, CS and trust, were measured using the Cronbach’s alpha. This was followed by descriptive statistics, correlations between variables, t-tests and analyses of variance (ANOVA).

For this study snowball sampling was used, as firstly participants were selected both randomly and from an initial circle of colleagues/associates. They were then asked to propose more participants from their circle of colleagues and associates. For this reason, Harman’s one factor analysis was used to determine the existence or absence of the common method bias. This analysis identified that the largest single factor explained less than 50% of the variance, i.e. 41%. Therefore, no significant common method bias was identified in this research project.

3. Results

3.1 Descriptive statistics

The respondents were mostly civil aircraft maintenance employees (83%) while their military counterparts made up 13% of respondents (4% of the sample did not state their civil/military status). The newly hired employees (less than 6 months experience) comprised just 7%. Respondents were found to be evenly equally distributed according to their total experience: 19% had total experience between 0 to 9.5 years, 26% 10 to 19.5 years, 31% between 20 to 29.5 years, 24% more than 30 years of experience. Half of the respondents were either holding a supervisory or a managerial post. Of the respondents 51% held one license and worked for a maintenance company regulated by the European Aviation Safety Agency (EASA), 6% held a single license from the Federal Aviation Administration (FAA) and 9% held a single license from the Civil Aviation Safety Authority (CASA). 12 % of the respondents held military license while another 12 % held multiple licenses and the remaining held no license.

The Cronbach’s alpha values were measured for both CSQ and TCMQ whole questionnaires and the different group of questions (constructs) that each questionnaire was divided in: the managers’ questions group in CSQ and the 7 constructs of the TCMQ questionnaire. All of these Cronbach’s alpha values ranged between 0.77 and 0.97. Particularly, the Cronbach’s alpha for the whole CSQ was 0.97 similar to that found by past researchers who used the same questionnaire (Downs & Hazen, 1977; Mount & Back, 1999) , the whole TMCQ was 0.91, the CSQ managers’ group was 0.88 and the TCMQ’s Trust in company's software Capability was 0.92. These were high reliability scores and therefore acceptable for this research.

3.2 Hypotheses testing

Hypotheses 1(a)(b) are suggesting that interpersonal trust is positively linked to overall CS among aircraft maintenance employees and between supervisors/managers (referred as managers in the rest of the text) and their subordinates. Hypothesis 1 (a) was supported using the bivariate correlation. This correlation indicated a positive association between interpersonal trust and overall CS among employees ($r = 0.56$, $p < 0.01$, $N = 261$) and is illustrated in figure 2A. In figure 2A it should be noted there are some outliers present that have increased very slightly the strength of the association. The overall CS score for all employees and their interpersonal trust score are the means of the scores of all items of CSQ (sections C, D excluding D10 and D20) and the items F1 to F11 of the TMCQ respectively. The overall scores are measured on the same scale as the original scores and this applies to all scores measured in this section.

For Hypothesis 1(b) the strong association between the managers' CS towards their subordinates and the managers' interpersonal trust towards their subordinates ($r = 0.75$, $p < 0.01$, $N = 129$) is shown in figure 2B. It is noted here that the outliers do not significantly alter the correlation. The managers-subordinates CS score and the managers-subordinates' interpersonal trust score are the means of the scores of all items of CSQ that were responded to by managers only (section E) and all items of the section G of the TMCQ respectively.

Hypotheses 2(a)(b) were statistically well supported. The correlations indicated the positive association between trust towards the company's software for employees and their overall CS, as well as the managers' trust towards the company's software and their overall CS. For Hypothesis 2(a) the Pearson correlation r between employees' overall CS and their software trust was $r = 0.51$, $p < 0.01$, $N = 261$. The association between employees' software trust and overall CS is shown in figure 2C indicating moderate-large scatter about the line of best fit. The employees' overall CS score and their trust towards the company's software score are the means of the scores of all items of CSQ (sections C, D excluding D10 and D20) and the items F14 to F17 of the TMCQ respectively. For Hypothesis 2(b) the correlation between the managers' levels of trust for the company's software and their CS towards their subordinates indicated a weak association ($r = 0.33$, $p < 0.01$, $N = 132$), as illustrated by the large scatter in figure 2D.

It is worth mentioning here that, even though there is a statistically significant correlation between these two traits, the association is quite weak. On the other hand, the correlation between the managers' levels of trust for the company's software and their CS towards their company and peers indicated a stronger association ($r = 0.57$, $p < 0.01$, $N = 132$), see figure 2E. It should be noted there are some outliers present that have increased very slightly the strength of the association. The managers-subordinates CS score and the managers' trust towards the software score are the means of the scores of the items in section E of the CSQ and managers' responses in items of the TMCQ (items F14 - F17) respectively. The managers' CS towards their company and peers score is the mean of the score of the items in sections C and D for the selected cases of the managers.

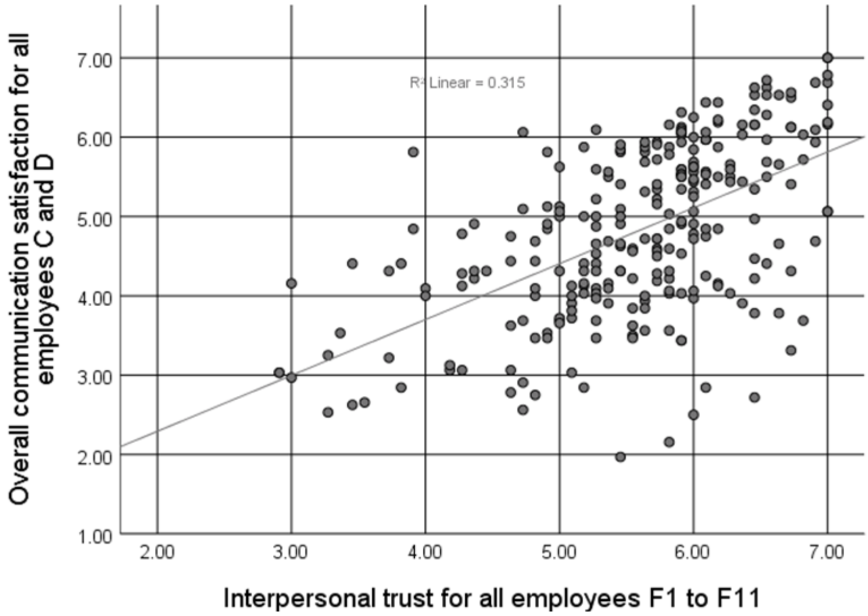
Hypotheses 3(a)(b) were supported as well. For Hypothesis 3(a) the correlation between the subordinates' overall CS and their interpersonal trust, indicated a moderate relationship between the two traits ($r = 0.60$, $p < 0.01$, $N = 129$) with figure 2F supporting the evident association of this form of trust with the subordinates' overall CS. The subordinates' overall CS score and their interpersonal trust score are the means of the scores of the items in sections C and D of the CSQ for the subordinates' as selected cases and items of the TMCQ (items F1 - F11) respectively.

For Hypothesis 3(b) the correlation between the subordinates' overall CS and their trust towards the company's software, showed a medium strength relationship between the two traits ($r = 0.45$, $p < 0.01$, $N = 129$) and indicated some association of this form of trust with the subordinates' overall CS, figure 2G with a moderate-large scatter about the line of best fit. The subordinates' overall CS score and their trust towards the company's software score are the means of the scores of the items in sections C and D of the CSQ for the subordinates' as selected cases and items of the TMCQ (items F14 - F17) respectively.

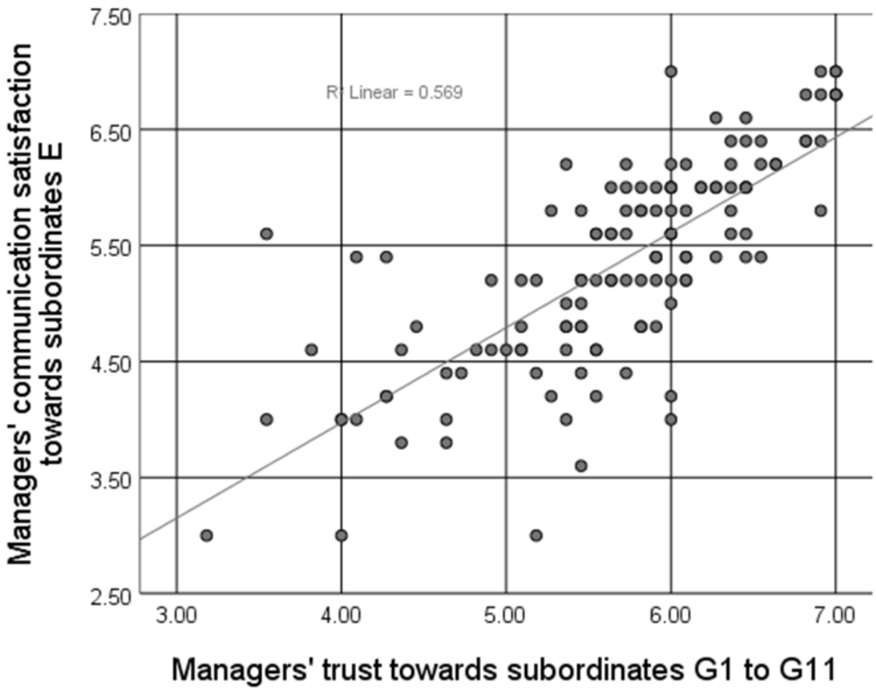
Hypothesis 4(a)(b)(c). For this analysis the sample size of the newly hired personnel ($N = 17$) was anticipated and found to be very small compared to the rest of the experienced personnel ($N = 244$). Due to the large difference in sample sizes of the two groups, descriptive statistical analysis was conducted and a comparison between the means of each group was used as an indicator of possible support of each part of this hypothesis. In particular: For Hypothesis 4(a), while measuring interpersonal trust, the newly hired group showed greater levels of trust (M: 5.90, SD = 0.72) in comparison to the experienced group (M: 5.57, SD = 0.87). For Hypothesis 4(b) the levels of trust towards the company's software were found to be greater among the newly hired group (M: 5.51, SD = 0.87) than the levels of trust in the experienced group (M: 4.59, SD = 1.53). Furthermore, the group of newly hired personnel showed greater overall CS (M: 5.40, SD = 0.97) than the group of more experienced personnel (M: 4.75, SD = 1.09).

Figure 2: A. Scatterplot of interpersonal trust score and overall CS score for all employees; B. Scatterplot of mangers' CS towards subordinates and managers' interpersonal trust towards subordinates; C. Scatterplot of employees' overall CS and their software trust; D. Scatterplot of managers' levels of trust for the company's software and their overall CS towards their subordinates; E. Scatterplot of managers' levels of trust for the company's software and their overall CS; F. Scatterplot of subordinates' levels of interpersonal trust and their CS; G. Scatterplot of subordinates' levels of trust for the company's software and their CS.

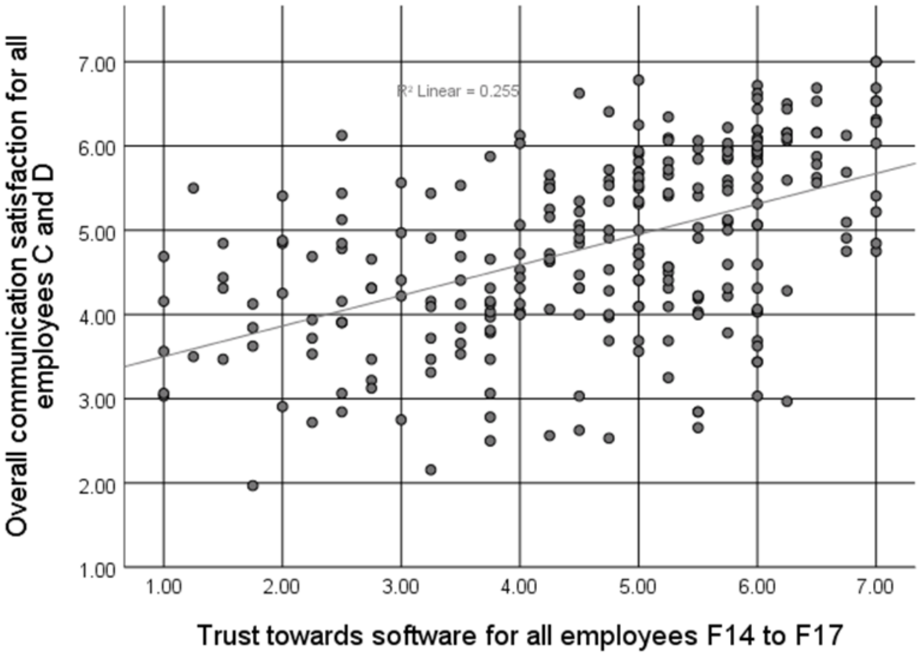
A


Overall communication satisfaction for all employees C and D
Interpersonal trust for all employees F1 to F11
R² Linear = 0.315
1.00
2.00
3.00
4.00
5.00
6.00
7.00
2.00
3.00
4.00
5.00
6.00
7.00

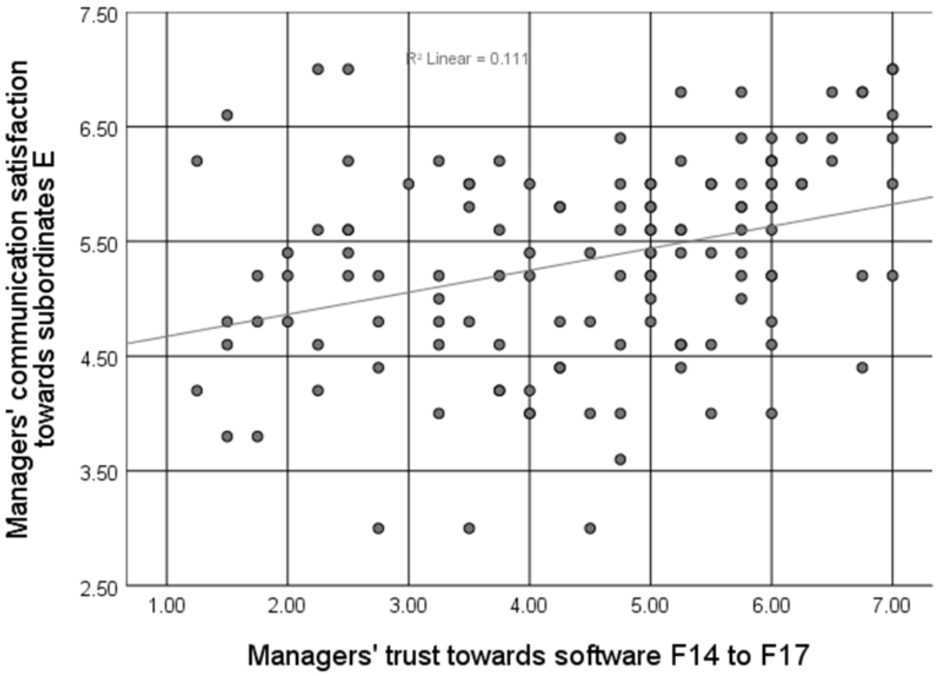
B


Managers' communication satisfaction towards subordinates E
Managers' trust towards subordinates G1 to G11
R² Linear = 0.569
2.50
3.50
4.50
5.50
6.50
7.50
3.00
4.00
5.00
6.00
7.00

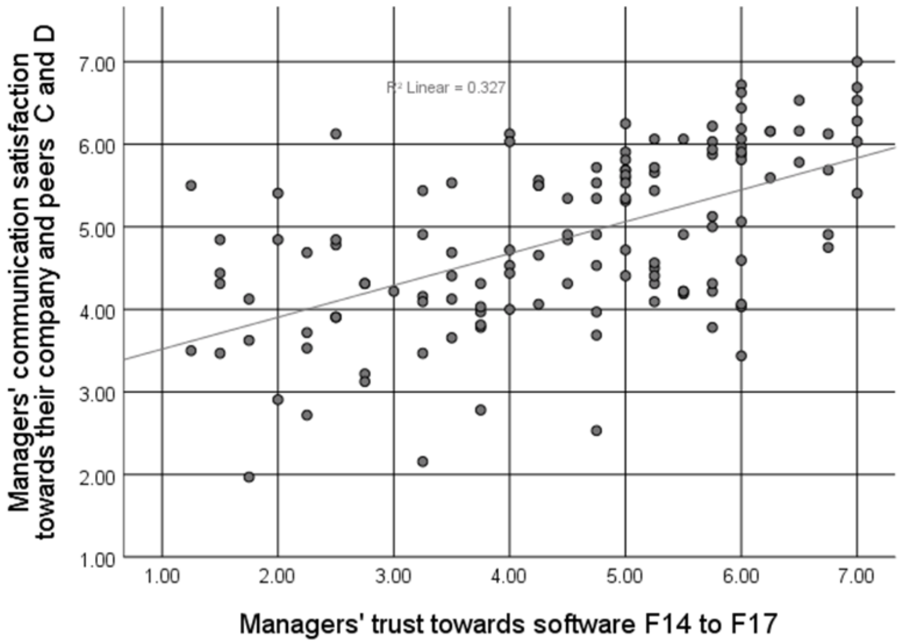
C


R² Linear = 0.255
Overall communication satisfaction for all employees C and D
Trust towards software for all employees F14 to F17
1.00
2.00
3.00
4.00
5.00
6.00
7.00

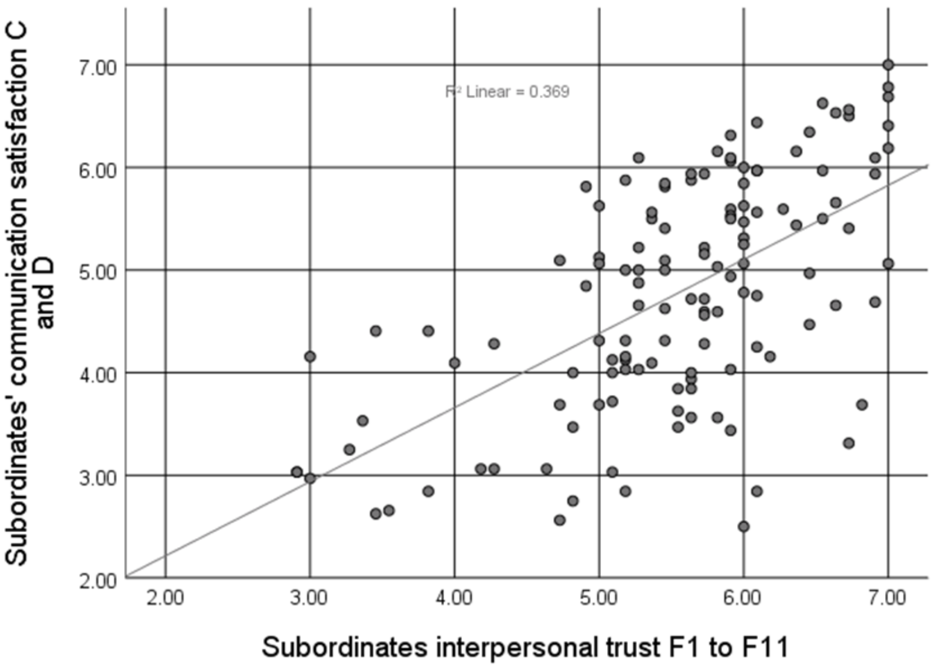
D


R² Linear = 0.111
Managers' communication satisfaction towards subordinates E
Managers' trust towards software F14 to F17
2.50
3.50
4.50
5.50
6.50
7.50
1.00
2.00
3.00
4.00
5.00
6.00
7.00

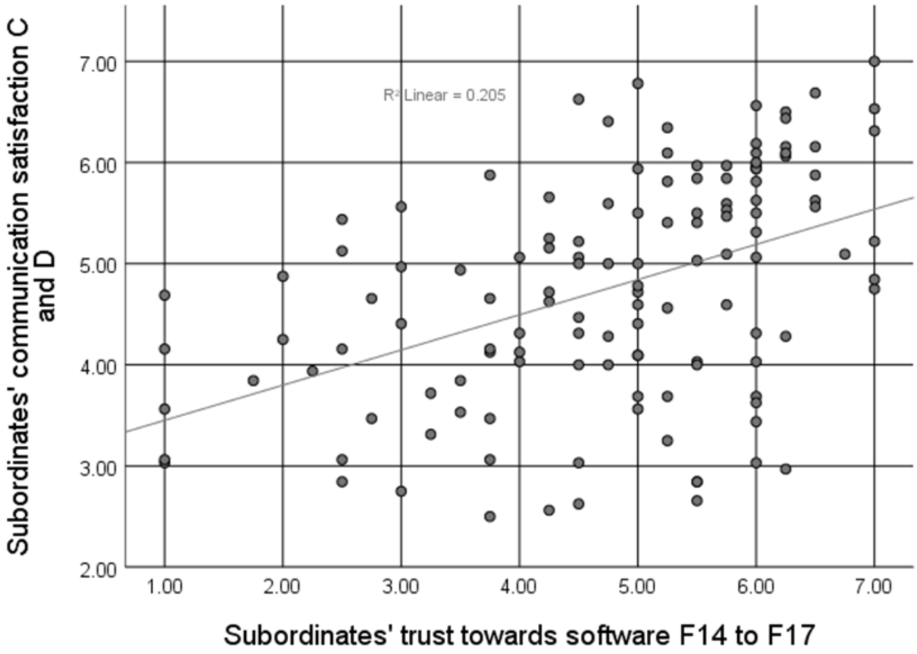
E


Managers' communication satisfaction towards their company and peers C and D
7.00
6.00
5.00
4.00
3.00
2.00
1.00
R² Linear = 0.327
1.00
2.00
3.00
4.00
5.00
6.00
7.00
Managers' trust towards software F14 to F17

F


Subordinates' communication satisfaction C and D
7.00
6.00
5.00
4.00
3.00
2.00
R² Linear = 0.369
2.00
3.00
4.00
5.00
6.00
7.00
Subordinates interpersonal trust F1 to F11

G



3.3 Other observations from the data

Next, an independent samples t-test was conducted to examine the differences in the means of CS and trust scores for civil aviation maintenance employees compared with their military counterparts, as shown in figure 3. The independent samples t-test showed a statistically significant difference in the means for the overall CS score and trust towards software between the civil and military employees. However, the difference in the means of the interpersonal trust scores between civil and military employees was not statistically significant (table 1). It is noted here that the means of all three traits in table 1 are greater for the civil than the military employees. Note that Hedge's g is used here to indicate effect size of the difference in means due to the large difference in sample sizes between the military and civil employees The Hedges' g values for the effect size the difference between the two types of employees with reference to overall CS and software trust represent a small to medium effect size and were found to be statistically significant, while the Hedge's g for the interpersonal trust represents a small effect size and is not statistically significant (table 1). Due to the large difference in sample sizes between the two groups of employees, Mann-Whitney U tests were conducted and since they led to the same conclusions as those from the t-tests, it was deemed that only results from the t-tests need be reported.

Figure 3: Means of overall CS, interpersonal trust and software trust for civil and military aviation maintenance employees

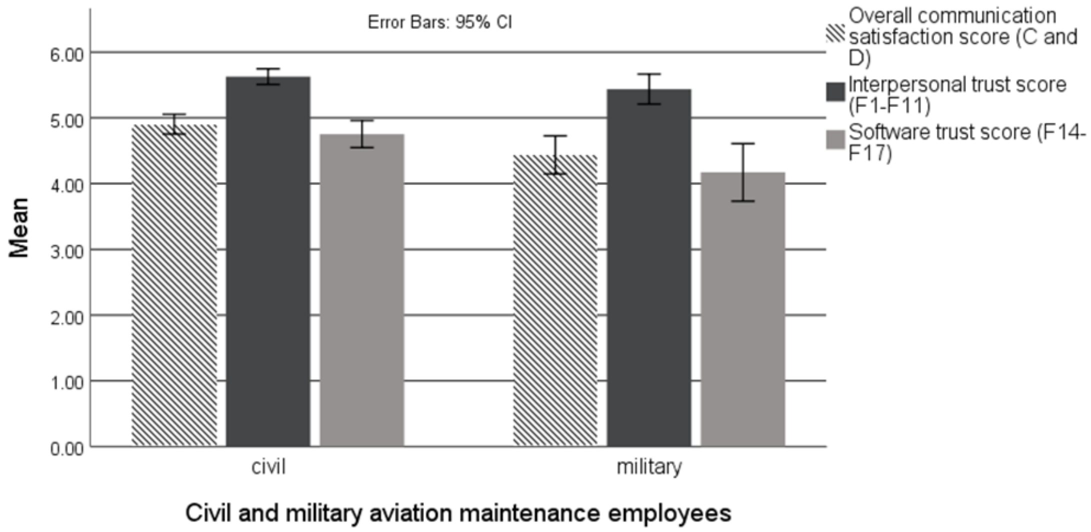


Table 1: T-tests for CS and trust between civil and military aviation maintenance employees

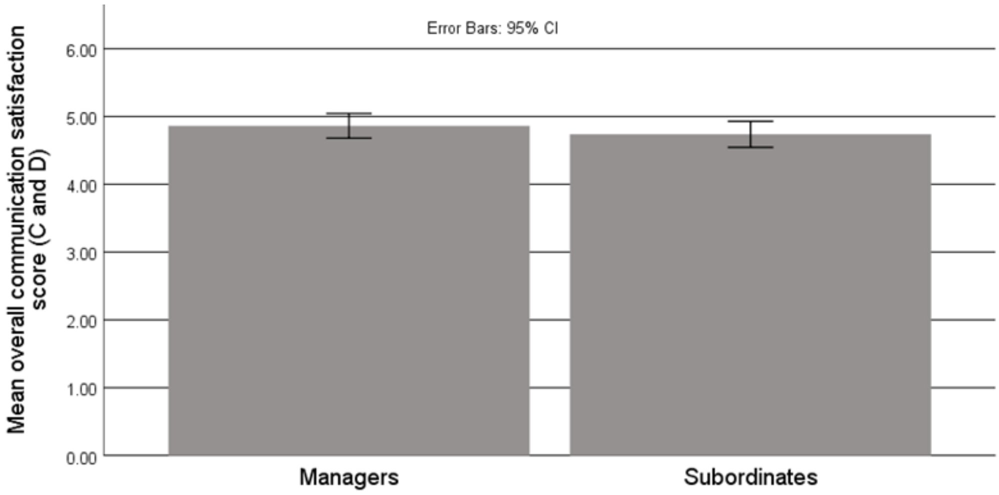
Traits	Groups	N	Mean	St. Deviation	t	df	p	Hedges' g
Overall communication satisfaction score (C and D)	civil	227	4.88	1.12	2.75	58.98	0.008 *	0.40
	military	38	4.44	0.88				
Interpersonal Trust score (F1-F11)	civil	210	5.63	0.88	1.27	246	0.206	0.22
	military	38	5.44	0.70				
Software Trust score (F14-F17)	civil	210	4.75	1.51	2.22	246	0.027 *	0.39
	military	38	4.17	1.33				

* Statistically significant

Accordingly, independent samples t-tests were conducted to examine the differences in the means of CS and trust scores for managers compared with subordinates in aviation maintenance, as shown on figure 4. The t-tests indicated no statistically significant differences in CS and trust scores for managers compared with subordinates (table 2). Thus, it is noted here that the overall CS score, the interpersonal trust score and the trust towards the company's software are statistically no different for the groups of managers and subordinates in aviation maintenance as all *p* values are greater than 0.05 (table 2). Even though differences were not statistically significant, Cohen's d values were used to measure effect sizes of differences between managers and subordinates on the three traits and all were found to be small.

Figure 4: A. Means of overall CS for managers and subordinates B. Means of interpersonal trust and software trust for managers and subordinates

A.



B.

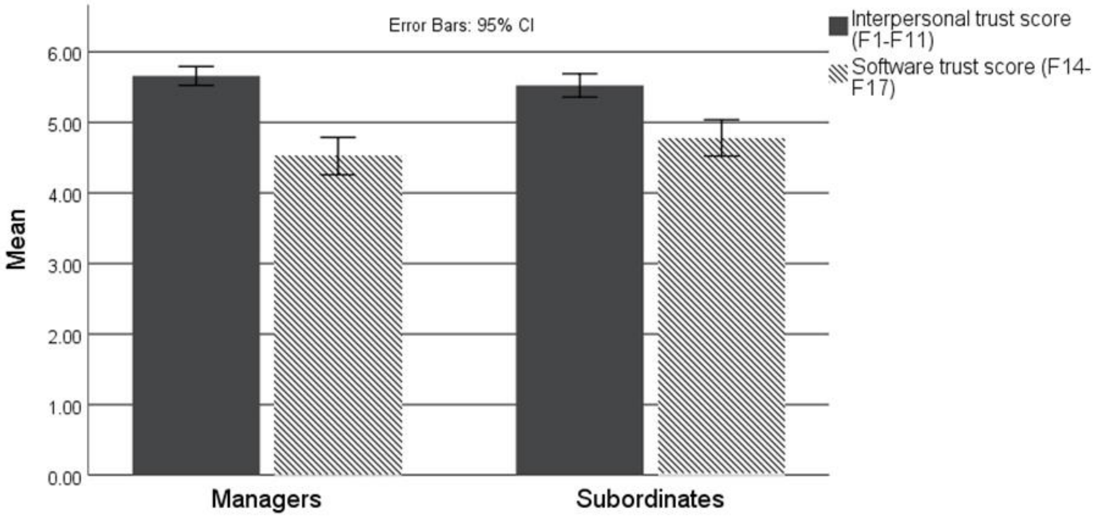
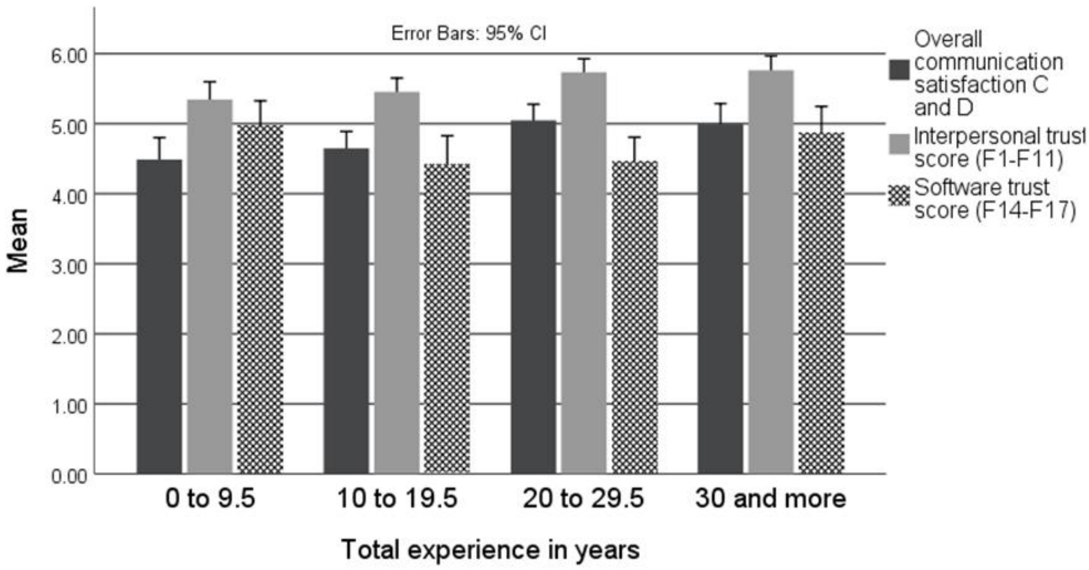


Table 2: T-tests for CS and trust between managers and subordinates in aviation maintenance

Traits	Groups	N	Mean	St. Deviation	t	df	p	Cohen's d
Overall communication satisfaction score (C and D)	managers	136	4.86	1.07	0.93	269	0.353	0.11
	subordinates	135	4.74	1.13				
Interpersonal Trust score (F1-F11)	managers	133	5.66	0.78	1.25	259	0.211	0.16
	subordinates	128	5.52	0.94				
Software Trust score (F14-F17)	managers	133	4.52	1.54	-1.37	259	0.171	0.17
	subordinates	128	4.77	1.47				

Figure 5: Means of overall CS, interpersonal trust and software trust for all participants in their total years of experience



Differences in traits of CS and trust amongst 4 groups based on years of experience were investigated using a one-way analysis of variance (ANOVA). Differences in CS mean scores across the levels of experience were found to be statistically significant (F = 5.96, $p < 0.01$). Post hoc LSD tests showed significant differences amongst the groups as follows: 0 to 0 9.5 years of experience compared with 20 to 29.5 years (p = 0.001, Cohen's d= 0.57), indicating a medium effect size; 0 to 9.5 years of experience compared with 30 years and more (p = 0.001, Cohen's d = 0.56) also indicating a medium effect size; 10 to 19.5 years of experience compared with 20 to 29.5 years (p = 0.001, Cohen's d = 0.44) indicating a small to medium effect size; and 10 to 19.5

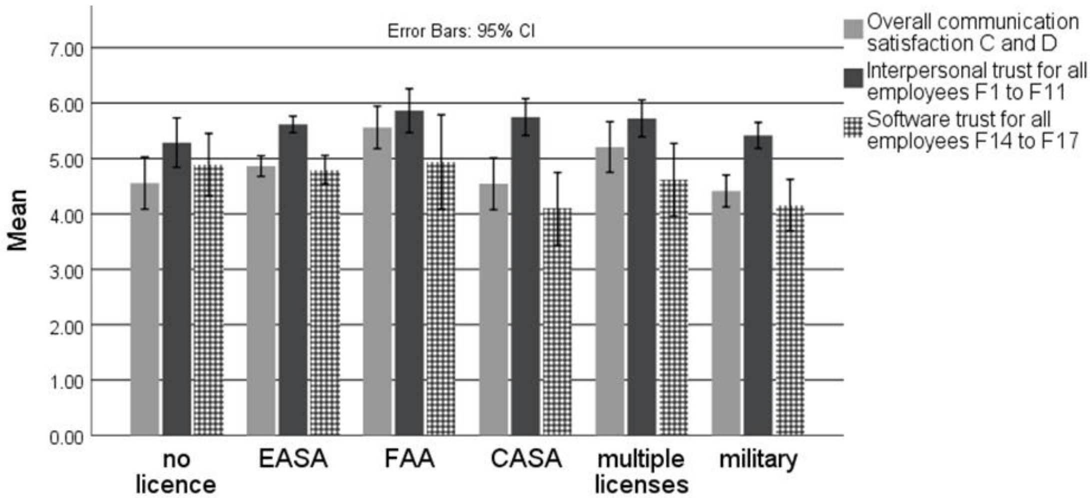
years of experience compared with 30 years and more (p = 0.001, Cohen's d = 0.43) indicating a small to medium effect size (table 3).

There was no significant statistical difference between the 0 to 9.5 years group and the 10 to 19.5 years group and also between the 20 to 29.5 years group and the 30 years and more group. Furthermore, the differences in the means of interpersonal trust and software trust were investigated using one-way ANOVA tests, among the different groups by level of experience, and none were statistically significant. Another observation from table 3 is that the employees with less experience (0 to 9.5 and 10 to 19.5 years) have lower CS scores than the employees with more years of experience (20 to 29.5 and 30 years and more).

Table 3: Means and standard deviations of CS for groups of aviation maintenance employees based on years of experience

Total years of experience	**Mean**	**N**	**Std. Deviation**
0 to 9.5	4.41	55	1.16
10 to 19.5	4.60	71	1.00
20 to 29.5	5.04	87	1.02
30 years and more	5.06	65	1.12
Total	4.81	278	1.10

Figure 6: Means of overall CS, interpersonal trust and software trust for all participants according to the type of license held



One-way ANOVA, using the Bonferroni post hoc test, was run to identify the differences in the traits CS and trust among six different groups of the employees, based on type license held (no license, EASA, FAA, CASA, multiple licenses, military) as shown on figure 6. The differences in CS mean scores were investigated, across the different licenses under which employees are operating, and was found statistically significant ($F = 3.71$, $P < 0.003$). The two pairs of groups that showed significant differences in the post hoc tests are as follows: FAA-CASA ($p = 0.037$, Hedge's $g = 1.13$) indicating a large effect size and FAA-military ($p = 0.008$, Hedge's $g = 1.43$) also indicating a large effect size. As a check, due to concerns about violations of assumptions and large differences in sample sizes amongst the groups, the Kruskal-Wallis test was run for the same traits and gave the same results (see table 4 for means and standard deviations of CS).

Statistically significant differences were not indicated between the following pairs: no license-EASA, no license-CASA, EASA-CASA, EASA-multiple licenses, FAA-multiple licenses, military-EASA, military-CASA, military-no license, military-multiple licenses and FAA- no license. Furthermore, the differences in the means of interpersonal trust and software trust among the different license groups were investigated with a one-way ANOVA, and none were statistically significant.

Table 4: Means and standard deviations of CS for the different license groups of aviation maintenance employees

License groups of employees	Mean	N	Std. Deviation
No license	4.61	27	1.18
EASA	4.82	142	1.11
FAA	5.56	16	0.72
CASA	4.50	24	1.05
Multiple licenses	5.15	33	1.19
Military	4.43	36	0.82
Total	4.81	278	1.10

4. Discussion

The scatterplots that are presented in Figure 2 show the correlation between the variables of trust and CS. From there it is found that 57% of the variation in managers' CS towards their subordinates can be explained by the variation in their interpersonal trust towards them, with a supporting very high correlation between these two traits. This is the strongest association found in this study and could be due to the high interaction and interrelation between the two groups (managers and subordinates). In comparison in the subordinates' group 37% of that group's variation in CS can be explained by variation in interpersonal trust which is lower than that of the managers.

Next, the 31% in variation in overall CS for all employees can be explained by variation in interpersonal trust, with a supporting high correlation between these two traits as well. The association, even though it is not as strong as that of the managers, is strong enough to support a statistically significant positive association.

Conversely, trust towards the company's software and CS (especially for the managers towards their subordinates) indicate a very weak association ($r = 0.33$) (the weakest association found in this study). This could be partly due to other uses of the company's software, apart from the communication between managers and their subordinates. The use of the company's software could explain why the association between the subordinates' CS and their software trust is only slightly greater ($r = 0.45$), while the association of the managers CS towards their company and peers and their trust towards the company's software ($r = 0.57$), is slightly higher than the previous two, but still weak.

After finding the mean scores of all measures for all aviation maintenance employees and the differences between the managers and the subordinates in their CS and the different types of trust, t tests were run to identify if any of the differences between these groups regarding CS and trust were statistically significant. The results indicated that there is not enough evidence to show that differences between the managers and the subordinates' levels of CS, interpersonal trust and software trust were statistically significant. However, a t test to identify differences between the military and civil aviation personnel on these measures, while indicating no difference between them in the levels of interpersonal trust, did identify statistically significant differences in their levels of CS and software trust, with the civil employees having larger means for both these traits.

Aviation maintenance employees were separated into six groups according to their license status (no license, EASA, FAA, CASA, multiple licenses, military) and were investigated to determine the differences in their CS and the different types of trust. A one-way ANOVA was run for these groups and it revealed that there were no differences for the different groups in their interpersonal and software trust but, there were significant differences in the CS for two of the pairs of the groups (FAA-CASA and FAA-military). It is noted here that due to the small size of some of the license groups, they were not proportionally correspondent to the population sample, so they cannot be characterised as representative and further research is recommended. However, these results imply the existence of important differences among these groups and further investigation would be very beneficial.

In the exploration of the two traits (CS and trust) in the span of the employees' experience, there were differences in the levels of the CS between the less experienced and more experienced employees. More specifically, between the two less experienced groups (0 to 9.5 and 10 to 19.5 years) there is no difference in their CS and the same happens with the two more experienced groups (20 to 29.5 and 30 years and more). The significant differences in the levels of CS appear when any one of the less experience groups is compared with any one of the more experienced groups. So, it seems that CS is a trait that changes, as the level of experience increases, and since the mean scores of CS are larger for the more experienced groups, it seems reasonable to infer that CS levels get higher as experience grows.

Furthermore, in an attempt to identify the formation of the initial trust levels theory (McKnight et al., 1998) in this study, the aviation maintenance employees formed two groups according to the length of employment with their current employer. The newly hired employees formed one group and the other more experienced employees formed the second group. The newly hired group's CS, interpersonal and software trust mean scores were calculated and compared to the means of the more experienced group, for the same traits. All three mean scores for interpersonal trust, software trust and CS were found to be larger for the newly hired employees. As the newly hired group is a very small group, these results cannot be characterised as representative, however they are consistent to the initial trust levels theory and further investigation is recommended.

5. Conclusion

This is the first time that a positive association between communication and trust in the aviation maintenance sector has been reported. These findings can be very useful to a human factors approach to aviation maintenance safety management, given that both communication and trust are fundamental in aviation maintenance failure detection and analysis (Langer & Braithwaite, 2016) . Past research has shown CS associated with job satisfaction, organisational commitment and job performance (work values in general) which are not only very important to the successful and profitable operation of the organisation and productivity (Carrière & Bourque, 2009; Jalalkamali et al., 2016), but to the safety-related practices of the employees as well (Dode et al., 2016; Evans et al., 2007; Glendon & Litherland, 2001; Luria & Yagil, 2010; O'Connor, 2011).

Furthermore, poor communication itself has been linked to accident causation and poor safe work practices (Flin et al., 2002; Karanikas et al., 2017; Weick, 1990). Therefore, managers should find a way to enhance the organisation's communication system, in order to keep their employees' CS at high levels. Since this study has showed a positive association between CS and trust, management must take trust into consideration while implementing their effective communication systems. Due to the nature of aviation maintenance work, trust (especially interpersonal trust) is built around co-workers' relationships and cooperation, which are structured in a way so as to reduce the likelihood of error.

6. Limitations

This study was conducted using a sample of aviation maintenance employees that is not necessarily a representative sample of the total of these employees' population. More specifically, there were small numbers of participants from many different geographical areas and this does not mean that they would be representative of the total population of these areas. Therefore, it is suggested that further research is necessary before any results are generalised.

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Appendix A

The items of the distributed questionnaire in this research study

Section A: Demographic information of the participants (Based on Downs & Hazen 1977)

A1. My current post and duties require me to exercise my aircraft maintenance license privileges.

A2. My company is approved by .... to perform and certify maintenance.

A3. My experience with my current company is

A4. I have a total of .... years of experience in aviation maintenance.

Section B: General Questions (Based on Downs & Hazen 1977)
B1. How satisfied are you with your job?
B2. In the past 6 months, what has happened to your level of satisfaction?

Section C: Communication - My job (Based on Downs & Hazen 1977)
C1. Information about my progress in my job.
C2. Personnel news.
C3. Information about organisational policies and goals.
C4. Information about how my job compares with others.
C5. Information about how I am being judged.
C6. Recognition of my efforts.
C7. Information about departmental policies and goals.
C8. Information about the requirements of my job.
C9. Information about government action affecting my organisation.
C10. Information about changes in our organisation.
C11. Reports on how problems in my job are being handled.
C12. Information about benefits and pay.
C13. Information about our organisation's financial standing.
C14. Information about accomplishments and/or failures of the organisation.

Section D: Communication - My job and the people I work with (Based on Downs & Hazen 1977)
D1. My superiors know and understand the problems faced by subordinates.
D2. The organisation's communication motivates and stimulates an enthusiasm for meeting its goals.
D3. My supervisor listens and pays attention to me.
D4. My supervisor offers guidance for solving job related problems.
D5. The organisation's communication makes me identify with it or feel a vital part of it.
D6. The organisation's communications are interesting and helpful.
D7. My supervisor trusts me.
D8. I receive in time the information needed to do my job.
D9. Conflicts are handled appropriately through proper communication channels.
D10. The grapevine (person to person informal communication / gossip) is active in our organisation.
D11. My supervisor is open to new ideas.
D12. Communication with my colleagues within the organisation is accurate and free flowing.
D13. Communication practices are adaptable to emergencies.
D14. My work group is compatible.
D15. Our meetings are well organised.
D16. The amount of supervision given me is about right.
D17. The attitudes towards communication in the organisation are basically healthy.
D18. Informal communication is active and accurate.
D19. The amount of communication in the organisation is about right.
D20. Are you a supervisor / manager?

Section E: Communication - Only for managers / supervisors (Based on Downs & Hazen 1977)
E1. My subordinates are responsive to downward directive communication.
E2. My subordinates anticipate my needs for information.
E3. I *do not* have a communication overload.
E4. My subordinates are receptive to evaluation, suggestions, and criticism.
E5. My subordinates feel responsible for initiating accurate upward communication.

Section F: Trust (Adapted from Li et al. 2012)
F1. My colleagues fulfil my expectations in our collaboration.
F2. My colleagues perform their duties very well.
F3. Overall, my colleagues are capable and proficient technical staff.
F4. In general, my colleagues are knowledgeable about our organisation.
F5. My colleagues act in the best interest of the project.
F6. If I required assistance, my colleagues would do their best to help me.
F7. My colleagues are interested in my professional well-being, not just their own.
F8. My colleagues are truthful in their contact with me by actively exposing the whole truth on any work-related matter.
F9. I would characterize my colleagues as honest by not telling lies.
F10. My colleagues would keep their verbal commitments.
F11. My colleagues are sincere and genuine.
F12. My company's software has the functionality I need.
F13. My company's software has the ability to do what I want it to do.
F14. Overall, my company's software has the capabilities I need.
F15. My company's software is very reliable.
F16. I can depend on the software when I perform/certify maintenance tasks.
F17. This software performs in a predictable way.
F18. Are you a supervisor / manager?

Section G: Trust - Only for managers / supervisors (Adapted from Li et al. 2012)
G1. My subordinates are effective in assisting and fulfilling my expectations in our collaboration.
G2. My subordinates perform their duties very well.
G3. Overall, my subordinates are capable and proficient technical staff.
G4. In general, my subordinates are knowledgeable about our organisation.
G5. My subordinates act in the best interest of the project.
G6. If I required assistance, my subordinates would do their best to help me.
G7. My subordinates are interested in my professional well-being, not just their own.
G8. My subordinates are truthful in their contact with me by actively exposing the whole truth on a matter.
G9. I would characterize my subordinates as honest by not telling lies.