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

Anna V. Chatzi

School of Commerce, University of Southern Queensland, 37 Sinnathamby Blvd, Springfield Central, Brisbane, QLD 4300, Australia; anna.chatzi@usq.edu.au

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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 of trust.

Keywords: aviation; communication; trust; aviation maintenance; prevention; human factors

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 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 Figure 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.

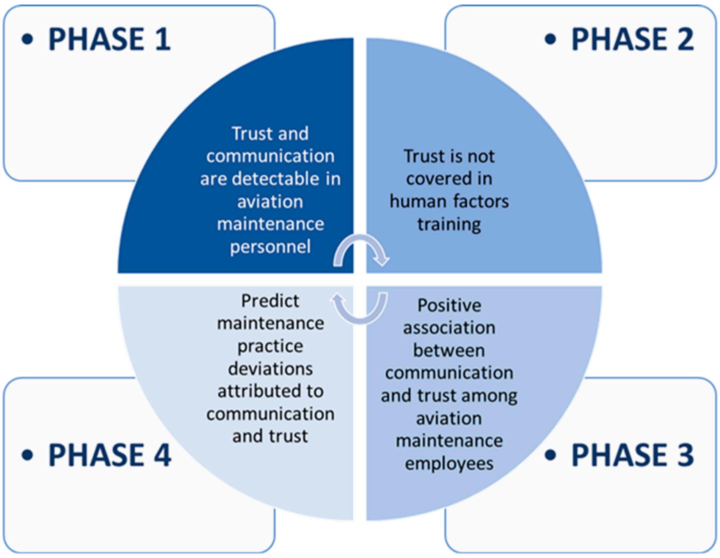

Figure 1. The foundation cyclic process of the proposed conceptual model used.

2.2. Model Tool: Communication and Trust Question Set

In order to accomplish the tasks involved in each of the four phases and by extension 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 [45]. 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 (Figure 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 and so forth (Phases 1 and 2 shown in Figure 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.

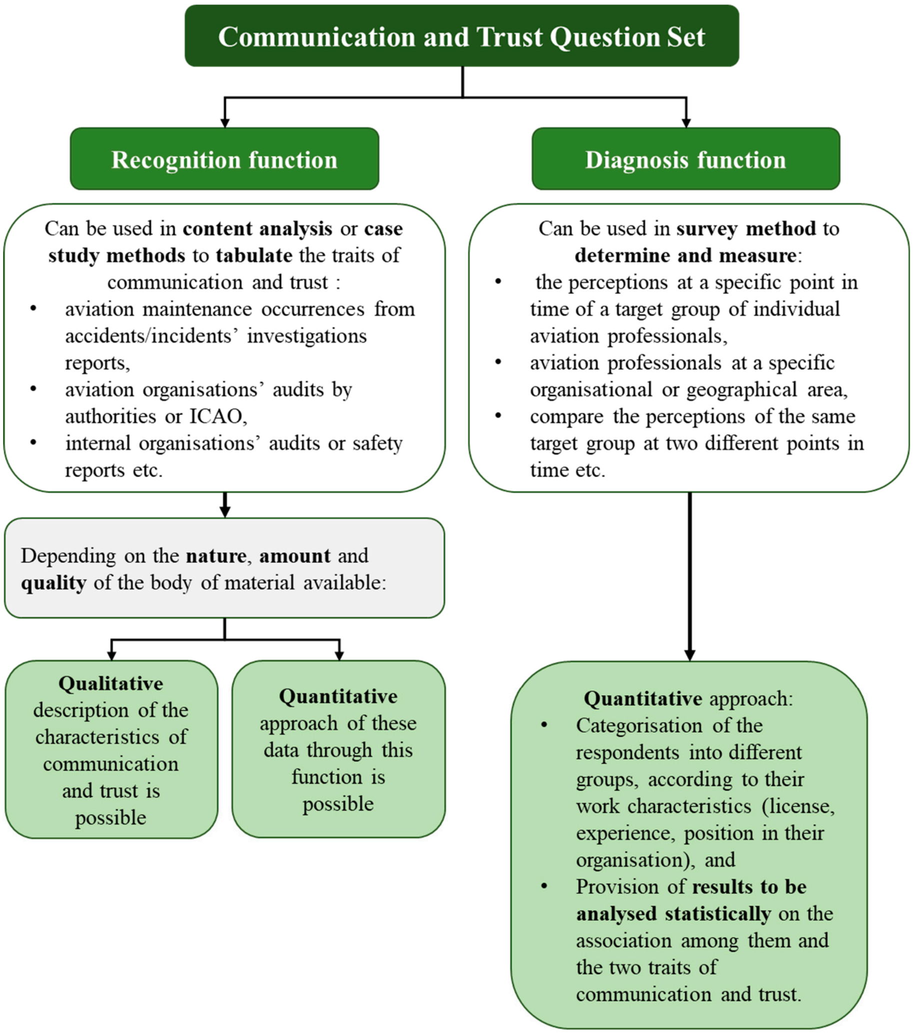

Figure 2. Multifunctional uses of the Communication and Trust Question Set (CTQS).

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 Figure 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.

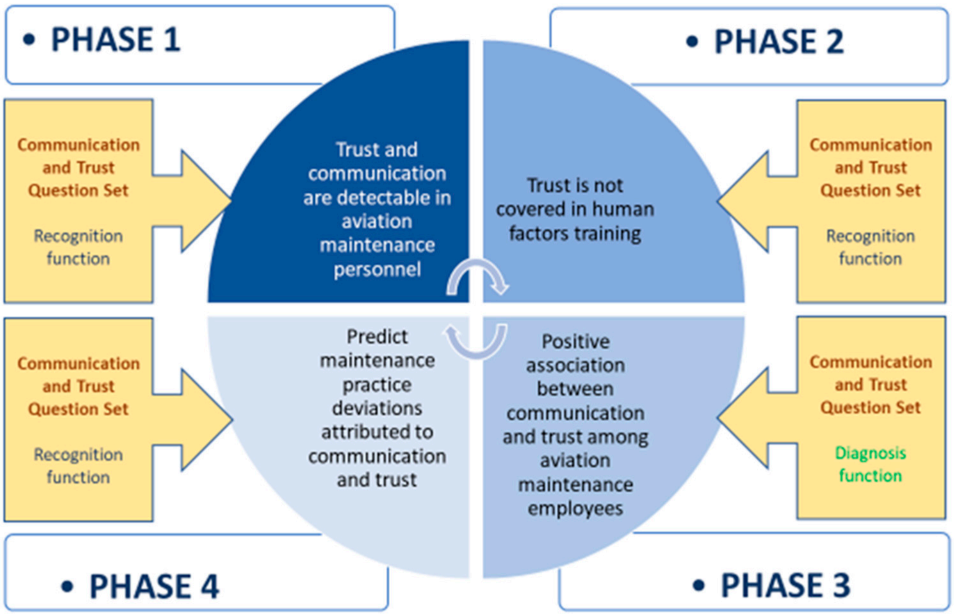

Figure 3. The complete Diagnosis of Communication and Trust in Aviation Maintenance (DiCTAM) model.

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 [46].

Each report was manually scanned for the keywords 'communication' and 'trust' by the author as a Subject Matter Expert (SME) (approved European Union Aviation Safety Agency (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 only 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 divided into 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 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 [47];
- **Coursebook 2:** 'Human factors for A level Certification, module 9' by N. Gold, published in 2015 by Aircraft Technical Book Company in the USA [48].

Table 2. Curriculum of the EASA [49] 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 [47], 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 [48], 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 European Union Aviation Safety Agency (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 [17,18,50–53]. These elements are dissimilar in nature and appear either on personal, group or organizational performance levels [54]. Communication is among these 12 most frequent causes of human error. These twelve factors are:

1. Lack of communication;
2. Complacency;
3. Lack of knowledge;
4. Distractions;
5. Lack of teamwork;
6. Fatigue;
7. Lack of resources;
8. Pressure;
9. Lack of assertiveness;

10. Stress;
11. Lack of awareness;
12. 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 [18,50–52,55]. 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 [52]. 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.

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.

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
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

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 purposes 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) and Harman's one factor, with the help of Statistical Package for Social Sciences (SPSS) Statistics 25.0.0. Further details are provided in a separate paper currently under review [45].

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 [45].

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 [56]. 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)) [56]. 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 [57].

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. [56], 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 a 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 Section 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 Section 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,
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,
D17—Issues whether the attitudes towards communication in the organisation are healthy,
C7—Information about departmental policies and goals,
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,
D6—The organisation's communications are interesting and helpful.

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: Similar 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 Scenarios 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: Similar 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 Scenarios 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 organization,
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 Scenarios 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: Similar to previous scenarios, the dual sign off in conjunction with a robust handover process could mitigate this. 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 Scenarios 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 (Scenarios 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. In bold are the minimum means for communication and trust for each scenario.

		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 output of this exercise summarised the results presented in Table 7, with a two-tier ranking obtained (Groups 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 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

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 [22].).

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 [22]).

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 [22]).

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 [22]).

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 [22]).

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 [37]).

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 [37]).

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

Table A1. 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) [58]	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) [59]	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) [60]	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) [61]	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) [62]	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) [63]	R6.1	F4	C8
		R6.2	F2, F3, F5	
		R6.3		C8, D19

Table A1. *Cont.*

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
R7	Airbus A330-243, A6-EYJ, 06/05/2016, Australian Transport Safety Bureau, Australia (Serious Incident) [64]	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) [65]	R8.1	F2, F3, F5	
		R8.2		C8, D19
R9	Boeing 767, N669US, 28/09/2016, NTSB, USA (Incident) [66]	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) [67]	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) [68]	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) [69]	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	

Table A1. *Cont.*

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
R13	Embraer 190-100LR, P4-KCJ, 02/05/2019, Gabinete de Precenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviarios, Portugal (Accident) [70]	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) [71]	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) [72]	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

Table A2. Mapping of CTQS items against the Dirty Dozen elements.

		Dirty Dozen Element											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Communication and Trust Question Set Items	**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	

Table A2. *Cont.*

		Dirty Dozen Element											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Communication and Trust Question Set Items	**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

References

1. Silvagni, S.; Napoletano, L.; Graziani, I.; Le Blaye, P.; Rognin, L. Concept for Human Performance Envelope. EU Horizon 2020 Research and Innovation Programme. 2015. Available online: https://ec.europa.eu/programmes/horizon2020/en (accessed on 8 January 2018).
2. Bachmann, R. The Coordination of Relations Across Organizational Boundaries. *Int. Stud. Manag. Organ.* **2003**, *33*, 7–21. [CrossRef]
3. Flin, R. Measuring safety culture in healthcare: A case for accurate diagnosis. *Saf. Sci.* **2007**, *45*, 653–667. [CrossRef]
4. Karanikas, N.; Melis, D.J.; Kourousis, K.I. The Balance Between Safety and Productivity and its Relationship with Human Factors and Safety Awareness and Communication in Aircraft Manufacturing. *Saf. Health Work.* **2017**, *9*, 257–264. [CrossRef]
5. Dode, P.; Greig, M.; Zolfaghari, S.; Neumann, W.P. Integrating human factors into discrete event simulation: A proactive approach to simultaneously design for system performance and employees' well being. *Int. J. Prod. Res.* **2016**, *54*, 1–13. [CrossRef]
6. Evans, B.; Glendon, A.I.; Creed, P.A. Development and initial validation of an Aviation Safety Climate Scale. *J. Saf. Res.* **2007**, *38*, 675–682. [CrossRef] [PubMed]
7. Glendon, A.; Litherland, D. Safety climate factors, group differences and safety behaviour in road construction. *Saf. Sci.* **2001**, *39*, 157–188. [CrossRef]
8. Luria, G.; Yagil, D. Safety perception referents of permanent and temporary employees: Safety climate boundaries in the industrial workplace. *Accid. Anal. Prev.* **2010**, *42*, 1423–1430. [CrossRef] [PubMed]
9. O'Connor, P. Assessing the Effectiveness of Bridge Resource Management Training. *Int. J. Aviat. Psychol.* **2011**, *21*, 357–374. [CrossRef]
10. Kourousis, K.; Comer, A. Indian and Chinese aviation industry: The EASA framework option. *Aircr. Eng. Aerosp. Technol.* **2018**, *90*, 246–250. [CrossRef]

11. Balk, A.D.; Bossenbroek, J.W. *Aircraft Ground Handling and Human Factors—A Comparative Study of the Perceptions by Ramp Staff and Management*; NLR-CR-2010-125; NLR Air Transport Safety Institute: Amsterdam, The Netherlands, 2010.
12. Bureau of Air Safety Investigation. Human Factors in Airline Maintenance: A Study of Incident Reports. 1997. Available online: https://www.atsb.gov.au/ (accessed on 10 January 2018).
13. Hobbs, A.; Williamson, A. Associations between errors and contributing factors in aircraft maintenance. *Hum. Factors* **2003**, *45*, 186–201. [CrossRef]
14. Caldwell, J.A. Fatigue in aviation. *Travel Med. Infect. Dis.* **2005**, *3*, 85–96. [CrossRef] [PubMed]
15. Fisher, T.J. Cleared to Disconnect? A Study of the Interaction between Airline Pilots and Line Maintenance Engineers. Ph.D. Thesis, Massey University, Manawatū, New Zealand, 2016. Available online: http://hdl.handle.net/10179/11453 (accessed on 1 September 2019).
16. Mattson, M.; Petrin, D.A.; Young, J.P. Integrating safety in the aviation system: Interdepartmental training for pilots and maintenance technicians. *J. Air Transp. World Wide* **2001**, *6*, 37–64.
17. Dupont, G. The dirty dozen errors in maintenance. In Proceedings of the 11th Symposium on Human Factors in Maintenance and Inspection: Human Error in Aviation Maintenance, Washington, DC, USA, 12–13 March 1997.
18. Flin, R.; O'Connor, P.; Mearns, K. Crew resource management: Improving team work in high reliability industries. *Team Perform. Manag. Int. J.* **2002**, *8*, 68–78. [CrossRef]
19. Weick, K.E. The Vulnerable System: An Analysis of the Tenerife Air Disaster. *J. Manag.* **1990**, *16*, 571–593. [CrossRef]
20. Langer, M.; Braithwaite, G.R. The Development and Deployment of a Maintenance Operations Safety Survey. *Hum. Factors* **2016**, *58*, 986–1006. [CrossRef]
21. Chatzi, A.V.; Martin, W.; Bates, P.; Murray, P. The unexplored link between communication and trust in aviation maintenance practice. *Aerospace* **2019**, *6*, 66. [CrossRef]
22. Downs, C.W.; Hazen, M.D. A Factor Analytic Study of Communication Satisfaction. *J. Bus. Commun.* **1977**, *14*, 63–73. [CrossRef]
23. Appelbaum, S.H.; Benyo, C.; Gunkel, H.; Ramadan, S.; Sakkal, F.; Wolff, D. Transferring corporate knowledge via succession planning: Analysis and solutions—Part 2. *Ind. Commer. Train.* **2012**, *44*, 379–388. [CrossRef]
24. Brunetto, Y.; Farr-Wharton, R. Does the talk affect your decision to walk: A comparative pilot study examining the effect of communication practices on employee commitment post-managerialism. *Manag. Decis.* **2004**, *42*, 579–600. [CrossRef]
25. Carrière, J.; Bourque, C. The effects of organizational communication on job satisfaction and organizational commitment in a land ambulance service and the mediating role of communication satisfaction. *Career Dev. Int.* **2009**, *14*, 29–49. [CrossRef]
26. Chan, S.H.J.; Lai, H.Y.I. Understanding the link between communication satisfaction, perceived justice and organizational citizenship behavior. *J. Bus. Res.* **2017**, *70*, 214–223. [CrossRef]
27. Clampitt, P.G.; Downs, C.W. Employee Perceptions of the Relationship between Communication and Productivity: A Field Study. *J. Bus. Commun.* **1993**, *30*, 5–28. [CrossRef]
28. Gochhayat, J.; Giri, V.N.; Suar, D. Multilevel leadership and organizational effectiveness in Indian technical education: The mediating role of communication, power and culture. *Int. J. Leadersh. Educ.* **2017**, *20*, 491–505. [CrossRef]
29. Jalalkamali, M.; Ali, A.J.; Hyun, S.S.; Nikbin, D. Relationships between work values, communication satisfaction and employee job performance: The case of international joint ventures in Iran. *Manag. Decis.* **2016**, *54*, 796–814. [CrossRef]
30. Mount, D.J.; Back, K.-J. A Factor-Analytic Study of Communication Satisfaction in the Lodging Industry. *J. Hosp. Tour. Res.* **1999**, *23*, 401–418. [CrossRef]
31. Pincus, J.D. Communication Satisfaction, Job Satisfaction, and Job Performance. *Hum. Commun. Res.* **1986**, *12*, 395–419. [CrossRef]
32. Zwijze-Koning, K.; De Jong, M. Evaluating the Communication Satisfaction Questionnaire as a Communication Audit Tool. *Manag. Commun. Q.* **2007**, *20*, 261–282. [CrossRef]
33. Zwijze-Koning, K.H. *Auditing Organizational Communication: Evaluating the Methodological Strengths and Weaknesses of the Critical Incident Technique, Network Analysis and the Communication Satisfaction Questionnaire*; Universiteit Twente: Enschede, The Netherlands, 2016.

34. Rubin, R.B.; Palmgreen, P.; Sypher, H.E. *Communication Research Measures: A Sourcebook*; The Guilford Press: New York, NY, USA, 1994.
35. Gray, J.; Laidlaw, H. Improving the Measurement of Communication Satisfaction. *Manag. Commun. Q.* **2004**, *17*, 425–448. [CrossRef]
36. DeWine, S.; James, A.C. Examining the communication audit: Assessment and modification. *Manag. Commun. Q.* **1988**, *2*, 144–169. [CrossRef]
37. Li, X.; Rong, G.; Thatcher, J.B. Does technology trust substitute interpersonal trust? Examining technology trust's influence on individual decision-making. *J. Organ. End User Comput.* **2012**, *24*, 18–38. [CrossRef]
38. Gefen, D. What Makes an ERP Implementation Relationship Worthwhile: Linking Trust Mechanisms and ERP Usefulness. *J. Manag. Inf. Syst.* **2004**, *21*, 263–288. [CrossRef]
39. Lowry, P.B.; Vance, A.; Moody, G.; Beckman, B.; Read, A. Explaining and Predicting the Impact of Branding Alliances and Web Site Quality on Initial Consumer Trust of E-Commerce Web Sites. *J. Manag. Inf. Syst.* **2008**, *24*, 199–224. [CrossRef]
40. McKnight, D.H.; Carter, M.; Thatcher, J.B.; Clay, P.F. Trust in a specific technology: An investigation of its components and measures. *ACM Trans. Manag. Inf. Syst.* **2011**, *2*, 1–25. [CrossRef]
41. McKnight, D.H.; Kacmar, C.; Choudhury, V. Developing and Validating Trust Measures for e-Commerce: An Integrative Typology. *Inf. Syst. Res.* **2002**, *13*, 334–359. [CrossRef]
42. Nicolaou, A.I.; McKnight, D.H. Perceived Information Quality in Data Exchanges: Effects on Risk, Trust, and Intention to Use. *Inf. Syst. Res.* **2006**, *17*, 332–351. [CrossRef]
43. Stewart, K.J.; Malaga, R.A. Contrast and Assimilation Effects on Consumers' Trust in Internet Companies. *Int. J. Electron. Commer.* **2009**, *13*, 71–94. [CrossRef]
44. Vance, A.; Elie-Dit-Cosaque, C.; Straub, D.W. Examining Trust in Information Technology Artifacts: The Effects of System Quality and Culture. *J. Manag. Inf. Syst.* **2008**, *24*, 73–100. [CrossRef]
45. Chatzi, A.V.; Bates, P.; Martin, W. Communication Satisfaction and Trust towards Safe Practice in the Aviation Maintenance Environment. 2019; under review.
46. Vogt, W.P.; Gardner, D.C.; Haeffele, M.L. *When to Use What Research Design*; Guilford Press: New York, NY, USA, 2012.
47. Strike, C. *Module 9-Human Factors*; Cardiff and Vale College: Cardiff, UK, 2018.
48. Gold, N. *Human Factors for A Level Certification, Module 9*; Aircraft Technical Book Company: Tabernash, CO, USA, 2015.
49. European Aviation Safety Agency. Notice of Proposed Amendment (NPA) 2012-05. Available online: https://www.easa.europa.eu/sites/default/files/dfu/NPA%202012-05.pdf (accessed on 10 June 2019).
50. Blaise, J.-C.; Levrat, E.; Iung, B. Process approach-based methodology for safe maintenance operation: From concepts to SPRIMI software prototype. *Saf. Sci.* **2014**, *70*, 99–113. [CrossRef]
51. Chang, Y.-H.; Wang, Y.-C. Significant human risk factors in aircraft maintenance technicians. *Saf. Sci.* **2010**, *48*, 54–62. [CrossRef]
52. Marquardt, N.; Gades, R.; Robelski, S. Implicit social cognition and safety culture. *Hum. Factors Ergon. Manuf. Serv. Ind.* **2012**, *22*, 213–234. [CrossRef]
53. Wise, J.A.; Hopkin, V.D.; Garland, D.J. *Handbook of Aviation Human Factors*; CRC Press: Boca Raton, FL, USA, 2010.
54. Reiman, T. Understanding maintenance work in safety-critical organisations—Managing the performance variability. *Theor. Issues Ergon. Sci.* **2011**, *12*, 339–366. [CrossRef]
55. Federal Aviation Administration. FAA Aviation Maintenance Technician Handbook-General, Chapter 14, Addendum/Human Factors. In *Aviation Maintenance Technical Handbook*; Service of the United States Department of Transportation, & Flight Standards Service: Newcastle, WA, USA, 2011.
56. Kourousis, K.I.; Chatzi, A.V.; Giannopoulos, I.K. The airbus A320 family fan cowl door safety modification: A human factors scenario analysis. *Aircr. Eng. Aerosp. Technol.* **2018**, *90*, 967–972. [CrossRef]
57. Leedy, P.D.; Ormrod, J.E. *Practical Research: Planning and Design*, 10th ed.; Pearson: London, UK, 2013.
58. Air Accident Investigation Unit. Synoptic Report Serious Incident Airbus, A320-214, EI-GAL Cork Airport (2019-004). Available online: http://www.aaiu.ie/reports/aaiu-investigation-reports (accessed on 10 June 2019).
59. Komite National Keselamatan Transportasi. Indonesia Air Asia Airbus A320-216; PK-AXC Karimata Strait Coordinate 3°37′19″ S-109°42′41″ E (KNKT.14.12.29.04). 2015. Available online: http://knkt.dephub.go.id/knkt/ntsc_aviation/aaic_case.htm (accessed on 10 June 2019).

60. Air Accident Investigation Unit. Serious Incident DHC 6-300, C-GSGF Weston Airport, Co. Kildare. 2016. Available online: http://www.aaiu.ie/reports/aaiu-investigation-reports (accessed on 10 June 2019).
61. Australian Transport Safety Bureau. Undetected Engine Thrust Reverser Deactivation Involving Airbus A320, VH-VGZ. 2019. Available online: https://www.atsb.gov.au/ (accessed on 10 June 2019).
62. The Dutch Safety Board. Gear Collapse during Landing. 2018. Available online: https://www.onderzoeksraad.nl/en/ (accessed on 10 June 2019).
63. Air Accidents Investigation Branch. Boeing 747-443, G-VROM, Damage to Right Wing Landing Gear Door and Strike Board, Near London Gatwick Airport. 2015. Available online: https://www.gov.uk/aaib-reports (accessed on 10 June 2019).
64. Australian Transport Safety Bureau. Air Data System Failure involving Airbus A330-243 A6-EYJ (AO-2013-212). 2016. Available online: https://www.atsb.gov.au/ (accessed on 10 June 2019).
65. National Transportation Safety Board. Aviation Incident Final Report, Boeing 767, N360AA, Incident Report ENG12IA010, 07/12/2012. Available online: https://www.ntsb.gov/investigations/AccidentReports/Pages/AccidentReports.aspx (accessed on 10 June 2019).
66. National Transportation Safety Board. Aviation Incident Final Report, Boeing 767, N669US, Insident Report ENG14IA027, 28/09/2016. Available online: https://www.ntsb.gov/investigations/AccidentReports/Pages/AccidentReports.aspx (accessed on 10 June 2019).
67. Directorate General of Civil Aviation. Ground Fatal Accident to Air India Ltd. Airbus A-319 aircraft VT-SCQ. 2016. Available online: http://dgca.nic.in/ (accessed on 10 June 2019).
68. Japan Transport Safety Board. Aircraft Accident Investigation Report China Airlines, Boeing 737-800, B 18616. 2009. Available online: https://www.mlit.go.jp/jtsb/english.html (accessed on 10 June 2019).
69. Air Accidents Investigation Branch. Report on the Accident to Airbus A319-131, G-EUOE London Heathrow Airport on 24 May 2013. Available online: https://www.gov.uk/aaib-reports (accessed on 10 June 2019).
70. Gabinete de Precenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviarios. Aircraft Accident Information Notice, Embraer 190-100LR, P4-KCJ, 02/05/2019. Available online: www.gpiaa.gov.pt/ (accessed on 10 June 2019).
71. Accident Investigation Division. Report on the Accident to Airbus A330-342 B-HLL Operated by Cathay Pacific Airways Limited at Hong Kong International Airport, Hong Kong on 13 April 2010. Available online: https://www.thb.gov.hk/aaia/eng/index.htm (accessed on 10 June 2019).
72. United States Air Force Accident Investigation Board. Lockheed WC-130H, T/N 65-0968 1.5 Miles Northeast of Savannah/Hilton Head International Airport, Georgia. 2018. Available online: https://www.afjag.af.mil/AIB-Reports/ (accessed on 10 June 2019).