ISSN 1648-7788 / eISSN 1822-4180

VILNIUS TECH
Vilnius Gediminas Technical University

AVIATION

2025
Volume 29
Issue 1
Pages 48–54
https://doi.org/10.3846/aviation.2025.23131

HUMAN FACTORS CONSIDERATIONS FOR CRITICAL MAINTENANCE TASKS AND THEIR EFFECT ON THE TRANSITION TO DIGITAL DOCUMENTATION: AN EXPLORATORY EXPERT SURVEY

David P. AHERNE [1], Ingrid HUNT [1], Kyriakos I. KOUROUSIS [1], Anna V. CHATZI [2]✉

[1]*School of Engineering, Faculty of Science and Engineering, University of Limerick, Limerick, Ireland*
[2]*Department of Nursing and Midwifery, Faculty of Educational and Health Sciences, University of Limerick, Limerick, Ireland*

Article History:
- received 5 October 2024
- accepted 13 December 2024

Abstract. Digitised maintenance documentation will soon be the norm in aviation. Failure to correctly perform maintenance tasks may lead to aviation safety hazardous events. This article explores the views of aviation maintenance subject matter experts on errors affecting critical maintenance tasks and how views can inform transition to digitised documentation. This exploratory study offers a fresh view on human factors' implications around critical maintenance tasks and their relation to digital documentation. A cross-sectional design method was utilised. Anonymous responses were collected with a mixed-methods questionnaire from convenience sample of participants from different aircraft maintenance and continuing airworthiness management organisations. Expert opinions of 25 aircraft maintenance and technical services engineers were recorded. All participants had personal experience with maintenance errors, where human factors attributed to these errors. They highlighted the lack of human factors' awareness and the need to strengthen their contributory role in critical maintenance tasks. Participants' views appeared divided in terms of challenges associated with digital documentation utilisation. Positive features emerged, such as critical maintenance tasks or duplicate/independent inspections' highlighting, notes and warnings' higher visibility, up-to-date documentation availability and better connectivity among activities. Negative themes concentrated on the tactile nature of paper and on the additional technology knowledge requirements.

Keywords: aircraft maintenance, human error, human factors, critical maintenance tasks, digitisation, aviation maintenance documentation.

✉Corresponding author. E-mail: *anna.chatzi@ul.ie*

1. Introduction

Aviation is a highly regulated industry as there is a necessity to ensure high standards of quality and safety. It is imperative that all measures needed to maintain the required standards are implemented. The area of maintenance is fundamental within the aviation operations, with their contribution to accidents and incidents being at the centre of research for many years (Aust & Pons, 2022; Bao & Ding, 2014; Kwakye et al., 2024; Marais & Robichaud, 2012; Paris et al., 2024). Maintenance errors pose a significant threat to quality and safety, with 75% to 80% of accidents attributed to human factors, and approximately 12% of this proportion are linked to aircraft maintenance activities, as per latest figures (Federal Aviation Administration, 2018; Zimmermann & Mendonca, 2021).

Aviation maintenance documentation is a focus area for safety improvement (Alomar & Yatskiv, 2023; Elakramine et al., 2021; Kwakye et al., 2024; Zimmermann & Mendonca, 2021). Research has found insufficient documentation and procedures to be the most frequent causes of accidents (Chatzi, 2019). Communication among aviation maintenance personnel has been identified as one of the primary contributing factor to accidents (Chatzi et al., 2020) with documentation being one of the most profound forms of communication within aviation maintenance (Elakramine et al., 2021; Paris et al., 2024; Zimmermann & Mendonca, 2021). Communication is on the list of the twelve most common factors associated with aviation accidents. These twelve preconditions or conditions to human error became known as the Dirty Dozen: Lack of Communication, Complacency, Lack of Knowledge, Distraction, Lack of Teamwork, Fatigue, Lack of Resources, Pressure, Lack of Assertiveness, Stress, Lack of Awareness, Norms (Blaise et al., 2014; Chang & Wang, 2010; Dupont, 1997; Flin et al., 2002; Marquardt et al., 2012; Wise et al., 2016). These conditions and preconditions are of a different nature and correspond to different levels of performance (personal, team and/or organizational (Reiman, 2011)).

To combat these preconditions, regulations, processes, and procedures have been put in force within the European Aviation Safety Agency (EASA) regulated space. The EASA regulations, outlined by Commission Regulation EU No. 1321/2014 (European Union, 2014), contain, amongst other requirements, ways to counter the effects of human factors. These regulations have been adopted by the Aircraft Maintenance Organisation (AMO) and Continuing Airworthiness Management Organisation (CAMO) departments. The final product has been the creation of the Maintenance Organisation Exposition (MOE) and the Continuing Airworthiness Management Exposition (CAME) documents respectively. These documents are significant in this domain as they indicate the implemented processes and procedures in the adherence to the regulations. This set of requirements indicate that, in an effort to reduce maintenance errors and the accidents associated with these errors, we must take into consideration the human factors that lead to these occurrences.

In the course to modernise aviation maintenance and enhance efficiency, the discussion has commenced on digitising all maintenance documentation. Reflecting relevant research activity in enhancing aviation maintenance documentation (Alomar & Yatskiv, 2023; Aust & Pons, 2022; Bao & Ding, 2014; Elakramine et al., 2021; Kwakye et al., 2024), EASA recently issued guidelines on effective use (European Aviation Safety Agency, 2023b). The aim of this article is to explore the views of aviation maintenance subject matter experts under their capacity as expert system users. These views are very critical in identifying the challenges of moving towards the maintenance documentation digitisation.

2. Method

Research design

This project uses a phenomenological design utilizing a structured, open-ended questionnaire collected anonymously through a convenience sample from different AMOs and CAMOs. Phenomenological design is the appropriate design when exploring experiences and attitudes of participants regarding the research topic of the study (Leedy & Ormrod, 2020). The snowball sampling method was utilised for the purposes of this study. Initial invitations to the project were sent by email to work contacts and consequently to participants that were referred or proposed by initial contacts/participants. Participants were able to reply to questions anonymously through Google Forms. This project is exploratory in nature, in qualitatively extracting subject matter experts' views in identifying the challenges of moving towards the maintenance documentation digitisation.

Participants

Twenty-five full responses were collected and were deemed typical for the phenomenological design of this study (Leedy & Ormrod, 2020). Participants' inclusion criteria were holding Category B1 certification as Aircraft Maintenance Technician (AMT), having experience with aircraft maintenance records and/or aircraft maintenance documentation, in Quality, Technical services and CAMO or aircraft maintenance certification, with no exclusion criteria in regard to age (besides the need for participants to be over eighteen years old) and years of experience. The years of experience among participants was not an exclusion criterion as the aim was to gather unbiased responses; digitisation is a new development in the area and feedback from participants both novice and experienced professionals in aircraft maintenance certification was deemed beneficial. Being a Category B1 AMT requires standardised training and meeting certain regulatory requirements. Twenty-five EASA approved Category B1 AMTs participated in this questionnaire-based survey who, at the time of the survey, held either the role of technical services engineer or certifying aircraft maintenance staff. Participants workplaces were three AMOs, and four CAMOs.

Ethics

Ethics approval for this work was obtained from the Ethics Committee of the Faculty of Science and Engineering of the University of Limerick. The corresponding Ethics Approval identification is 2022_12_07_S&E.

Instrument

This structured, open-ended questionnaire was designed by the authors to allow pragmatic data collection with items included in the Appendix. Textual responses to questions were analysed with the use of content analysis methodologies. Answers were evaluated for the identification of themes in participants' answers. Next, themes were evaluated as per their weight, depending on the number of participants they were supported by.

3. Results

From the study's demographic questions results indicated that 64% of the participants had experience of performance/review of balancing aircraft flight controls. 72% of participants had more than ten years' experience of aircraft maintenance certification. With regards to critical maintenance

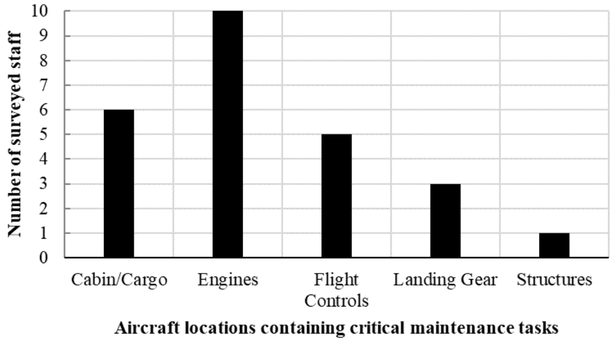

Figure 1. Number of surveyed staff with experience on the different aircraft locations containing critical maintenance tasks

tasks, the primary locations are the engines, flight controls and landing gear, with limited exposure to critical maintenance tasks in cabin/cargo and structures; therefore, most of the surveyed staff had experience on engines, and less on landing gear and flight controls (Figure 1).

Participants' responses were collected, and content analysis was performed to identify themes. Four major themes emerged from data: awareness on maintenance error, human factors, proposed changes and digitisation of documentation.

Awareness on maintenance error

The majority of participants had, at a minimum, a basic understanding of the check flight requirements following the balancing of aircraft flight controls. Some participants went into great detail regarding the reasons behind the flight test and the importance of safety on those aircraft with certain types of emergency control systems. This shows that participants were mostly aware of the possible requirements in theory rather than having practical experience of the task themselves. This could be linked with some participants appearing unaware of the potential follow-on tasks.

Participants (56%) believed that there is not sufficient awareness of the impact of maintenance errors within aviation. The aircraft maintenance manual was reported to be the primary source of participants' knowledge (64%), as illustrated on the upper layer of the Figure 2 graph. Few of the participants (3%) would turn to another maintenance engineer/certifier when in question regarding the balancing of flight controls and potential check flight requirements.

Next, participants were requested to rate the instructions as described in the maintenance documentation (i.e., aircraft maintenance manual, structural repair manual), on the ability for these tasks to be easily followed and understood. The tasks in question were the flight control balancing and any subsequent follow-on maintenance tasks. Respondents rated them 6.32 out of 10, which is a little above average.

Human factors

When asked, all participants indicated human error and/or human factors to be the most probable causes of aviation maintenance errors. The participants either named one of the Dirty Dozen listed human factors/error as the most probable cause or stated other items which can easily be linked to one of the Dirty Dozen. The answers that appeared most popular among participants were lack of knowledge, pressure, stress and poor communication. These four themes (human factors) constitute the pillars in the graph of Figure 2 (top layer), under which the findings of the three other themes (awareness on maintenance error, proposed changes and digitisation of documentation) are related and/or interact with each human factor.

The errors described in their responses ranged from serious incidents, (such as the flight deck window blow out due to incorrect parts and a McDonnell Douglas MD-80 aircraft stabilizer loss due to insufficient lubrication), to less serious maintenance errors (like incorrect recording of part number and serial numbers, improper completion of maintenance paperwork). Other errors listed, while they did not cause an incident as they were captured, they did incur additional costs, both financially and timewise, such as performing tasks on the wrong components or systems, (e.g., the wrong engine). Such occurrences, if not captured, have the potential for profound consequences.

Proposed changes

When asked on the processes and procedures within their department to help minimise maintenance errors when performing critical maintenance tasks, participants indicated duplicate/independent inspections as the prominent answers. Their basic idea was that two sets of eyes are better than one at spotting errors or omissions (namely, embedding redundancy features in the processes). They indicated this method as appropriate in helping to reduce the risk of a maintenance error occurrence. Another popular theme that emerged was the importance of indicating (highlighting) critical maintenance tasks to increase the visibility of when special care and procedures are required. In particular work orders, last done / next due statuses, and tally sheets were the most frequent documentation categories mentioned.

Each participant proposed actions that they felt would contribute positively to reducing maintenance errors. These actions were in the remit of reducing the human factors impacts on certifiers, reducing the pressure from management, not distracting certifiers and engineers when performing complex and/or critical maintenance tasks. Another proposal from participants was to shift to managers the responsibility for the certified return to service. This change could make managers prioritising safety/quality of the final product over the financial cost. Also, participants supported the introduction of checklists for more complex tasks, dedicated training for critical maintenance tasks and increased certification requirements for complex/critical maintenance tasks.

Participants were asked whether they thought additional steps or explanation were required on other critical or follow-up maintenance tasks they had performed. Some participants thought that further steps and/or explanation were needed for the following tasks: leak checks after pressure panel installation, flight control cable rigging, engine vibration surveys, aircraft weighing, elevator rigging, elevator/aileron balance tab. In particular, their proposed safeguards included linking task cards directly to the applicable maintenance manuals. This would allow quick access for review of the maintenance task instructions. Also, the addition of such links would benefit the MOE, as the internal procedures could be reviewed more easily that way (i.e. if required during the task to ensure correct compliance, such as in the case of accessing company's refuelling procedures in preparation for such a maintenance task).

In relation to critical maintenance tasks, the addition of requirement for independent inspections on creation of the task card, would ensure its visibility to the performers and would require the certification of a duplicate inspection before the task card could be closed. The simple addition of a check box for accurate compliance with the independent inspection procedure would act as a reminder to certifiers for double check before signing the card as complete. Also, the wide use of colour-coded notes and warnings in the task card or maintenance manual would increase visibility.

More general recommendations were also made. These included: increasing familiarity with critical maintenance tasks and independent inspections, making tasks that include many pre–Service Bulletin and post-Service Bulletin options more straight forward, reducing the noise of unwanted or unneeded information in maintenance documents, addition of independent inspection requirements to the maintenance documentation. Other responses indicated that there were no additional tasks they deemed requiring additional steps and/or explanation, with one participant stating they believed that the relevant systems they have used were quite user friendly. The findings from this theme are summarised in the middle layer of the Figure 2 graph (where the maintenance documentation-related findings are indicated separately).

Digitisation of documentation

There is an ongoing discussion on moving towards the digitisation of aircraft maintenance task cards as it is a substantial milestone in the modernisation of the aircraft maintenance environment. The participants were asked how they thought this would impact the occurrence of maintenance errors. Responses were mixed as some participants believed it will have a positive impact on safety, namely lowering the occurrence of maintenance errors (52%), others supported

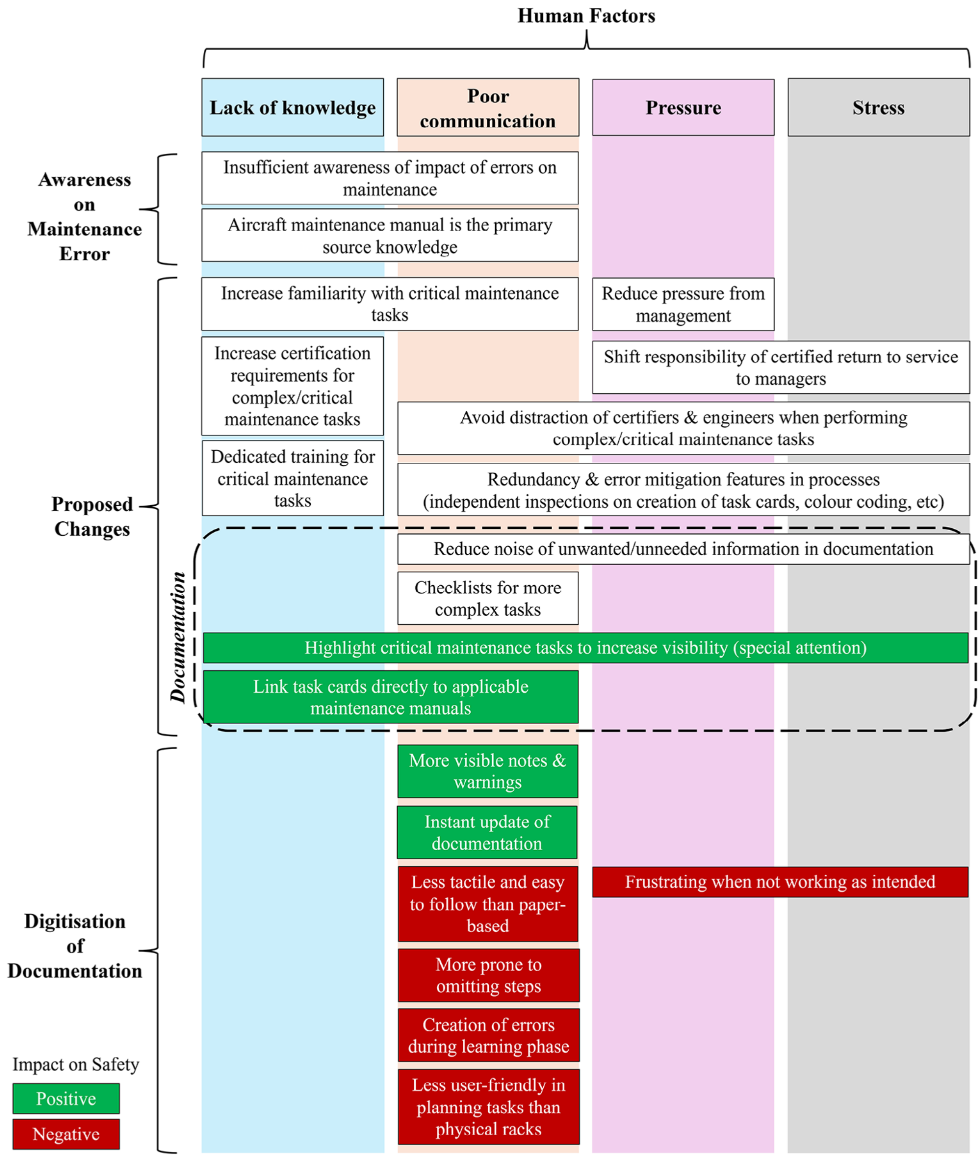

Figure 2. Graphic summary of the findings for each of the four themes which emerged from the exploratory research and their relations/interconnections

a negative impact on safety (44%), and few thought no impact on maintenance errors will occur (3%).

The positives offered in the survey responses included the ability to highlight certain tasks such as critical maintenance tasks or duplicate/independent inspections. This could also work for notes and warnings which would be more visible on the screen than on printed paper. The digitisation would allow for the most recent revisions of the maintenance documentation to be available instantly to the mechanics performing the tasks and the AMTs/engineers performing the certification. It would also allow for better linking between tasks and any related function, adjustments, or follow-on maintenance requirements.

On the negative impacts on safety, it is thought that a physical piece of paper is more tactile and easier to follow than instructions on a screen. Soft documents, when read on screen, increase the possibility of omitting steps as personnel might be inclined to "tick the box" more easily. Extra frustration and stress (human factors) when the digital system does not work as intended. Also, the possibility of additional errors occurring until engineers come up to speed with the new system was mentioned. From a planning perspective, personnel would be more easily able to view the workload when all task cards are displayed on a rack, than just viewing digital labels on a screen.

In the bottom layer of the Figure 2 graph, again the findings for this theme are summarised. A distinction between those which have positive and negative impact on safety is made.

4. Discussion and conclusions

Regulations, processes, and procedures within aviation maintenance are designed to mitigate or eliminate maintenance errors, however errors still occur every day (Federal Aviation Administration, 2018; Zimmermann & Mendonca, 2021). These errors are mostly low risk and pose little to no danger to flight safety, but, when a maintenance error occurs during the performance of a critical maintenance task, the risk to flight safety is high. One of this study's themes is the participants belief that there is not sufficient awareness of maintenance errors and their potential consequences. The coverage of the specified area of maintenance errors in human factors initial and recurrent training modules would be of great benefit. The participants' responses supported an analytical review of the critical maintenance task procedures to identify potential sources of error.

With the inevitable move towards digitisation of maintenance documentation and task cards, the opportunity presents itself to provide additional safeguards against maintenance errors. According to this project's results, any identified sources of opportunity for maintenance errors could be amended through the human factors perspective. The expert participants of this project have identified such opportunities. As for the digitisation of aviation maintenance task cards, participants did not appear to be cohesive to their reactions. The group was split in half between those who identified the positives and those who identified the negatives.

This shows the concern of expert practitioners on the novelty of digitisation as it is anticipated to create a new source of concern to their already complex operational activities (Alomar & Yatskiv, 2023). Positive features have been identified such as: critical maintenance tasks or duplicate/independent inspections' highlighting, notes and warnings' higher visibility, up to date documentation availability and better linking between tasks and any related function, adjustments, or follow-on maintenance requirements. However, a physical piece of paper is more tactile and easier to follow with no need for extra training and knowledge on any software.

Within the not-too-distant future, maintenance personnel will be carrying tablet computers around instead of paper documents. This exploratory project provides aviation maintenance expert opinion on relevant areas that need attention. Further research on implications and improvements towards safety in aviation maintenance digital documentation is recommended. These timely recommendations are especially aligning with the actions set out in the EASA European Plan for Aviation Safety (EPAS) 2023-25 on the development of design principles for electronic checklists for maintenance tasks (European Aviation Safety Agency, 2023a).

Limitations

The small sample size (N = 25) and snowball sampling do not mean that the sample represents the total population. This project is categorised as exploratory by providing aviation maintenance expert opinion on relevant areas that need attention. From its nature, this project aim is to provide direction for further research on implications and improvements towards safety during the digitisation of aviation maintenance documentation. For this reason, participants' responses were treated qualitatively, by identifying the emerged themes.

Acknowledgements

To Liam Moloney for our conversations and feedback through the course of the project.

Funding

No funding was received for conducting this study.

Author contributions

DA, IH and AVC conceptualised the study. DA performed the data curation, formal analysis and data visualisation. DA, IH and AVC performed the investigation. DA, IH, AVC and KIK were responsible for the methodology. DA and IH administered the project. DA, AVC and KIK performed the validation. DA and AVC wrote the original draft. DA, AVC, KIK and IH reviewed and edited the draft.

Disclosure statement

The data used and/or analysed in the current study are contained within the manuscript or available from the corresponding author on reasonable request.

References

Alomar, I., & Yatskiv, I. (2023). Digitalization in aircraft maintenance processes. *Aviation*, *27*(2), 86–94. https://doi.org/10.3846/aviation.2023.18923

Aust, J., & Pons, D. (2022). Assessment of aircraft engine blade inspection performance using attribute agreement analysis. *Safety*, *8*(2), Article 23. https://doi.org/10.3390/safety8020023

Bao, M., & Ding, S. (2014). Individual-related factors and management-related factors in aviation maintenance. *Procedia Engineering*, *80*, 293–302. https://doi.org/10.1016/j.proeng.2014.09.088

Blaise, J.-C., Levrat, E., & Iung, B. (2014). Process approach-based methodology for safe maintenance operation: From concepts to SPRIMI software prototype. *Safety Science*, *70*, 99–113. https://doi.org/10.1016/j.ssci.2014.05.008

Chang, Y.-H., & Wang, Y.-C. (2010). Significant human risk factors in aircraft maintenance technicians. *Safety Science*, *48*(1), 54–62. https://doi.org/10.1016/j.ssci.2009.05.004

Chatzi, A. (2019). *The role of communication in aviation maintenance and its relation to trust* [PhD Thesis, University of Southern Queensland]. https://research.usq.edu.au/item/q5xwv/the-role-of-communication-in-aviation-maintenance-and-its-relation-to-trust

Chatzi, A. V., Bates, P. R., & Martin, W. L. (2020). Exploring the association between communication satisfaction and trust in the aviation maintenance environment: An international study. *The International Journal of Aerospace Psychology*, *30*(3–4), 190–214. https://doi.org/10.1080/24721840.2020.1801347

Dupont, G. (1997). The dirty dozen errors in maintenance. In *11th Symposium on Human Factors in Maintenance and Inspection: Human Error in Aviation Maintenance*. Washington, DC, USA.

Elakramine, F., Jaradat, R., Hossain, N. U. I., Banghart, M., Kerr, C., & El Amrani, S. (2021). Applying systems modeling language in an aviation maintenance system. *IEEE Transactions on Engineering Management*, *69*(6), 4006–4018. https://doi.org/10.1109/TEM.2021.3089438

European Aviation Safety Agency. (2023a). *European Plan for Aviation Safety (EPAS) Volume II EPAS actions* (European Plan for Aviation Safety (EPAS). EASA.

European Aviation Safety Agency. (2023b). *Guidelines on the use of electronic documents, records, and signatures*. EASA.

European Union. (2014). *Commission Regulation (EU) No 1321/2014 of 26 November 2014 on the continuing airworthiness of aircraft and aeronautical products, parts and appliances, and on the approval of organisations and personnel involved in these tasks* (L 362/361 - L362/194).

Federal Aviation Administration. (2018). *Aviation handbooks & manuals.* https://www.faa.gov/regulations_policies/handbooks_manuals/aviation

Flin, R., O'Connor, P., & Mearns, K. (2002). Crew resource management: Improving team work in high reliability industries. *Team Performance Management*, *8*(3/4), 68–78. https://doi.org/10.1108/13527590210433366

Kwakye, A. D., Jennions, I. K., & Ezhilarasu, C. M. (2024). Platform health management for aircraft maintenance – a review. *Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering*, *238*(3). https://doi.org/10.1177/09544100231219736

Leedy, P. D., & Ormrod, J. E. (2020). *Practical research: Planning and design* (12th ed.). Pearson Education.

Marais, K. B., & Robichaud, M. R. (2012). Analysis of trends in aviation maintenance risk: An empirical approach. *Reliability Engineering & System Safety*, *106*, 104–118. https://doi.org/10.1016/j.ress.2012.06.003

Marquardt, N., Gades, R., & Robelski, S. (2012). Implicit social cognition and safety culture. *Human Factors and Ergonomics in Manufacturing & Service Industries*, *22*(3), 213–234. https://doi.org/10.1002/hfm.20264

Paris, F., Casanova, R., Bergeonneau, M.-L., & Mestre, D. (2024). Differences between Experts and novices in the use of aircraft maintenance documentation: Evidence from eye tracking. *Applied Sciences*, *14*(3), Article 1251. https://doi.org/10.3390/app14031251

Reiman, T. (2011). Understanding maintenance work in safety-critical organisations–managing the performance variability. *Theoretical Issues in Ergonomics Science*, *12*(4), 339–366. https://doi.org/10.1080/14639221003725449

Wise, J. A., Hopkin, V. D., & Garland, D. J. (2016). *Handbook of aviation human factors*. CRC Press. https://doi.org/10.1201/b10401

Zimmermann, N., & Mendonca, F. A. C. (2021). The impact of human factors and maintenance documentation on aviation safety: An analysis of 15 years of accident data through the PEAR framework. *The Collegiate Aviation Review International*, *39*(2), 1–25. https://doi.org/10.22488/okstate.22.100230

Appendix

1. Survey Information Sheet
2. Survey Consent Form
3. Which of the following most closely describes your current role?
   - Aircraft Maintenance Engineer/Certifier/CRS
   - Technical Services Engineer with Aircraft Maintenance Experience
   - Technical Services Engineer with No Aircraft Maintenance Experience
   - Other
4. How much experience, if any, in Aircraft Maintenance Certification do you have?
   - Less than 5 Years
   - 5–10 Years
   - 10+ Years
   - None
5. Which of the following Aircraft areas would you have the most experience with?
   - Cabin/Cargo
   - Engines
   - Flight Controls
   - Landing Gear
   - Structures
6. What do you think are some of the most probable causes of Aviation Maintenance Error?
7. Can you please provide some examples of Aviation Maintenance Errors you are aware of?
8. In your opinion, how might Human Factors affect the occurrence of Aviation Maintenance Errors?
9. Have you performed the aviation maintenance task and/or reviewed the maintenance records for the Balancing of Aircraft Flight Controls?
   - Yes
   - No
10. Please provide a brief synopsis of your understanding of the Maintenance Tasks and potential Check Flight Requirements following Balancing of Aircraft Flight Control Surfaces on aircraft types with a Manual Reversion Emergency Control system?
11. With regards to the previous question, what was the primary source of your knowledge?
    - Aircraft Type Course
    - Aircraft Maintenance Manuals
    - Another Maintenance Engineer/ Certifier
    - Other
    - N/A
12. On a scale of 1–10, Do you find the directions outlined in the Maintenance Manuals, AMM/SRM, relating to Flight Control Balancing and any follow-on tasks easy to follow and understand?
13. What are some of the processes and procedures within your department to help minimise maintenance errors when performing Critical tasks?
14. Are there any additional steps that you believe could be implemented to lessen the impact of Human Factors on maintenance errors during critical maintenance tasks?
15. Are there other Critical or Follow-on Maintenance Tasks you have performed, or reviewed, that you think require additional steps and/or explanation to be more user friendly?
16. Do you think there is enough awareness on the potential impact of Maintenance Errors within Aviation?
    - Yes
    - No
17. How do you think the move towards digitisation of aircraft maintenance task cards will impact the occurrence of Maintenance Errors?