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ANALYSIS OF HUMAN FACTORS IN AIRCRAFT MAINTENANCE FROM A LANGUAGE PERSPECTIVE

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Abstract. This paper deals with diverse human factors that affect the work of aircraft mechanics. The focus is centred on the role of knowledge of the language and its effects on safety in aircraft maintenance. The research of literature on human factors in maintenance proved that communication, and thus language, constitute an important part of them. Various models of human factors are presented, and their essence is compared in relation to communication and language. Communication can be done without words, but language is inseparable from communication, every time we use language we communicate. The communication present in aircraft maintenance is necessary for smooth and effective operation and language is used for communicating daily.

Keywords: communication, language, aircraft maintenance, human factors

1. INTRODUCTION

Aviation is a rapidly growing industry which reflects the increased need for pilots, air traffic controllers, cabin crew, and undoubtedly aircraft mechanics. Boeing's forecast predicts the need for around 620,000 new qualified aircraft technicians in the next 20 years worldwide [1]. Aircraft maintenance is of primary importance as, without it, no aircraft could fly. Aircraft mechanics are working hard on making flying safe and reliable; however, they are prone to mistakes as any other human being. Since mistakes in aviation cannot be always forgiven, special attention must be paid to human factors which can influence effectiveness, performance, and most importantly safety. The consequences of a certain first-glance minor mistake can lead to endangered safety on board, emergency landing, or in the worst-case scenario a fatal accident. While the percentage of accidents caused by maintenance varies over the years, we can say that around 15-25% of accidents are maintenance-caused [2-4]. This rather serious number of accidents is one of the reasons why our focus is centralized on the issue of errors caused by maintenance.

The work of aircraft mechanics is well associated with the English language. Most maintenance manuals, parts catalogues, troubleshooting manuals, final assembly instructions and other documents are written in English. These materials are rarely translated into other languages for many different reasons, one being the cost of a quality translation. Over the years it has been well established that English is the language of aviation and the number of English documents that an average aircraft mechanic encounters only proves it. However, the issue may be that around 80% of all aircraft technicians are not native English speakers. Even though these documents are to be written in Simplified Technical English (STE), which helps with the overall understanding, its rules are not always respected by the manufacturers who compose these manuals. The non-compliance with the rules of STE goes against the primary idea of STE – to make the text easier to understand [5,6]. The importance of English is essential, not only to understand the necessary manuals but also to understand the verbal communication which may be present in big international MROs worldwide.

Communication constitutes an important aspect of the everyday routine duties of an aircraft mechanic. Whether it is verbal or non-verbal communication, face-to-face or through some kind of media, it is omnipresent. Efficient communication is crucial as it promotes efficiency, performance,

and well-being of the workers. The inseparable part of communication is speech, which may be conducted in English. The international nature of the aviation industry only upholds the importance of speaking English, the aircraft technicians have to understand with ease instructions, talk about issues that may arise during their shift, and be able to consult the manual or other co-workers. There are many barriers to effective communication, and not speaking the same language sufficiently may be one of them. The better the person speaks English in an English-speaking environment, the easier it is for them to work more efficiently since the demands on their mental processing capacity are decreased with the higher level of language. All different types of communication are to ensure safety, by clearly understanding instructions and the possibility to ask questions, when not sure. It is crucial not to assume the meaning, as it may lead to various misunderstandings, that can have different consequences [7].

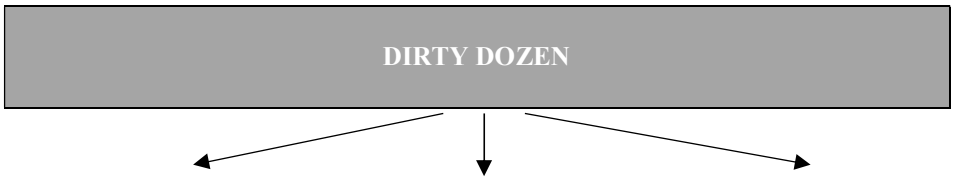
2. OVERVIEW OF HUMAN FACTORS IN AIRCRAFT MAINTENANCE

Human factors are present in aircraft maintenance just as much as in any other aviation profession. Firstly, much attention was not paid to the human factors in maintenance but rather to those present on board an aircraft, especially in the cockpit. With the continuous technical improvements, more focus was being centred on the aircraft mechanic, who had to keep up with the fast-changing working environment. Over time the design of equipment used by the aircraft mechanic started to reflect the needs and limitations of people [8].

Human factors connect diverse disciplines together, such as psychology, engineering or industrial design. These sciences each contribute to the overall study of human factors as they represent a very complex set of elements. The causes of human factors cannot be eliminated by knowledge from only one of the disciplines, an interdisciplinary approach is inevitable [8]. In the text below different models and approaches to human factors in maintenance are presented.

2.1. Dirty Dozen

Many aircraft accidents caused by maintenance in the 80s and 90s encouraged Gordon Dupont to look closely at the human factors in aircraft maintenance. In 1993, according to his observations, he established the twelve most common human factor-related aspects of maintenance jobs that can compromise the safety, shown in Figure 1. These twelve factors are viewed as preconditions for possible accidents and incidents and are described as dirty because they are unwanted and dangerous. The dirty dozen is a crucial theoretical knowledge that all maintenance workers should be familiar with in order to maintain safety and apply mitigation measures when necessary [8-10].



Lack of Communication	Lack of Teamwork	Lack of Assertiveness
Complacency	Fatigue	Stress
Lack of Knowledge	Lack of Resources	Lack of Awareness
Distraction	Pressure	Workplace norms

Figure 1 Dirty dozen

Our main focus is on lack of communication as it is directly linked to English language knowledge, however having the appropriate knowledge of English can be connected to other of these human factors, but this connection may be viewed as less direct. For example, many aspects can contribute to the build of fatigue as well as speaking in a foreign language that is not well mastered. It may

contribute to the overall fatigue of a worker, as it demands a certain amount of mental activity. Similarly, a connection can be found in the factors of stress, pressure, and lack of knowledge.

When we talk about lack of communication, it is more about the lack of effective communication, which must take place. All participants in the communication must try to make it as effective as possible, to ensure that there is a mutual understanding and everyone knows what is expected from them, and what are they supposed to work on. One should never assume that a job has been done, they have to be sure about that. Communication is essential in shift turnover; it must be clear which aspects of the work are finished and which still need to be done. It is especially true for jobs that require more than one technician. Effective communication in this aspect is the best when it is face-to-face with the option to use or point to the objects that have a direct link to the job that has to be done. It is also important to maintain the logbook and worksheets as clear and up-to-date as possible. In case of faulty communication during shift turnover, which is related to the unfinished job, there is the risk of omission of certain procedures that are required. Maintaining effective communication can be significantly harder when one, both, or all participants of the communication have different native languages, and they have to rely on their knowledge of English [8].

2.2. SHELL Model

SHELL Model was the result of Edward's research in 1972 and it is well-known for its block structure. The acronym SHELL stands for the blocks that are present in the model, namely software, hardware, environment, and liveware, as portrayed in Figure 2. This model states that when we are talking about human factors it is not only the human that should be put to blame. Human error is a combination of active failures and latent conditions in a system. The centre of the model is the person (liveware) who encounters many elements during their work, which are represented by other blocks in the model [10].

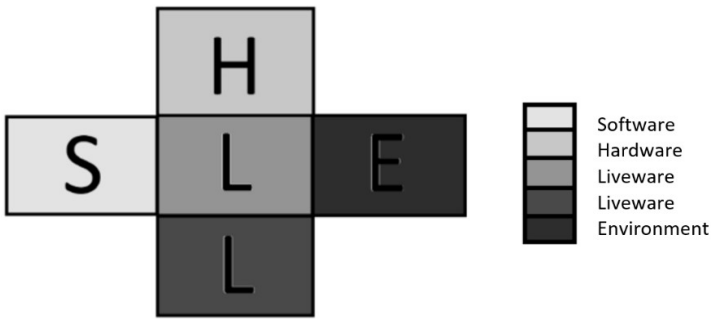


Figure 2 SHELL Model

The interface between liveware and software can be represented by checklists, manuals, or regulations. Further, there is the interface between liveware and hardware, which is for example diverse equipment or machines. The interface between liveware and environment can be understood as the relationship with any internal or external environment such as any illness, fatigue, light, temperature, humidity, or sound. And the last interface is between liveware and liveware meaning the interaction between people in the form of communication with colleagues in the working environment, important here is the organizational culture, interpersonal skills, group dynamics, or Crew Resource Management [10].

This model recognizes communication as an important part of human factors present in aviation. This model indirectly also points to the need for knowledge of English provided it is the language of communication at the workplace. Knowledge of the language is definitely a necessity in order to maintain effective communication which is essential in keeping the required level of safety.

2.3. Swiss Cheese Model

It is widely recognized that aviation accidents are never the result of a single error or factor. In fact, it is the sequence of errors happening that follow each other. This is well represented in the Swiss Cheese Model that was developed in 1990 by Reason and since then it has been adapted in risk management across different fields including aviation. In risk management, different measures are being taken to ensure safety. In an ideal scenario, these measures would be completely efficient, but unfortunately, it is not possible as every measure has its weaknesses. In Figure 3, we can see four slices of Swiss cheese, where each represents a certain measure. Weaknesses are represented by holes in the cheese. When these holes coincide and happen to be all in the same place, it allows the accident to happen. If one of these slices would not have the hole at that precise place or at all, the accident would not happen thanks to the intact measure [10].

Reason recognizes two causes of holes in the cheese slices. The first are active failures which are unsafe acts of people who are in direct connection with the system, it can be represented by certain violations or mistakes. The second reason are latent conditions, which are not immediately seen, but they keep dormant for years until the "holes" coincide and the accident happens. The difference between these two is that while active failures are hard to be foreseen, latent conditions can be eliminated in advance before they contribute to an accident [11].

We could state that one of these conditions could be the knowledge of English. To better illustrate, some maintenance employees do not have sufficient knowledge of English, but during a normal workday, they can get their work done, for example by asking other colleagues for help. This system can be relatively effective for years until other latent conditions or active failures come to play, and they all together contribute to an accident.

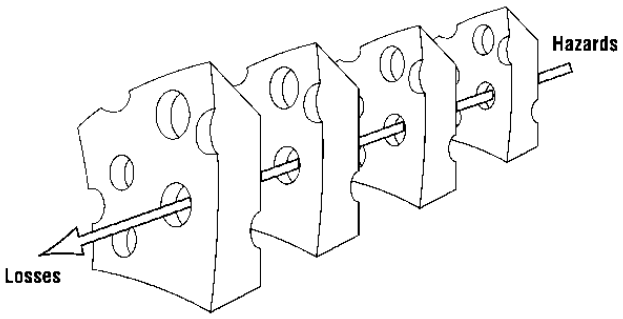


Figure 3 Swiss Cheese Model [11]

2.4. PEAR Model

The PEAR model characterizes human factors in aviation maintenance. Each of the letters stands for four aspects for assessing human factors, namely people with whom they come into contact, the environment in which they work, actions they perform, and resources that are needed for job completion [8].

When the company wants to reduce the number of errors caused by human factors, it must focus on these four aspects presented in Figure 4. Focusing on the aspect of people, they must consider the individual workers' strength, endurance, experience, or motivation standards which are specific to each person. The company must consider the size, age, and eyesight of the employees to ensure that everyone is able to perform the required tasks. During some tasks, the aircraft mechanic must be of smaller size so they could fit into narrow spaces. The well-being of workers is important, they must have regular breaks, the working environment must be favorable, and the company must care about their physical and mental health in the form of regular medical check-ups. Another issue comprised in this category is the communication within the team, teamwork, and cooperation among workers or managers [8].

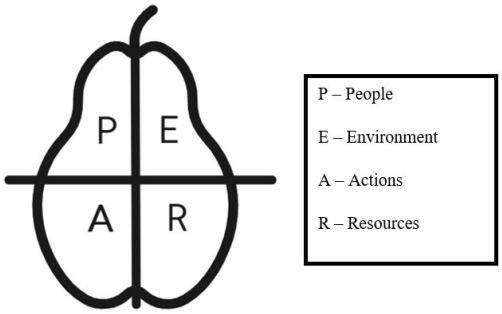


Figure 4 PEAR Model

The environment the employees are working in was already briefly mentioned, but the essence of this aspect is that workers should have an adequate environment to work in based on the required task, for example, lightning or noise control, and the organizational environment within the company. The adequacy of the physical environment is linked to the aspect of resources since they directly influence the quality of the physical environment. The organizational environment is linked to the company culture, communication, and besides other mutual respect. There should be stated common goals of safety, profitability, and other important values [8].

Actions that are being performed must be carefully thought through. Maintenance workers must be properly trained and must have all necessary equipment available. The distribution of tasks, the use of job cards, or technical documentation falls under this aspect.

Last are resources, which are sometimes hardly separable from other previously stated elements of PEAR because usually, the other three dictate the resources. Some resources are tangible, for example, equipment, and some are less tangible like time allocated for a certain task or level of communication between crew, supervisors, or managers [8].

3. HUMAN FACTOR INVESTIGATION AND TRAINING IN AIRCRAFT MAINTENANCE

Determining the causes of maintenance errors is crucial in the prevention of similar errors in the future. Therefore, a system for the investigation of maintenance errors may be a great asset to the maintenance and repair company. After such investigation of error, various issues may be discovered which can require the aircraft mechanics to participate in training that would help them avoid such mistakes in the future. The discovered issues may be related to human factors, communication or language, if that is the case proper human factors training should be implemented by the company.

3.1. MEDA (Maintenance Error Decision Aid)

MEDA was developed by Boeing in the 90s and it serves for investigating contributing factors in maintenance errors. MEDA is now considered a standard practice used for maintenance error investigation. MEDA provides the possibility for maintenance and repair organizations to learn from their own mistakes by discovering the causes of diverse maintenance problems. In aviation accidents, it is never a single factor that can be determined as the only cause, but it is always a combination of contributing factors. The same applies to maintenance errors. The phenomenon of contributing factors is the core idea of the well-known Swiss cheese model. Due to MEDA, the workplace can take precautions for eliminating or minimizing these factors to ensure that similar mistakes will not take place in the future [2].

Maintenance errors are undesirable for multiple reasons, one being the increased airline operating costs. For example, MEDA statistics state that maintenance errors cause 20-30% of engine in-flight shutdowns, while each cost around 500,000 USD. It is beneficial for the company to decrease the number of maintenance errors not only to improve safety but also to cut costs. One of the airlines that adapted MEDA reduced maintenance delays by 16%, MEDA is used by more than 500 aircraft maintenance organizations. In the last century, the main cause of aircraft accidents has shifted from

machine causes, responsible for 80% of accidents in 1903, to the human factor, which is today responsible for 80% of accidents [2].

MEDA's central philosophy is that people do not make errors on purpose, and a different employee in the same situation could have done the same mistake, for example, because of bad lighting. According to the data from U.S. Navy showed that contributing factors are the same in the case of low-cost or no-injury events as in high-cost or personal-injury events. This means that addressing contributing factors can help with both types of events. A typical investigation procedure is that when an error occurs it is not sufficient to only punish the person responsible. On the under hand under MEDA investigation the responsible person is interviewed and helps to determine contributing factors which then should be eliminated so that the error will not happen in the future. The important part of MEDA is that honest errors should not be punished as they could have happened to anyone, but punishment can be considered for specific violations [2].

In the MEDA Users Guide, communication is defined as one of the contributing factors. The communication factor has many subcategories such as language barriers, use of slang or unfamiliar terms/acronyms, incomplete/vague written communication, failure to communicate important information, misinterpretation of words/intent/tone, and many others [12]. This shows that communication is an important part of the work process, and it must be taken seriously, together with the knowledge of English, which is represented by the issue of a language barrier, and it can contribute to all other issues regarding communication in general.

3.2. Human factors training in aircraft maintenance

One of the initiatives for making the workplace safer and error-free is Maintenance resource management (MRM). It is a process for improving communication, effectiveness, and safety in the maintenance workplace with aim of achieving a safety culture [13]. MRM shares some common points with Crew Resource Management (CRM) especially, those concerning communication and team coordination. The target audience of MRM is wider than the audience of CRM, it includes aviation mechanics, engineers, support personnel, managers and others. One of the outcomes of the first workshop on MRM developed by Transport Canada was the identification of the Dirty Dozen. US Airways developed its MRM program that continues in its evolution. Some other airlines developed their own MRM courses for maintenance personnel related to human factors [14, 15].

According to Cannon-Bowers et al. [16], skills required and trained by various MRM courses correspond to the skills of adaptability, shared situational awareness, performance monitoring and feedback, leadership together with interpersonal skills, coordination skills, communication skills and decision-making skills. Even though all these skills are present in CRM and MRM, they are to be viewed as separate programs as some of the principles of CRM cannot be transferred into MRM. Although both share similarities the main difference lies in the target audience and their job tasks. Flight crews tend to be a homogenous group of similarly educated and experienced people however, maintenance crews consist of people with various education and experience [16].

The difference in job tasks performed by flight crews, pilots and maintenance crew is evident and well-known. We can see that this difference was the reason why MRM was developed, and CRM could not be used for training maintenance crews. Such realization must be done also in the case if ICAO would establish obligatory knowledge of the English language for maintenance personnel. In such case there is the need to evaluate the needs of aircraft mechanics as they vastly differ from those present in for example pilot and air traffic controller communications. There would be a long way of research and development of proper English teaching and testing systems that could satisfy the needs of maintenance personnel and at the same time provide a unified level of English language among aircraft mechanics. We see that the issues of communication and prevention of human factors exist, however, these courses do not address the issue of language, which is directly connected to interpersonal or asynchronous communication, which is inevitable in the maintenance workplace.

For MRM to be implemented successfully there must be a positive attitude from the management as it has to be spread across the whole organization. MRM encourages individuals to feel personally responsible for safety as the effectiveness of this program relies upon the employees, who should be

encouraged to use the tools provided to them by the program. The introduction of this program shows a positive influence on the morale of the maintenance crew, and it also results in improved safety by increased coordination and exchange of information between crew members. Change in the attitude towards safety can result in better performance, which can be measured by lower financial losses connected to human factors [13].

4. CONCLUSION

Presented human factors are focused on the issues connected to aircraft maintenance. Each model approaches the problem of human factors in maintenance in a different form, but the overall essence and purpose are the same in all of them. These models have more aspects in common, and one of them is the importance of communication and subsequently also the knowledge of the language. Communication is an essential part of human interaction which is inevitable and necessary to ensure safety. Even though communication is not conducted only by words, they represent an important part of it. The attention, which is devoted to communication may be sufficient, however, more attention should be paid to the knowledge of English and the dissemination of the idea of efficient communication. This may be achieved by diverse courses or other extra-curriculums that each aircraft mechanic should be included in. It may seem like a subtle element when compared to diverse technical issues that may arise, but communication is crucial. Through communication, we can solve many issues, but many issues may arise from communication.

The investigation process of maintenance errors can be done by the means of MEDA. It is used to determine the possible factors which allowed the errors to occur. One of the factors which can contribute to the errors is communication, which is further divided into more detailed sub-causes, one of which is defined as a language barrier, meaning that insufficient knowledge of language can cause a maintenance error. The development of Maintenance Resource Management proves that communication and language needs for aircraft maintenance differ from the ones of pilots, air traffic controllers and flight crews. Since their duties and their competencies vary, the requirements for their communication and language proficiency should be also different. Further research could focus on determining the communication and language needs of aircraft mechanics.

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