Influence of information technologies on the human factors in aviation

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Abstract

Human factors' role in aviation is crucial for ensuring the safe and efficient integration of technology with humans. This is of utmost importance, especially given the rapid development and widespread use of information technologies. Studies have revealed that detecting and addressing mistakes made by maintenance personnel can be particularly difficult and their effects may remain unnoticed, compared to other threats to aviation safety. The purpose of this paper is to investigate the impact of information technologies on human factors in aviation, particularly in the context of maintenance. After an analysis of literature and incident statistics, the distinct human factors concern in aviation maintenance has been brought to attention. The results indicate that one of the most critical criteria is a tight limitation of time and rush. On this basis, it is recommended to update current approaches and models for the reliability estimation of aviation staff or create new ones. Further research is needed to determine the most critical quality-relevant factors and the lasting influence of information technologies on aviation personnel.

Keywords

Informational technologies, aviation safety and security, human factors, reliability, maintenance, errors

1. Introduction

The primary goal of civil aviation is to guarantee the safety and consistency of aircraft operations. Human factors and performance impact every aspect of safety. It is crucial to understand that addressing human factors leads to safety enhancements across all safety-related concerns. With the rapid advancement of information technology in aviation, this problem has become even more critical. Information technology (IT) has spread faster than most other technologies in modern times, leading to numerous human factors issues in aircraft operations that still require solutions.

It should be noted that for decades, one of the most popular ideas in aviation reports and literature is the idea that human factor means pilot errors. It's crucial to prioritize human performance for aviation safety. This means taking an integrated approach that considers equipment and system design, procedures, training, and competency, while also acknowledging the impact of rapidly advancing technology.

Ensuring proper maintenance is crucial for aviation safety. Unfortunately, aviation accidents and incidents often occur due to improper maintenance, which can result from human errors. These may include incorrectly installed parts, missing components, and neglected checks. While the exact numbers are unknown, most maintenance errors are likely minor. However, a small percentage of these errors can pose serious safety risks. Unlike other aviation safety threats, detecting maintenance personnel

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mistakes can be difficult, and their effects can remain hidden, potentially compromising the safety of aircraft for extended periods. [1]

Sometimes, maintenance responsibilities can be overly detailed and not specific enough, which can result in errors under certain circumstances. Aviation maintenance engineers often operate pressed on time due to the importance of flight schedules. The carriers continuously increase the usage rate of aircraft to cope with the economic difficulties in the aviation industry.

So, the significant advancements in information technology are that they can unload aviation staff and better manage their work. On the other hand, IT has its negative points as well. They can lead to a loss of vigilance, and responsibility and a decrease in attention of staff during aircraft operation.

A challenging problem that arises in this domain is that aircraft reliability and aviation safety are based on the operational efficiency of aircraft maintenance engineers and their ability to perform responsibility on time, error-free, and accurately.

An analysis of current approaches and methods of human-operator reliability prediction and research of operational aspects of aviation maintenance engineer tasks have detected a range of common factors in engineer activities. Users can assess their dependability and identify the significant quality-related aspects, along with the impact of information technologies on them.

2. Literature review

Previous studies for a human-operator reliability estimation were traditionally related to the flight crew activity and, to a lesser degree, to air traffic controller (ATC) activities.

In the past, there has been a lot of confusion in written works about how trustworthy maintenance engineers are. It is a significant deficiency since it is quite understandable that human error during the maintenance of an aircraft is as critical to flight safety as well as mistakes of pilots or air traffic controllers.

Regrettably, the majority of current reliability prediction practices for human operators are primarily associated with industries such as atomic energy or chemistry. Some of these practices include:

- A Technique for Human Error Rate Prediction (THERP) [34];
- Accident Sequence Evaluation Program (ASEP) [2];
- Human Error Assessment and Reduction Technique (HEART) [3, 4, 5, 6, 27];
- A Technique for Human Event Analysis (ATHEANA) [7, 8];
- Cognitive Reliability and Error Analysis Method (CREAM) [9, 26];
- Absolute Probability Judgements (APJ) [10, 11];
- Human Reliability Management System (HRMS) [12, 13, 14];
- Conclusions from Occurrences by Descriptions of Actions (CODA) [15].

It's important to recognize that some practices related to aviation maintenance fail to consider the unique aspects of the industry and the critical factors that impact maintenance personnel. However, there have been efforts to update certain practices to better suit the aviation industry's needs, such as the adaptation of Connectionism Assessment of Human Reliability (CAHR) for ATC tasks in EUROCONTROL. In some instances, accidents in other industries, like the nuclear industry, have been compared to aviation incidents.

Furthermore, there are techniques that concentrate on investigating particular aspects of the human operator in the aviation industry. The study of maintenance engineer reliability is a continuous process, with earlier research serving as a basis for more comprehensive comprehension. In collaboration with the International Air Transport Association (IATA), the Human Factors Research Project at the University of Texas in Austin established the Threat and Error Management (TEM) framework. This framework enables the evaluation of data from regular and anomalous operations (as demonstrated in Fig. 1), with a primary emphasis on pilot behavior.

However, Boeing Commercial Aviation Services has developed the Maintenance Error Decision Aid (MEDA) process, which investigates events caused by maintenance technicians and inspector performance. Recently, MEDA has been referred to as an "event" investigation process rather than an "error" investigation process, as events can involve both errors and noncompliance with regulations, policies, processes, and procedures.

One effective approach to address maintenance tasks is through decomposition or structuring. An example of this is the SLIM-MAUD Success likelihood index method, which utilizes multi-attribute utility decomposition and can be tailored to specific maintenance needs [17].

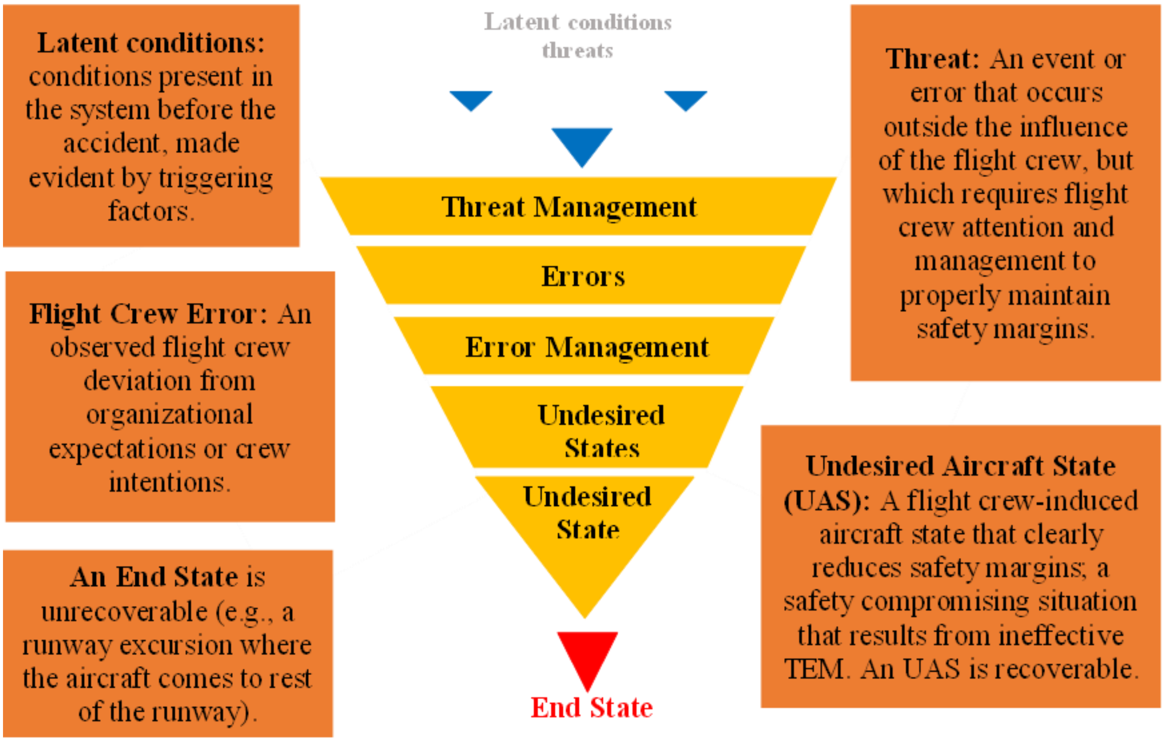

Figure 1: Threat and error management (TEM) framework

Moreover, other reliability models and practices used the techniques of structural decomposition of operator activity [18, 19]. However, such an approach requires a detailed study and grouping of factors having an impact on the reliability of maintenance engineers. Additional studies to understand more completely the critical tenets of the reliability of maintenance engineers are required.

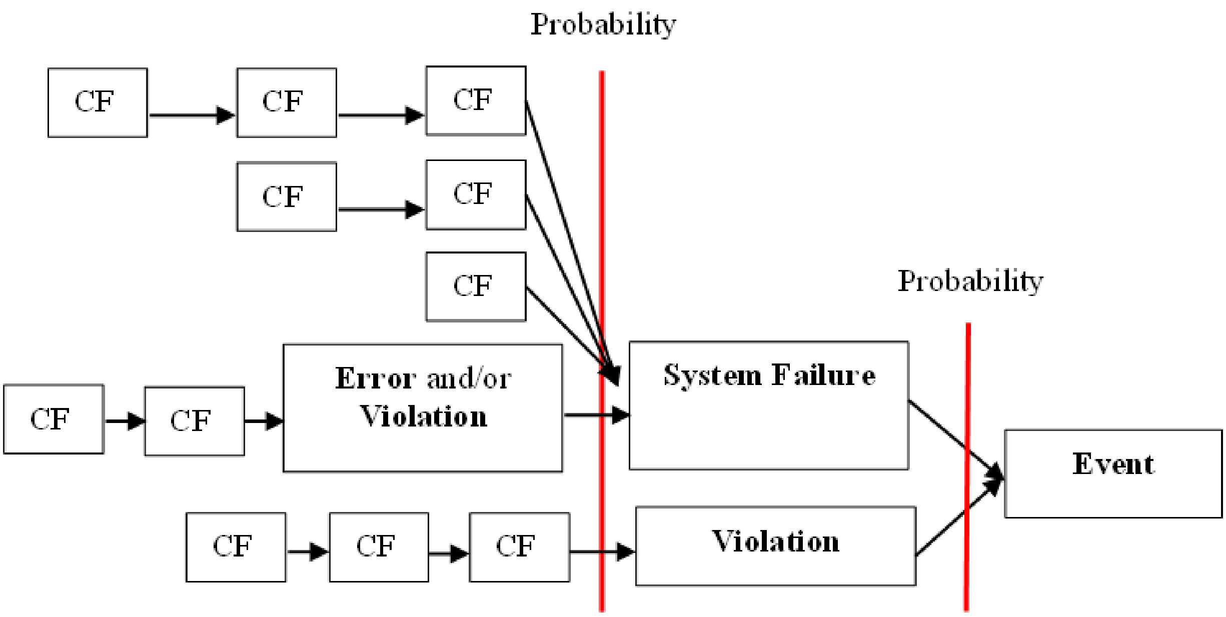

Figure 2: MEDA Event Model. Where CF - Contributing Factor

3. Problem statement

There is a growing awareness of the importance of taking into account the reliability of a human operator in the maintenance and inspection of aviation systems. Statistical analysis performed by IATA [33] shows that approximately 10% of all aviation accidents are caused by maintenance events (Fig. 3).

Safety and efficiency of flights also become more directly related to the operating quality of people who check and maintain aircraft fleets of airlines, remotely piloted aviation systems (RPAS), and others.

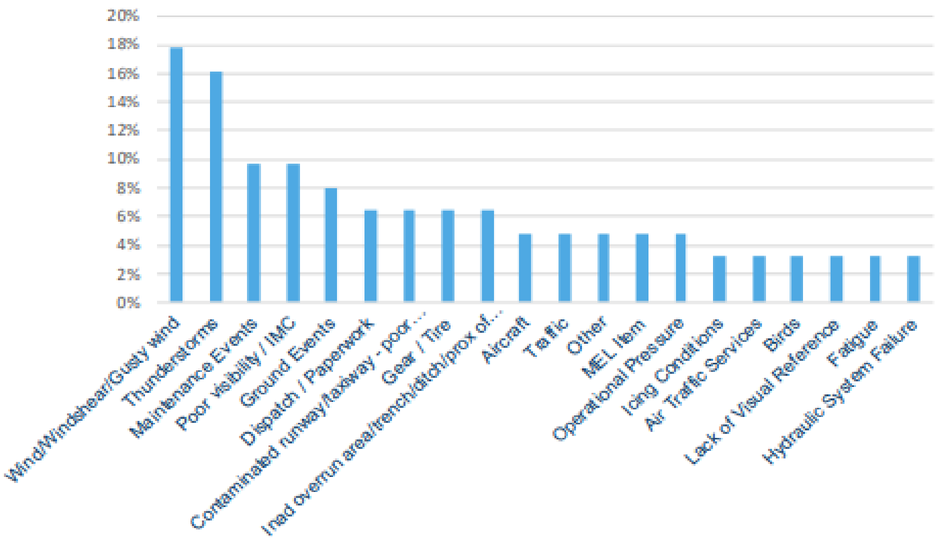

Figure 3: Accident Secondary Contributing Factors Distribution by IATA

The reliability estimation of aviation maintenance engineers can be a probabilistic estimate of the successful completion of an operation or set of tasks at a given stage of system operation during a specific time interval (Fig. 4).

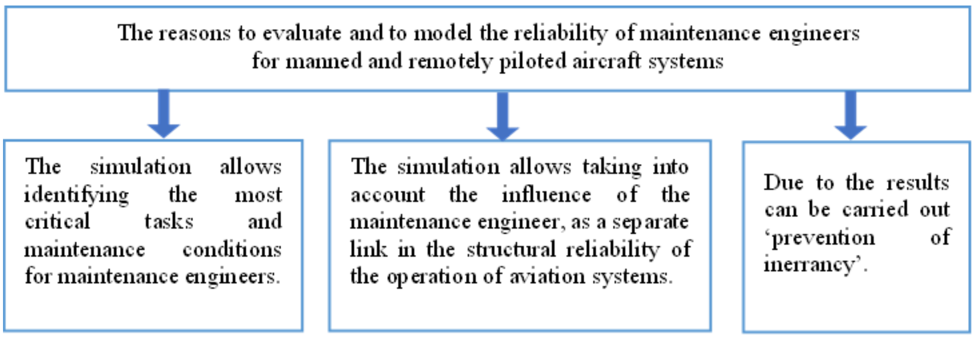

Figure 4: Reasons for new approaches and models for assessing the reliability and operator error

Unfortunately, current practices, which is used in reliability, ergonomics, engineering psychology, aviation psychology, aviation medicine, and other areas, do not make it possible in full evaluate the efficiency and reliability of manned and remotely piloted aircraft systems maintenance engineer, as well as his impact on the reliability of aviation systems and flight safety.

The findings mentioned above, signal the need for additional studies to understand more about the reliability prediction of aviation maintenance staff and its vital importance for fight safety, and determine the problem statement, purpose, and objectives of the research.

4. Approach for assessment of aircraft maintenance engineer errors or events

The most critical factor that is emphasizing the necessity of the reliability prediction of an aircraft maintenance engineer is that the simulation allows a better understanding of the causes of errors occurring for various human operators in different conditions and the relationship between these causes. In addition, to identify the most critical task for the aircraft maintenance engineer, which caused the most significant flow of errors.

The obtained results and data can be used for advanced professional training of aircraft maintenance engineers. Reduce the probability of error, as well as for taking into account human error during reliability prediction for any aviation systems.

When evaluating the reliability of an operator, the probability of error-free operation is a crucial factor, similar to how the probability of successful operation is vital in assessing technical systems' reliability. The probability of error-free operation, represented by R(t), indicates the operator's consistent performance during their duty cycle.

$$R(t) = \Phi\left(\frac{\alpha - t}{\beta \cdot \sqrt{\alpha \cdot t}}\right) - \exp\left(\frac{2}{\beta^2}\right) \cdot \Phi\left(\frac{\alpha + t}{\beta \cdot \sqrt{\alpha \cdot t}}\right) \quad (1)$$

where α is the average time of operation of aviation engineer to the first error, β is the coefficient of variation of aviation engineer to error, $\Phi(\bullet)$ is an integral Laplace function.

The reliability of an aircraft maintenance engineer refers to the likelihood of successfully completing a task at a certain system operating step within a specified time interval [20]. To maintain reliable operation, it is essential to maintain a predetermined level of accuracy in the engineer's activities over an extended period. Therefore, the reliability of a human operator can be defined as their ability to maintain necessary operating qualities even under challenging operational circumstances.

Nowadays, it has become necessary to evaluate the reliability of human operators not just based on the outcome of their tasks but also on their psychological and physiological indicators [21].

Knowing the functional of operating procedure, regularity and mechanisms of the behaviour of a human operator and state in special conditions allows not only to assess the level of reliability but also to justify recommendations for keeping reliability at the required level. An error of a maintenance engineer can occur in the following cases see Fig. 5 [22].

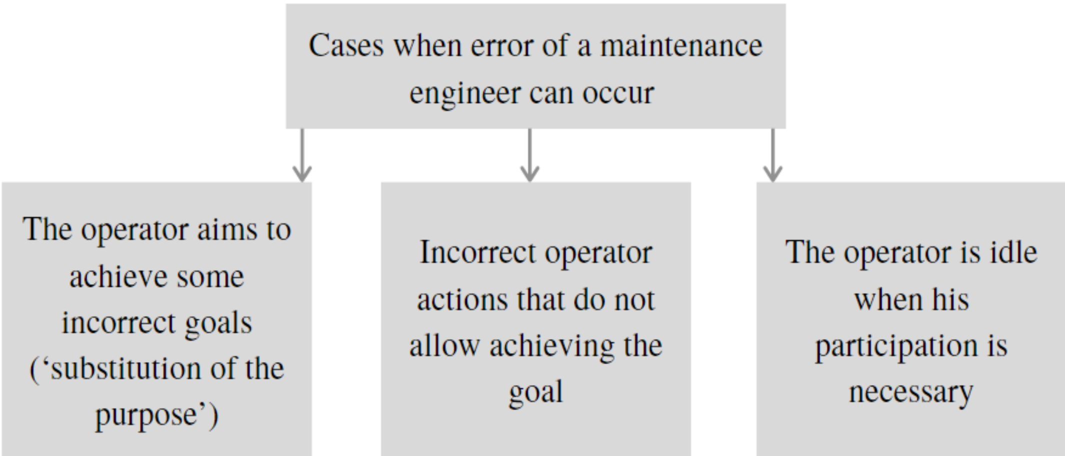

Figure 5: Cases when error of a maintenance engineer can occur

5. Maintenance-related events

Aviation maintenance employs two error-reducing systems - the Air Proactive Error Reduction System (PERS) and the Maintenance Error Decision Aid (MEDA). MEDA is a byproduct of human reliability analysis and is used to analyze maintenance incidents. The system identifies Performance Shaping Factors (PSFs) that describe situational variables affecting error likelihood, such as insufficient training or adverse weather conditions. These factors are based on common errors observed in maintenance and are utilized to minimize such errors (refer to Fig. 6).

According to IATA's report from 2014 to 2018, the primary causes of errors were related to Manual Handling/Flight Controls, Standard Operating Procedures (SOPs) Adherence/Cross Verification, and Callouts [33]. Maintenance operations suffered from various breakdowns due to non-compliance with SOPs, operational instructions, company policies, regulations, and controls for evaluating compliance with regulations and SOPs. These breakdowns include deficiencies in technical documentation, unrecorded maintenance, and the use of unauthorized parts or modifications.

In the realm of training systems, various factors were overlooked, such as inadequate language skills of maintenance crews, deficient qualifications and experience, training cutbacks in response to operational needs, and flaws in training assessment, including the quality of training manuals or CBT devices. In a concerning 12% of accidents, maintenance events were identified as a contributing factor, and tragically, one fatal incident occurred during 2014-2018. Specifically, a Boeing B737-800 lost altitude shortly after take-off, ultimately crashing into the sea, resulting in the loss of the aircraft and 189 lives.

The aforementioned statistics highlight incidents where there were deficiencies in maintenance activities, checking and training, and standard operating procedures at an organizational level, also known as latent conditions.

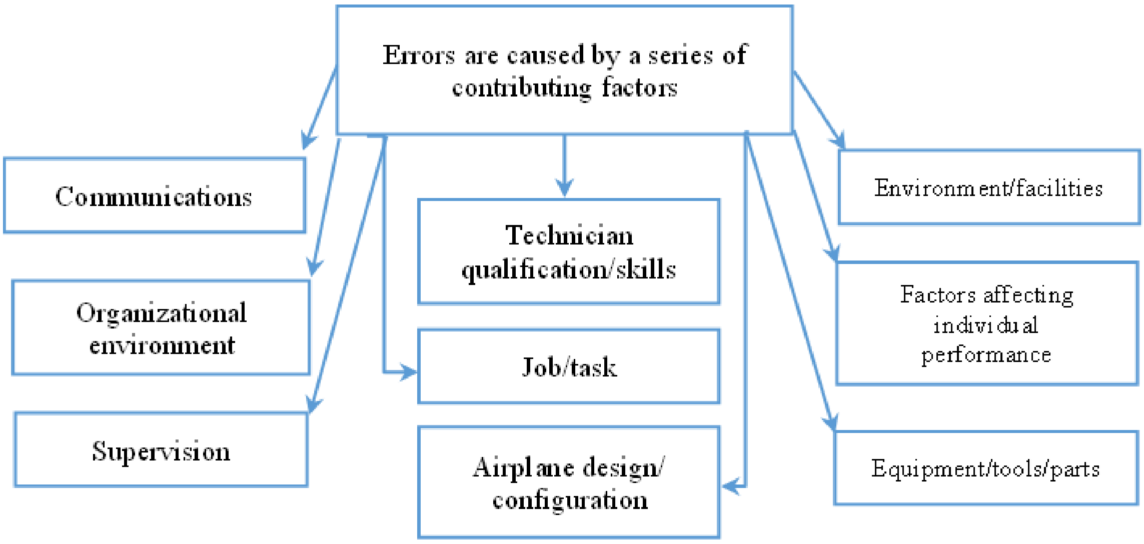

Figure 6: Mistakes occur due to a combination of various contributing factors.

Recent data [33] indicates that maintenance operations are a major cause of accidents. The study found that SOPs and checking were responsible for 10% of all accidents and 14% of fatal accidents, while training systems accounted for 2% of all accidents and 14% of fatal accidents. Moreover, aviation authorities have reported several trends that suggest errors or events caused by maintenance staff can be attributed to factors such as low staff qualifications, unsatisfactory operating procedures, adverse working conditions, lack of incentives, high information overload, and poor physical condition. These error causes can be classified into four types: functional, operational, information, and professional [19].

To undertake the analysis using the data collected above operational reliability of the aviation maintenance engineer and its features was considered.

6. The operational reliability of maintenance engineer of aircraft systems. Unique human factors issue in aviation maintenance

Maintaining the working capacity under standard conditions in a specified period is referred to as operational reliability. In the commercial airline industry, a maintenance error investigation process that follows the performance contributing factor concept can be effective. However, implementing this process requires a strong commitment from management.

Maintenance technicians work in an inherently risky environment, making their job one of the most hazardous in the labor force. They may work at great heights, in cramped spaces, and under extreme temperatures. The job is physically demanding but also requires strong organizational skills and attention to detail. It is common for maintenance technicians to spend more time preparing for a task than actually performing it, as shown in Figure 7.

In addition to such factors as climate and temperature, lighting, noise, and vapor, which have a direct impact on the human operator, it is also necessary to identify some factors that to a considerable degree hinder the operation process. Among them may be alcohol and drugs, which can lead to changes in the behavior of the aircraft maintenance engineer.

It should also be noted that medical drug intake might cause sleep mood or other changes and adverse effects on aircraft maintenance engineer conditions. That is why it is not recommended to use new medicines 24 hours before a shift.

Among the factors that contribute to a significant decrease in the attention of aircraft maintenance engineers should be highlighted overload and underload, along with sleep disturbance, fatigue, and stress.

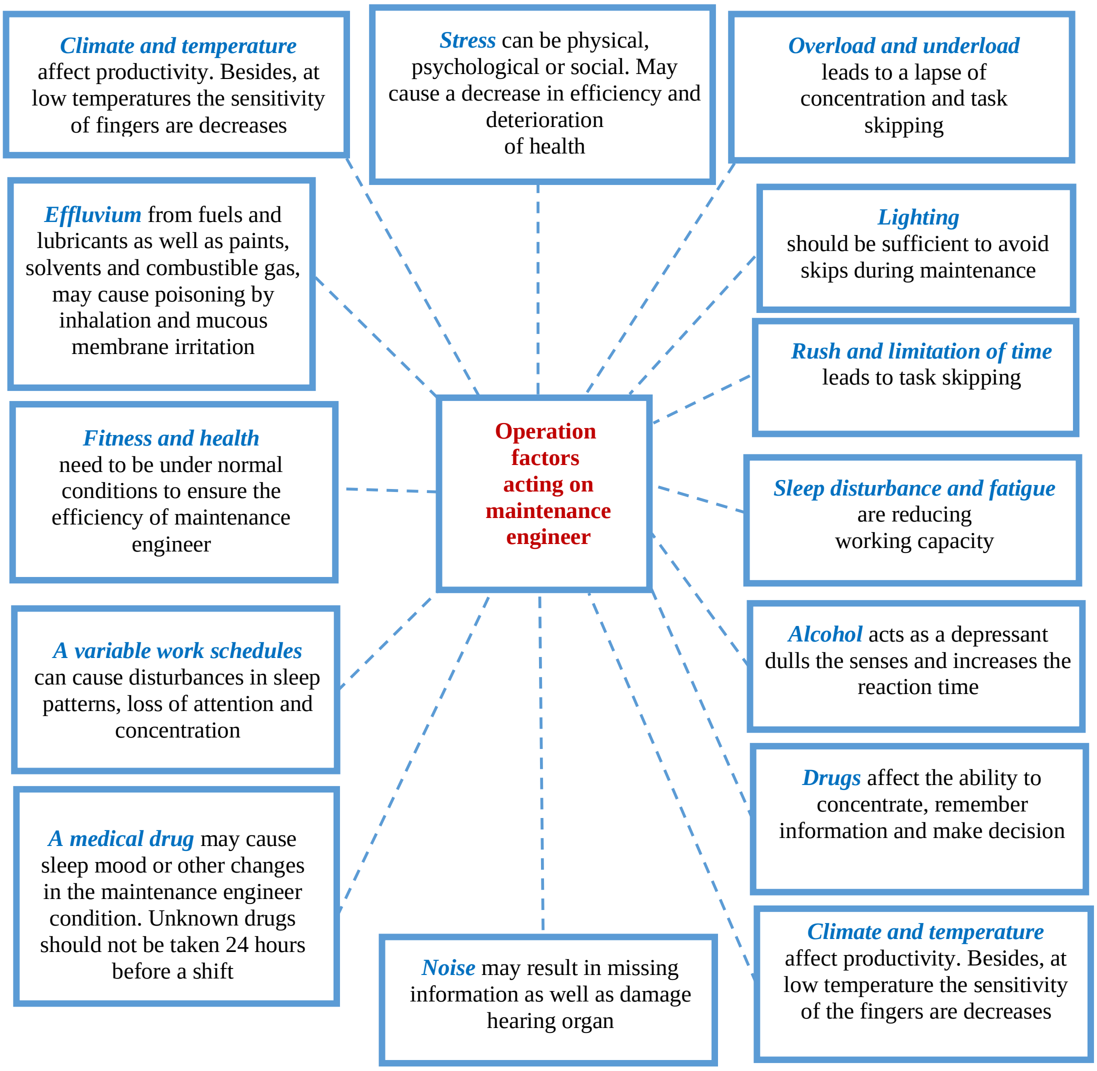

Figure 7: List of factors acting on the operational reliability of maintenance engineer

Nevertheless, one of the most critical criteria is still a tight limitation of time and rush. They are especially critical due to IT spread usage increases. An aircraft maintenance engineer often needs to decide quickly whether a particular defect or failure is vital, or whether the aircraft can fly with it. When making such a decision, every minute is essential, since an idle aircraft cost the airline money. Sometimes, external pressures can lead to mistakes and incorrect decisions. This can be particularly risky in the aviation industry, where such errors can result in incidents or accidents.

7. Safety culture

The SHELL model is utilized by ICAO to depict the key elements of human factors. The SCHELL model is an enhanced version of this, with the addition of component C that represents culture - encompassing the influence of organizational and national cultures on interactions.

The safety culture of airlines is influenced by a combination of personal and collective values, attitudes, perceptions, competencies, and behavior patterns. These factors can impact an organization's level of dedication, approach, and effectiveness in maintaining a health and safety management system. A research report by the UK Health and Safety Executive examined safety culture and climate literature and found that there are three interconnected components to safety culture, as depicted in Figure 8.

To exemplify the strong connection between safety culture and flight safety, it is fitting to quote James Reason who stated that airlines operate under similar conditions, using almost identical types of aircraft, and with flight crews, air traffic controllers, and aircraft maintenance engineers all trained and licensed to comparable standards.

However, in 1995, the risk to passengers, estimated as the probability of being involved in an aviation accident with at least one fatal outcome and calculated for 42 airlines around the world, differed many times: from 1 chance to 260 000 in the worst cases to 1 chance of 11 million in the best cases. Of course, factors such as government resources or resources of a particular company play a certain role, but there is no doubt that differences in safety culture contributed the lion's share to this enormous spread' [30].

That is why it is so essential to research the above listed (Fig. 7, Fig.8) and not only the impact factors in each maintenance organization that will help identify problems systematically in the safety culture of airlines that reduce the reliability of the aircraft maintenance engineer.

There are two groups of expert assessments:

- Individual estimates are based on using the opinions of individual experts, independent of each other.
- Collective assessments are based on the use of collective expert opinion.

Joint opinion has higher accuracy than the individual view of each of the specialists. This method is used to obtain quantitative estimates of the quality characteristics and properties.

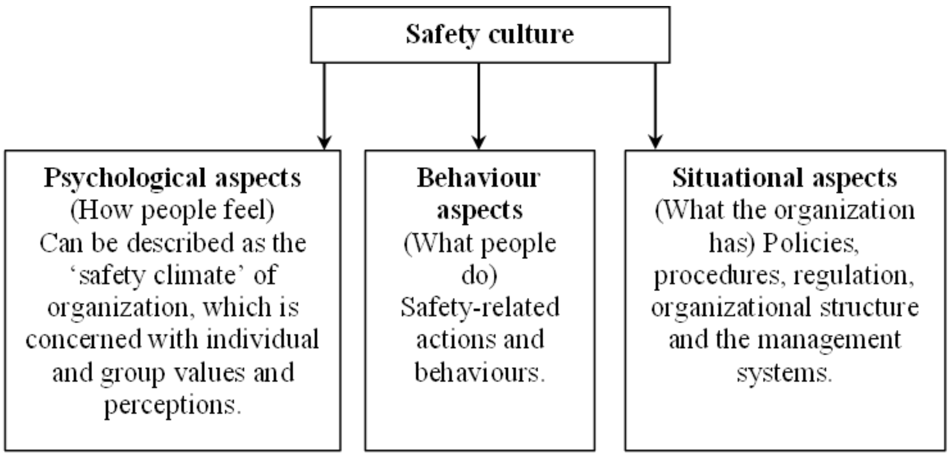

Figure 8: A Three-Aspect Approach to Safety Culture

After studying the trends in required quality level reduction, it was determined that maintenance technicians do not intentionally make mistakes. Rather, errors are often the result of multiple contributing factors, many of which can be managed by management. This approach to understanding errors could also be applied to investigating fabrication, assembly, and operational errors in other areas.

8. Conclusion

This article discusses the impact of information technologies on the human element in aviation. With the rapid advancement of these technologies in all aspects of aviation, this issue has become increasingly relevant. Proper implementation of these technologies can result in improved safety levels, airline safety culture, and flight frequency. Conducted analysis of factors affecting the reliability of maintenance personnel can be used to draw up a chart of the risks of human factors during aircraft maintenance with taking into account IT effects. It should be pointed out that significant advancements in IT are that they can unload aviation staff and better manage their work. On the other hand, IT has its negative points as well. They can lead to a loss of vigilance, and responsibility and a decrease in attention of staff during aircraft operation. Considering all, the research results can be used to create or update the current methodological basis during the design and modernization of aircraft operating systems and for keeping aviation safety and air-line safety culture at the required level.

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