JAR - 7 / 2 E-ISSN: 2687-3338 AUGUST 2025

JOURNAL OF AVIATION RESEARCH

HAVACILIK ARAŞTIRMALARI DERGİSİ

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7 / 2

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AVIATION
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This is a scholarly, international, peer-reviewed, open-access journal published international journal published twice a year.

Cilt: 7
Sayı: 2
Yıl: 2025

Volume: 7
Issue: 2
Year: 2025

2019 yılından itibaren yayımlanmaktadır.

Published since 2019.

Elektronik ortamda yayınlanmaktadır.
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JOURNAL OF AVIATION RESEARCH
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Journal of Aviation Research
Cilt/Vol: 7, Sayı/Issue 2,
Ağustos/August, 2025
E-ISSN: 2687-3338
URL: www.dergipark.gov.tr/jar

Current Human Factors Approaches in Aircraft Maintenance Sector: Transformation of Dirty Dozen into Filthy Fifteen

Ramazan ÇOBAN[1]

Derleme	**DOI:** 10.51785/jar.1640698	
Gönderi Tarihi: 16.02.2025	Kabul Tarihi: 02.05.2025	Online Yayın Tarihi: 30.08.2025

Abstract

In the early 1990s, aircraft accidents caused by human factors in aircraft maintenance tasks became an important agenda item in the aviation sector. In this context, as a result of studies conducted by Transport Canada employee Gordon Dupont and his teammates in 1993, twelve human factors that caused aircraft maintenance workers to make mistakes were identified, and these factors were named the Dirty Dozen. In the long process from the emergence of the Dirty Dozen model to the present day, there have been organizational and technological changes worldwide that could affect the performance of aircraft maintenance workers. For this reason, in recent years, it has been observed that some of the world's leading aircraft maintenance organizations have been using new approaches in human factors training. One of these new approaches is the Filthy Fifteen model put forward by Hawker Pacific Aerospace. However, it is seen that the studies in the literature on the Filthy Fifteen are extremely limited. In this context, the aim of this study, which is carried out theoretically, is to first examine the Dirty Dozen model, which is integrated with the concept of human factors in the aircraft maintenance sector, then to examine in detail the theoretical structure of the Filthy Fifteen model, which expands the Dirty Dozen, and to discuss the current human factors that can be added to the Filthy Fifteen model in the conclusion section. It is thought that the study will make an original contribution to the literature on human factors in the aircraft maintenance sector.

Key Words: Filthy Fifteen, Dirty Dozen, Aircraft Maintenance, Human Factors, Aviation

JEL Classification: M10, M14, M19

Uçak Bakım Sektöründe Güncel İnsan Faktörleri Yaklaşımları: Kirli Düzinenin Kirli Onbeş'e Dönüşümü

Öz

1990'lı yılların başında uçak bakım görevlerinde insan faktörlerinden kaynaklı uçak kazaları havacılık sektöründe önemli bir gündem olmuştur. Bu kapsamda 1993 yılında Transport Kanada çalışanı Gordon Dupont ve takım arkadaşları tarafından yapılan çalışmalar sonucunda uçak bakım çalışanlarının hata yapmasına neden olan on iki insan faktörü tespit edilmiş ve bu faktörlere Kirli Düzine adı verilmiştir. Kirli Düzine modelinin ortaya çıkmasından günümüze kadar geçen uzun süreç içinde uçak bakım çalışanlarının performanslarını etkileyebilecek dünya çapında örgütsel ve teknolojik değişimler yaşanmıştır. Bu nedenle son yıllarda dünyanın önde gelen bazı uçak bakım organizasyonlarının insan faktörleri eğitiminde yeni yaklaşımlar kullandığı görülmektedir. Bu yeni yaklaşımlardan biri Hawker Pacific Aerospace firması tarafından öne sürülen Kirli On Beş modelidir. Ancak Kirli On Beş ile ilgili literatürdeki çalışmaların son derece sınırlı olduğu görülmektedir. Bu kapsamda teorik olarak yürütülen bu çalışmanın amacı, öncelikle uçak bakım sektöründe insan faktörleri kavramıyla bütünleşmiş olan Kirli Düzine modelini ele almak; sonra Kirli Düzineyi genişleten Kirli On Beş modelinin teorik yapısını detaylı olarak incelemek ve sonuç kısmında Kirli On Beş modeline eklenebilecek güncel insan faktörlerini tartışmaktır. Çalışmanın uçak bakım sektöründe insan faktörleri ile ilgili literatüre özgün bir katkı yapacağı düşünülmektedir.

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Anahtar Kelimeler: Kirli On Beş, Kirli Düzine, Uçak Bakım, İnsan Faktörü, Havacılık

JEL Sınıflandırma: M10, M14, M19

INTRODUCTION

The aviation sector, which is an important part of the transportation sector worldwide, is growing in line with globalization and technological developments. The aviation sector has a respected place in the eyes of countries today as it allows people and cargo to be transported faster and safer than before (Çoban, 2019). By its nature, all operations in the aviation sector are carried out within the framework of international rules. Therefore, safety is an indispensable requirement in aviation operations. Aviation safety defines the conditions required for activities in the sector to take place in an environment where all risks are defined and minimized (Gerede, 2005). Thanks to the strict safety rules applied, air transportation has become the most reliable type of transportation worldwide today (Koornneef, Verhagen & Curran, 2016).

The aircraft maintenance sector is an important sector that directly contributes to the timely and safe performance of flight operations in airline transportation. Aircraft maintenance tasks, which are an integral part of the aviation sector, are carried out within a complex system that includes many inputs such as people, materials and technology (Çoban, 2017). Maintenance technicians, who perform many different and difficult tasks, often have to work in teams and communication. The main task of aircraft maintenance technicians is to keep aircraft in a flight-worthy condition at all times (FAA, 2008). Maintenance technicians are at the center of aircraft maintenance tasks. Technicians perform different tasks such as maintenance, repair, control, troubleshooting and revision on mechanical and avionic systems. Maintenance technicians can work in groups in closed maintenance hangars or they can work alone in dynamic and riskier environments such as flight lines (Zaharevitz, 1980).

It is possible to constantly encounter serious incidents and accidents during sectoral commercial activities around the world. As a result of these accidents, many people lose their lives or are injured. In addition, commercial enterprises suffer serious financial losses (Ergai, Cohen, Sharp, Wiegmann, Gramopadhye & Shappell 2016). When the causes of accidents in the aviation sector are examined; it is seen that accidents are caused by the interaction of environmental, technological, organizational and human factors. Technological factors that cause aircraft accidents refer to technical malfunctions in a system or part. Conditions such as weather conditions, noise, heat and lighting are included in environmental factors. Factors such as inadequate procedures, lack of training, communication problems and management style are some of the organizational factors that cause accidents (Reason, 1990).

Human factors in aviation, as a concept directly related to the job performance of aviation employees, brings a systematic perspective to aviation safety (Lyssakov & Lyssakova, 2019). Human factors is an interdisciplinary concept that attempts to examine how people interact with equipment, physical environment, organizational rules and other people in the same environment in work. As in most sectors, in the aviation sector, where the concepts of safety and security are extremely important, the concept of human factors is directly related to the performance of employees. Understanding the human factors that cause accidents

continues to be one of the biggest challenges of the aviation sector (Reason, 1990). Today, while the number of accidents caused by technological factors has decreased, the number of accidents caused by human factors has increased significantly and constitutes more than 80% of total accidents (Piwek, 2018).

Aircraft maintenance tasks are aviation activities that are mostly carried out under difficult working conditions and time pressure due to commercial concerns of airline companies and have the potential to produce many errors (Reason & Hobbs, 2003). The performance of aircraft maintenance workers is greatly affected by the scope of the task and the design of the parts to be maintained. In terms of aviation safety, maintenance errors may not be seen until the system or part being maintained fails. However, these maintenance errors, which are mostly hidden, can later cause aircraft accidents that can lead to serious loss of life and property. In 1988, the disintegration of the fuselage of a Boeing 737 commercial passenger aircraft belonging to Aloha Air in Hawaii during flight revealed that errors caused by human factors in the aircraft maintenance sector can have fatal consequences (Çoban, 2017).

After the Aloha Air accident, studies on human errors in aircraft maintenance tasks have increased worldwide since the early 1990s. The most striking of these studies is the **"Dirty Dozen"** model developed by Gurdon Dupont, who worked at Transport Canada in 1993 (Çoban & Aydoğdu, 2020). According to this model, there are 12 basic human factors that cause aircraft maintenance workers to make mistakes (Dupont, 1997). Over time, the Dirty Dozen has been accepted worldwide as a convenient and easy method for explaining human errors not only in the aircraft maintenance sector but also in other sectors.

More than thirty years have passed since the emergence of the Dirty Dozen model in the 1990s, and during this long process, organizational and technological changes have occurred worldwide that may affect the performance of aircraft maintenance workers. It is seen that these changes have been reflected in the human factors training curricula of some of the world's leading maintenance and repair training organizations in recent years. Therefore, it is possible to see human factors approaches that expand the Dirty Dozen model in recent years. One of these new approaches is the **"Filthy Fifteen"** model proposed by Hawker Pacific Aerospace (HPA) in 2016. However, it is seen that the studies in the literature on Filthy Fifteen are extremely limited.

Based on this gap in the literature, this study sought an answer to the question *"What is the content of the Filthy Fifteen model, which expands the Dirty Dozen model in the aircraft maintenance sector today, but has limited literature?"* with the theoretical review method. Theoretical reviews are studies that aim to contribute to the literature by systematically and impartially scanning, evaluating and synthesizing studies conducted on the same subject to find an answer to the research question determined on a specific subject (Çınar, 2021). The basic stages of theoretical review studies, which require a preparation process similar to research articles, are as follows in terms of method: Determining the research question and purpose, conducting a literature review from the specified databases, evaluating the data obtained from the literature, and analyzing and interpreting the findings. A classic theoretical review study has three main sections: introduction, literature review and evaluation, discussion and conclusion (Özer & Görgülü, 2020).

In this context, the study first examined the Dirty Dozen model, which is integrated with the concept of human factors in the aircraft maintenance sector, by scanning the Scopus, Web of Science, EBSCO and Google Scholar databases between September and December 2024. Then, the theoretical structure of the Filthy Fifteen model, which expands the Dirty Dozen, was examined in more detail. In the discussion and conclusion section, a discussion was made on the existing human factors that could be added to the Filthy Fifteen model, and suggestions were made for future studies. To ensure the reliability and validity of the study, the findings obtained from the literature review were presented to the reader by the researcher in an unbiased, transparent and systematic manner in line with experts' opinions in the fields of aviation and aircraft maintenance.

1. DIRTY DOZEN IN THE AIRCRAFT MAINTENANCE SECTOR

The increase in accidents and incidents caused by aircraft maintenance errors in the late 1980s and early 1990s was a notable development in the aviation industry worldwide. In 1993, during a period when aircraft maintenance errors came to the fore, Gordon Dupont, an aircraft maintenance engineer at Transport Canada, and his teammates examined nearly 2,000 incident and accident reports that had occurred in the aircraft maintenance sector in previous years due to human errors. Dupont's study was also contributed to by the Canadian Department of Defense, the Royal Canadian Air Force and members of an industry liaison committee. As a result of their seven-month study, Dupont and his teammates revealed the 12 most common human factors that cause employees in the aircraft maintenance sector to make errors and named all of these factors the Dirty Dozen (Mellema, 2018).

At the end of this study, Dupont suggested that the errors made by aircraft maintenance workers were mostly related to one or more factors in the Dirty Dozen. Dupont also stated that there was a series of safety nets related to each factor that made up the Dirty Dozen. *Safety nets are practices or procedures designed to reduce the probability of any factor turning into an actual incident or accident.* The Dirty Dozen made a big splash in the aviation industry at the time it was released. The human factors that make up the Dirty Dozen are presented in Table 1.

Table 1. Dirty Dozen in Aircraft Maintenance Sector

1	Lack of Communication	7	Lack of Resources
2	Complacency	8	Pressure
3	Lack of Knowledge	9	Lack of Assertiveness
4	Distraction	10	Stress
5	Lack of Teamwork	11	Lack of Awareness
6	Fatigue	12	Norms

Source: (Dupont, 1997).

Due to the increase in aircraft accidents due to maintenance errors worldwide, Dr. Bill Shepherd, an FAA officer, initiated a series of meetings in the early 1990s to investigate human factors-related problems in aircraft maintenance operations. In these meetings held between 1993 and 1997, Dupont presented the Dirty Dozen to an international consortium jointly supported by the USA, Canada and the UK (Dupont, 1997). The Dirty Dozen quickly

became widely accepted as a framework for examining aircraft maintenance worker errors in the aviation industry worldwide in the period following 1997 and spread rapidly. Within just a few years, Dirty Dozen posters adorned the walls of many aircraft maintenance facilities in and outside the USA and Canada. The Dirty Dozen was approved and included in the publications of world-renowned aviation authorities such as the Federal Aviation Administration (FAA), European Aviation Safety Agency (EASA), Australian Civil Aviation Safety Authority (CASA) and Transport Canada. During this period, the FAA defined the Dirty Dozen as *"twelve human factors that reduce the ability of people to perform safely and effectively in maintenance operations and that can lead to errors."* The Dirty Dozen comprised most of the human factors section of the FAA's Aircraft Maintenance Technician Handbook (FAA, 2008). In addition, the Dirty Dozen has become a part of the basic human factors training conducted by the world's leading aircraft maintenance training organizations such as Delta TechOps, Lufthansa Technik, and Aveos. The rapid spread of the Dirty Dozen in the aircraft maintenance sector was due to the idea that it was based on scientific data and experience, along with effective marketing methods (posters, etc.) (Mellema, 2018).

Compared to the models developed for human factors adopted by the aviation industry, such as Edwards' (1988) SHEL Model, Reason's (1990) Swiss Cheese Model, Human Factors Analysis and Classification System-Maintenance Extension (HFACS-ME), Boeing's Maintenance Error Decision Aid (MEDA), Maintenance Line Operations Safety Assessments (M-LOSA), and the intensive research behind these models, the origin and development of Dupont's Dirty Dozen may be more modest. Although scientific studies that take the aircraft maintenance sector as an example regarding all or part of the human factors that make up the Dirty Dozen (Latorella & Prabhu, 2000; Hobbs & Williamson, 2003; Patankar & Taylor, 2008) are limited in the literature, there are scientific studies in the healthcare sector that reveal that the Dirty Dozen contributes to the solution of human performance problems in complex and highly technical surgical areas (Marquardt, Treffenstadt, Gerstmeyer & Gades-Buettrich 2015; Mellema, 2018). Despite the limitations of the Dirty Dozen regarding its scientific aspect, it is possible to say that it presents a logical and easy model to explain the mistakes and violations made by aircraft maintenance workers worldwide and therefore is closely identified with the aircraft maintenance culture. The twelve basic human factors that make up the Dirty Dozen are explained below in order.

1.1. Lack of Communication

Communication refers to the process of transferring a message or information from a sender to the target receiver. For effective communication, both the sender and the receiver must have communication skills. Communication skills include verbal behaviors such as using the right words at the right time, active listening, appropriate tone of voice and choice of communication tool, as well as body language such as gestures, facial expressions, gazes and written communication (Chatzi, Martin, Bates & Murra, 2019). Communication, which is effective in social interactions between individuals in every area of life, is also one of the most important tools for effective and safe organizational performance and preventing stress in teamwork in business sectors that carry out complex operations, involve constant risk and

work under high pressure (Vieria, Santos & Kubo, 2014). Communication is at the focal point of teamwork as one of the most important components that provide the connection between people, systems, processes, structures and technology in all sectors (Dickinson & McIntyre, 1997). A lack of communication refers to the failure to communicate, receive, and provide the information needed to complete a task. A lack of communication occurs when individuals have misperceptions about what is being said or done (Shorrock, 2007). Effective communication is an essential element for the safety and security of aviation operations. Therefore, all aviation personnel have the responsibility to communicate effectively. Otherwise, a lack of communication can lead to disasters in aviation operations (Vieria et al., 2014).

Lack of communication is a significant human factor that can lead to faulty or inadequate maintenance. Maintenance technicians may be in contact with many employees, such as the pilot, ground handling workers, and spare part suppliers, while performing their duties. There is a potential for misunderstandings or breakdowns in communication with these employees. However, communication gaps, especially when more than one maintenance technician is working on an aircraft as a team, are riskier and can result in a maintenance error or aircraft accident (FAA, 2008). Shift change is a critical process in the aircraft maintenance sector where communication problems can occur. Often, a partially completed maintenance task during a shift is transferred from the technician who finished the job at the end of the shift to the technician who is coming to the next shift. Lack of communication that may occur during shift handovers can be seen verbally, in writing, or a combination of the two. For example, failure to communicate with the team coming to the day shift about an unfinished task during the night shift may cause technicians coming to the shift to assume that a task that was not done has been done (Dupont, 1997). Some studies in the literature show that written communication during maintenance tasks may cause more errors than verbal communication. This is because it is easy to obtain any explanation from the other party in verbal communication, but more difficult in written communication (Shukri, Millar, Gratton & Garner 2016)

As a precaution against communication deficiencies; maintenance technicians should communicate effectively with each other; never assume anything, always consult with teammates and provide feedback that messages are received and understood; keep written records to eliminate doubts about maintenance tasks; communicate to each other the tasks to be done and completed through briefings and discuss them if necessary (Dupont, 1997). In addition, during shift and task changes, continuing a task started by someone else after a face-to-face meeting, if possible, reviewing the steps related to the operations performed with checklists and always performing tasks according to approved maintenance procedures can prevent communication deficiencies (FAA, 2008).

1.2. Complacency

Complacency can be defined, in general terms, as a temporary or long-term psychological condition that causes a decrease in attention, alertness and awareness of dangers in an individual due to the confidence and satisfaction that an individual feels in himself (Dekker, 2003). Complacency is an insidious human factor that can cause judgment errors in

technicians due to the constant repetition of many maintenance tasks and controls (Dupont, 1997). Complacency is a condition that develops over time in the aircraft maintenance sector. As a maintenance technician gains knowledge and experience over time, his self-confidence and satisfaction with himself and his performance will develop. If a technician does not record the work he has done during a maintenance task or signs a task that he has not done, this is a sign of complacency. Especially in repetitive and control-based tasks, if the technician fails to find a fault several times, this may cause him to become self-confident and complacent in subsequent tasks. In such cases, the maintenance technician may think that the relevant procedure is not important, and some malfunctions and faults may be overlooked. Failure to detect the malfunction may cause an accident (FAA, 2008). Fatigue may also affect the individual's complacency behavior. For example, technicians who are tired after long maintenance tasks may gradually decrease their probability of noticing stimuli or faults in the visual fields, and this may delay the technicians' reaction times (Petrilli, Roach, Dawson & Lamond, 2006).

As a precaution against complacency in maintenance tasks; the maintenance technician should always comply with approved maintenance procedures, use checklists, train himself to find errors or faults in control tasks, focus mentally on his task, give equal importance to all control elements; never assume undone or unchecked work, never sign for these works, and learn from the mistakes of others (Dupont, 1997; FAA, 2008).

1.3. Lack of Knowledge

In the aviation sector, aircraft and the systems and equipment that support the operation of these vehicles are extremely complex and integrated. Therefore, maintenance technicians can't perform their duties effectively and safely without basic technical training, sufficient experience and current information based on documents. In addition, due to rapidly changing technology, there is a risk that technicians' technical knowledge may become outdated. In this context, lack of knowledge is a human factor that can cause errors and violations due to differences in aircraft technologies, inability to follow updates in airworthiness and maintenance procedures (EASA, 2015). In today's constantly changing world, maintenance technicians must have the necessary knowledge about the tasks they perform. Otherwise, lack of knowledge can lead the technician to misinterpret current situations and make unsafe decisions (FAA, 2008). When lack of knowledge is combined with the ***"I can do this"*** self-confidence of most maintenance technicians, more serious and risky results can occur (Dupont, 1997).

Different precautions can be taken against the lack of knowledge factor that may cause incorrect behaviors in maintenance technicians. First of all, receiving training on the subject in which there is a deficiency seems to be the most basic precaution against a lack of knowledge (Nzelu, Chandrahan & Pereira, 2018). In addition, performing all maintenance tasks according to approved and current maintenance documents; consulting a technician who has experience in the maintenance task in question in cases of doubt; contacting the representative of the aircraft manufacturer if there is no experienced technician; constantly emphasizing professional development; sharing your knowledge with your colleagues; avoiding working on assumptions and memorization can prevent errors and violations that

may arise from lack of knowledge (Dupont, 1997; EASA, 2015). *Rather than causing an incident or accident by performing a maintenance task incorrectly due to a lack of knowledge, delaying that task may be a more logical course of action for a technician.*

1.4. Distraction

Distraction is a situation that takes the individual away from the task they are doing, even for a moment, and can be caused by anything. Our minds work faster than our hands. Therefore, a distracting factor can quickly distract an individual from the work they are doing (Nzelu et al., 2018). Distraction is a human factor that causes a technician to leave their job both physically and mentally for any reason and is responsible for approximately 15% of all maintenance errors (Dupont, 1997). Distracting factors are inevitable in the work environment where aircraft maintenance tasks are performed. These factors can disrupt the maintenance process and cause the technician to miss details. Distracting factors can occur in physical and mental forms. For example, high noise levels in the maintenance hangar, requests for assistance from other technicians, a new aircraft being pulled into the hangar, and safety issues that require urgent attention, as well as administrative tasks, social conversations, or even responding to a phone call from the technician's wife can cause distraction (EASA, 2015). Regardless of the work environment, personal situations that are difficult to resolve, such as a family or financial problem, can also constantly occupy the technician's mind while working, causing distraction and inefficient maintenance tasks.

By nature, a technician should be aware of the many distractions that occur during an aircraft maintenance task and should take precautions against this situation. First, when attention is distracted, it is a logical practice to go three steps back from the task being performed and start from that point. It is useful to use a detailed written procedure and to sign only the tasks that have been completed, and to mark the place where the task was left off when leaving the task due to distraction (FAA, 2008). A technician should be aware that a disconnected part is a sign that the job was not completed. Similarly, when a part is installed in maintenance tasks, other technicians who perform that task tend to think that the job is done. In such cases, the installed part should be given sufficient torque and, if necessary, tied with a safety wire to avoid erroneous results. This practice will show that the maintenance task has been done correctly up to that point.

1.5. Lack of Teamwork

Teamwork can be defined as the coming together of managers and employees in an organization to perform their duties in line with the determined organizational goals (Ergün & Eyisoy, 2018). Common goals, mutual effective communication, structured relationships, leadership style, trust and common values are indispensable elements for effective and successful performance of teams (Proehl, 1996). In this context, lack of teamwork refers to the failure of a team to achieve the determined goals (Mellema, 2018). Since many tasks in aviation depend on teamwork, a single employee cannot be held solely responsible for the results of all tasks. An employee who does not contribute to teamwork can lead to unsafe situations. For this reason, for the tasks to be performed for their purpose, each member of the team must trust and support each other (https://skybrary.aero).

As in every field of aviation, many different and complex tasks in the aircraft maintenance sector require the teamwork of maintenance technicians within the framework of certain rules. Therefore, maintenance tasks that directly and significantly contribute to a safe flight operation must be performed in communication and based on teamwork (Çoban, 2017). In particular, information sharing between technicians, coordination of maintenance tasks, shift change process, and troubleshooting tasks in aircraft, together with the flight crew, are important maintenance activities that require teamwork. Therefore, teamwork is an important phenomenon inherent in maintenance tasks (CAP 715, 2002). Since lack of teamwork is directly related to lack of communication, it is an important human factor that can cause incorrect behavior in maintenance tasks (Dupont, 1997). The primary duty of maintenance technicians is to ensure the airworthiness of the aircraft. In this respect, airworthiness can be achieved by all maintenance technicians working as a team towards a common goal. Lack of teamwork can lead to faulty communication, which can complicate maintenance tasks and negatively impact aircraft airworthiness (FAA, 2008).

Team members should know how each other works, their performance levels, their strengths and weaknesses, and support each other when necessary to prevent maintenance errors that may arise from a lack of teamwork. To produce a fast and coordinated solution to problems, the roles and responsibilities of team members must be clearly defined (Nzelu et al., 2018). In addition, it should be ensured that the assigned tasks are accepted by each team member; communication between team members should be kept open, and the workload should be distributed equally within the team (Dupont, 1997).

1.6. Fatigue

Fatigue is a natural response of the human body to long-term physical and mental stress. Fatigue can be physical or mental (EASA, 2015). Fatigue is a human factor that does not immediately manifest itself. Because an employee usually does not realize that he is tired until it becomes excessive (Dupont, 1997). Fatigue can occur as a result of difficult physical work, intense focus on a task, emotional concentration or an overwhelming need for sleep. An individual can be said to be tired if there is a decrease or deterioration in any of their cognitive abilities, decision-making, reaction time, coordination, strength and balance abilities. Fatigue reduces alertness and the ability of the individual to focus and pay attention to the work he is doing (FAA, 2008). Maintenance technicians are at risk of fatigue due to reasons such as working night shifts, long and irregular task periods, complex tasks, sleep problems due to working conditions and stress (Hobbs, Avers & Hiles 2011). A tired maintenance technician may have symptoms such as short-term memory problems, lack of situational awareness, distraction, abnormal mood swings, poor judgment, and a decrease in performance standards. When these symptoms are seen, the maintenance technician is likely to make mistakes (FAA, 2008).

To prevent errors and violations that may arise from fatigue in the aircraft maintenance sector, the Fatigue Risk Management System (FRMS) is increasingly gaining attention from international organizations, national aviation authorities, airline companies and maintenance organizations. FRMS can be applied alone or as part of the Safety Management System (FAA, 2010). Within the scope of FRMS, inefficient periods, especially during maintenance

tasks performed during the night shift, should be determined by taking into account the reality of the circadian rhythm and long and tiring shifts that may cause maintenance technicians to make mistakes should be avoided (Çoban, 2019). As in all living things, physical, mental and behavioral changes seen in humans occur in a cycle. This cycle is called the circadian rhythm. Circadian rhythm affects many physical and mental variables such as body temperature, blood pressure, heart rate, attention, and alertness. Since the circadian rhythm drops from 2 a.m. to the early hours of the morning, it is extremely dangerous to perform during these hours. Therefore, planning complex and tiring maintenance tasks that are contrary to the circadian rhythm can lead to accidents (FAA, 2008; Çoban, 2019).

It is not a realistic goal to reduce fatigue to zero during maintenance tasks. What is important is to keep the risks of fatigue as low as possible (Stewart & Holmes, 2008). In addition, being aware of the symptoms of fatigue that occur in both yourself and your teammates during maintenance tasks, planning critical and complex tasks according to your circadian rhythm, sleeping and exercising regularly, and asking your teammates to help you control yourself during complex tasks are important measures to combat fatigue (Dupont, 1997). The main cause of fatigue is a lack of sleep. Therefore, adequate and restful sleep, free from drugs or alcohol, is a human necessity to prevent fatigue (FAA, 2008).

1.7. Lack of Resources

The main task of aircraft maintenance technicians in the aviation sector is to keep the aircraft in a commercial aircraft fleet well-maintained at all times. To perform this task safely, maintenance technicians need different resources. Resources such as labor, time, tools, equipment, and maintenance documents are vital for the performance of maintenance tasks (EASA, 2015). Lack of resources may prevent the maintenance technicians from completing their tasks due to a lack of supplies and support. In some cases, the available resources may be low in quantity, and sometimes the resources may be of poor quality. Appropriate resources in terms of quantity and quality will increase the chance of completing maintenance tasks correctly and safely the first time. On the other hand, poor quality and insufficient resources may cause serious incidents and accidents during maintenance tasks (FAA, 2008).

A maintenance organization needs to have the right and sufficient resources to do its job safely and in a planned manner. Otherwise, the work will proceed in an improvised manner and will be open to unsafe situations. Components are not the only resources needed to perform a maintenance task correctly, but they often cause frequent problems. Hand tools that are not suitable for the task during maintenance, damaged and uncalibrated are another source of problems. Such tools should be repaired or replaced with new ones as soon as possible. In addition, technical documentation is another critical resource that can cause problems in the maintenance sector. Because how maintenance tasks are to be performed is stated in technical documents (FAA, 2008; EASA, 2015). No matter which commercial maintenance organization an aircraft maintenance technician works in, there may be times when they experience a lack of resources and therefore are hesitant to complete the maintenance task. In such cases, the average technician tends to complete the task by saying ***"I can do it"*** and therefore feels proud (Dupont, 1997). However, it should not be forgotten

that such situations, where there is a lack of resources, may have negative consequences in terms of safety.

Aircraft maintenance organizations can take various precautions to prevent employee errors that may arise from a lack of resources. Since technicians are the most valuable and error-prone resource of maintenance organizations, planning a sufficient number and quality of manpower for the workload created by maintenance tasks is indispensable to prevent unsafe situations that may arise from resource insufficiency (Padil, Said & Azizan, 2018). During maintenance tasks, technicians must learn to use existing resources effectively and efficiently. If existing resources are not suitable for maintenance tasks, resource arrangements should be made proactively. In this context, first of all, suspicious areas where resource insufficiency may occur should be well identified before starting the maintenance task. Then, before starting the task, the inventory of the necessary parts should be taken, ordered and stocked if necessary. Thus, resource arrangement positively affects the airworthiness of aircraft by saving both time and money. In addition, it is necessary to keep technical documents constantly up to date and to contact the supervisor or manufacturer's representative in case of document deficiencies (FAA, 2008; Dupont, 1997).

1.8. Pressure

In civil aviation, the tight flight schedules and commercial concerns of commercial airlines, and in military aviation, the effort to immediately neutralize sudden security risks often cause aircraft maintenance technicians to work under pressure (Çoban & Aydoğdu, 2020). In the aviation sector, to ensure that scheduled flights can be carried out without disruption and in a sustainable manner, periodic maintenance must be carried out on time, unplanned maintenance is resolved immediately, and the aircraft is returned to flight as soon as possible. To reduce costs during economic crises, airlines prefer to fly aircraft more intensively rather than having them remain in maintenance for a long time. Due to such commercial concerns, the aircraft maintenance sector is constantly under time pressure (Yazgan & Kavsaoğlu, 2017).

Time pressure is a psychological condition that occurs when an individual has little time to perform their job (Çoban & Aydoğdu, 2020). Time pressure occurs as a natural consequence of working in a dynamic work environment, and some pressure can motivate employees to do their job. However, when time pressure begins to hinder the ability to complete tasks correctly, it becomes overwhelming. This pressure can be caused by a lack of resources, especially in the maintenance sector, and makes it difficult to cope with the workload (FAA, 2008). Maintenance technicians working under time pressure may experience negative behaviors such as stress, decreased performance in complex tasks, filtering important information, forgetfulness, and incorrect evaluation (Zakay, 1993). The majority of studies on time pressure reveal that time pressure negatively affects the decision-making process. When the literature is examined, it is seen that increased and perceived time pressure reduces teamwork, creativity, self-efficacy, motivation, performance, and negotiation efficiency; It has been observed that it increases burnout, stress and physical problems (Dreu, 2003; Güran & Güler, 2019; Bozacı, 2019). In a study conducted by Çoban and Aydoğdu (2020), it was seen that time pressure increases the technostress level of aircraft maintenance technicians.

The aircraft maintenance sector is a sector where technicians need to make fast and accurate decisions without making mistakes, and is directly responsible for flight safety. In this context, maintenance technicians working under pressure can prevent unsafe situations by taking some precautions. First of all, from an organizational perspective, a maintenance organization should not compromise on work quality and safety due to time pressure. Technicians should be aware that they can make mistakes while working under pressure. Unrealistic maintenance tasks, which put safety at risk and need to be done in a certain time frame, should be shared with managers, and a different action plan should be created if necessary (FAA, 2008; EASA, 2015). Maintenance technicians experiencing time pressure should express their concerns, ask for help from their teammates, and, if necessary, be able to say **"No"** in unsafe situations (Dupont, 1997). In addition, maintenance organizations should distribute the workload equally so that technicians do not experience time pressure, and plan a sufficient number of technicians and resources for each task (Çoban, 2019).

1.9. Lack of Assertiveness

Assertiveness can be defined as the ability to express our thoughts, feelings, beliefs and needs positively and productively. Being assertive is a human characteristic that is different from being aggressive. Lack of assertiveness is the inability of an individual to express their feelings and thoughts with self-confidence (EASA, 2015). The average maintenance technician is not an assertive person, and most of the time, their job does not require being assertive. However, when something goes wrong with their job and they encounter problems, technicians need to be assertive (Dupont, 1997). Being assertive requires talking about problems when things are not going well, especially in hierarchical organizational structures (Nzelu et al., 2018). Assertiveness is not a skill that comes naturally to every individual. However, it is a critical skill for maintenance tasks to be performed effectively and safely. Maintenance technicians need to be assertive in expressing problems, unsafe situations, or concerns about the job they encounter. In this context, a lack of assertiveness may cause maintenance technicians not to convey a concern about instructions, processes, or the actions of others. Failure to warn about a wrong or incorrect application due to timidity can lead to fatal consequences (FAA, 2008).

To be assertive in maintenance tasks, technicians can exhibit some positive behaviors. Addressing maintenance managers by stating the problem, explaining what the consequences of the problem will be, producing possible solutions to the problem, and getting feedback from teammates about the problem can be seen as assertive behaviors. Instead of dealing with multiple problems with management or teammates, it is necessary to focus on one problem at a time. It is also important to support the problem you are trying to explain to people with visual documentation and real evidence (FAA, 2008). Establishing direct, honest and open communication and respecting the thoughts and needs of others can only be achieved by not deviating from our standards. Unassertive maintenance technicians may have to comply with the decision of the majority, knowing that they are wrong or risky (Dupont, 1997). In addition, maintenance technicians should allow their teammates to voice the problems they see and should always be open to constructive criticism. As technicians exhibit assertive behaviors, they will contribute to the emergence and resolution of problems

in maintenance tasks, as well as realize that their self-confidence has improved and will contribute to the safety of maintenance tasks.

1.10. Stress

Selye (1956), one of the pioneer scientists on stress, defined stress as the general reaction of an individual to various environmental stimuli. Selye defined stimuli that create a series of reactions in an individual as stressors. In other words, stress is the effort that a person exerts beyond their physical and psychological limits due to negative conditions in the social and physical environment (Cüceloğlu, 1994). Stress is a phenomenon that has become a part of daily life in today's modern world, and it can become excessive. The important thing is to be able to recognize when stress has become excessive (Dupont, 1997). Most people encounter stressful situations while doing their daily routines. Stress is a factor that affects human behavior and their interactions with other people. Stress is not a situation that occurs on its own. For stress to occur, the environmental conditions in which a person is located must affect the person (Güçlü, 2001).

Aircraft maintenance technicians in the aviation sector are professional workers working under stress. One of the most important sources of this stress is the financial concerns of commercial airline companies. Maintenance technicians must perform their tasks flawlessly and on time, against any delays or cancellations that may occur in commercial flights. This commercial pressure often stresses technicians (Yazgan & Kavsaoğlu, 2017). The constantly changing technological environment, the need to receive training on new equipment, working in dark and narrow spaces, insufficient resources for maintenance tasks, shift work and long working hours are significant sources of stress in the aircraft maintenance sector. In addition, a serious accident that may occur due to faulty maintenance is always a significant source of stress for maintenance technicians (FAA, 2008).

It is possible to categorize the stress sources that may affect aircraft maintenance technicians under three headings: physical, psychological and physiological. Inappropriate ambient temperature, high noise, inadequate lighting, and limited, closed, and dark spaces are important physical environmental stress sources. (CAP 715, 2002). Problems experienced with managers and other employees at work, communication conflicts, financial problems, marital and private life issues are among the psychological stress sources. Poor physical condition, illness, malnutrition, lack of sleep, fatigue, and unplanned shift systems are factors that create physiological stress in maintenance technicians (EASA, 2015). Aircraft maintenance technicians can manage the stress they are exposed to by taking various precautions. Being aware of how stress affects your job; stopping during work and looking at the problem that causes stress logically; preparing a logical action plan and implementing this plan; temporarily leaving work and taking a break; asking for help from your colleagues, exercising; sleeping regularly, eating a balanced diet and establishing a work-life balance can reduce stress in the workplace (Dupont, 1997; FAA, 2008).

1.11. Lack of Awareness

Awareness can be defined as the ability of an individual to correctly identify factors related to themselves and their environment, to comprehend the meanings of these factors, and to

predict their effects shortly (CAP 715, 2002). Situational awareness is the awareness of the aircraft system and environmental conditions in which a technician is working in aircraft maintenance. Maintenance technicians must be aware of visual conditions such as metal fatigue, loose or missing parts, oil or fluid leaks, tire wear, and improperly functioning parts, as well as the status of the observed systems while working (Endsley & Robertson, 2000). Lack of awareness can be defined as the inability to recognize all the consequences of an action or the lack of foresight. Lack of awareness is frequently seen in experienced maintenance technicians who cannot fully consider the possible consequences of the tasks they perform. Because there are many repetitive tasks in the aircraft maintenance sector. Doing repetitive tasks over and over can eventually lead to problems such as complacency, lack of attention, and failure to recognize environmental conditions in experienced technicians. These problems can cause maintenance technicians to act incorrectly (Dupont, 1997; FAA, 2008). Not being aware of the full consequences of your situation and actions can lead to narrow-mindedness and a lack of understanding of the impact of your actions on others.

Maintenance technicians can prevent incorrect behaviors that may be caused by a lack of awareness by taking some precautions. First of all, since attention is closely related to situational awareness, technicians can maintain their attention by following workplace procedures such as checklists and effective communication. Constantly monitoring the work environment, creating possible task scenarios, thinking about what could happen in the event of an accident, asking your teammates to check your work, and approaching each task as if it were the first time can increase maintenance technicians' situational awareness (Dupont, 1997; EASA, 2015).

1.12. Norms

A human being, who is a social being, continues their life as a part of a certain community or group. For relationships to proceed in an orderly manner in the societies to which people belong, it is necessary to comply with the norms (Eroğlu, 2015). Norms are general rules that guide the behaviors of people belonging to a group or community. Norms can be in two forms: formal and informal. While formal norms are written, such as laws, regulations and procedures, informal norms are unwritten (İçli, 2002). It is also possible to see many written and unwritten norms that guide the behaviors of employees in the aircraft maintenance sector. Unwritten norms, in particular, normally show the shortcut of doing things. Unwritten norms are generally developed to solve problems with uncertain solutions. As the norms become increasingly fixed over time, new members who join the group accept the norms. Although norms are rarely changed, the experiences gained by technicians over time can shape norms (FAA, 2008).

Unsafe norms can be seen in the aircraft maintenance sector that negatively affect the behavior of employees and lead to inefficiency. Working from memory without complying with maintenance documents, resorting to shortcuts, not following procedures, and signing uncompleted maintenance tasks are some of the unsafe norms. However, a behavior generally accepted by technicians can be accepted as a norm even if it is not a standard procedure (EASA, 2015). In order not to encounter an unsafe situation caused by norms,

maintenance technicians must always work according to maintenance documents and be aware that not every norm is correct (Dupont, 1997).

2. TRANSFORMATION OF DIRTY DOZEN INTO FILTHY FIFTEEN

Years after the Dirty Dozen was proposed by Gordon Dupont in 1993, three more human factors were added to the Dirty Dozen in the human factors training provided to aircraft maintenance personnel by HPA in 2016, and the concept of the **"Filthy Fifteen"** emerged (Maggie & Grower, 2016). HPA is an aircraft maintenance company that provides maintenance, repair and overhaul services on landing gear and hydraulic systems for all major aircraft types, including models of major aircraft manufacturers such as Airbus, Boeing, Bombardier and Embraer, as well as helicopters. HPA has been operating under Lutfansa Technik, a subsidiary of Lutfansa, the flag carrier airline of Germany, since 2002 (https://en.wikipedia.org).

The three human factors that HPA added to the Dirty Dozen and created the Filthy Fifteen are: *not admitting limitations*, *lack of operational integrity*, and *lack of professionalism*. These three human factors are seen as typical reasons why aircraft maintenance technicians deviate from company processes and procedures and make mistakes or violations, just like the components that make up the Dirty Dozen (Maggie & Grower, 2016). It is thought that the Filthy Fifteen model (Figure 1), which HPA developed and uses in human factors training to promote aviation safety, will help identify and prevent risks that may arise from new technological changes, regulations, and human resources changes in the aircraft maintenance sector. This updated framework can be seen as a tool that lists the basic job responsibilities of professional employees, especially in aircraft maintenance and aviation, as well as in other maintenance and repair sectors. The three human factors that were added to the Dirty Dozen and created the Filthy Fifteen are explained below.

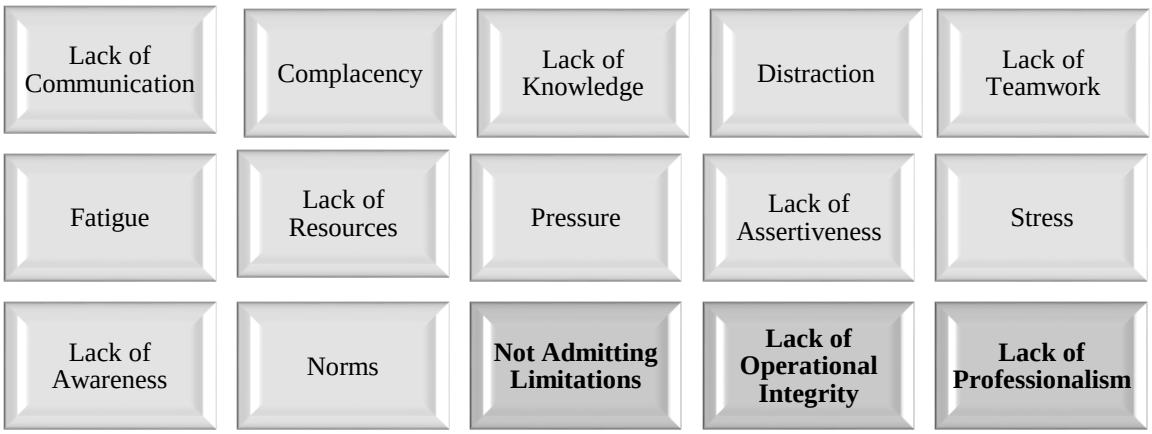

Figure 1. Filthy Fifteen in Aircraft Maintenance Sector

2.1. Not Admitting Limitations

People exhibit performance while performing a certain job or task in their daily lives. Performance can be expressed as the ability to perform a task according to set standards. According to another definition, performance is a concept aimed at determining the outputs of a targeted task in terms of quantity or quality (Doğan, 2020). The component of Filthy

Fifteen, not accepting limitations, emphasizes that every person has some limits that affect their performance while performing their activities or jobs in both daily and business life (https://skybrary.aero).

There are many components, both mechanical and electronic, such as systems, equipment or parts that make up a large aircraft or an ordinary small technological device. Each of these components has a certain capacity, performance level and some limitations while performing their duties. Similar to mechanical devices, some factors limit the performance of people while performing their duties. When compared to the performance values of a device with certain limits, it may be difficult to determine exactly which values a person's performance and limitations are between. However, it is possible to say that exposure to extreme situations will cause limitations in human performance. Aircraft maintenance technicians and managers need to consider the physical and cognitive abilities and limitations of a person when evaluating their own and others' performance (CAP 715, 2002).

People perceive the outside world using their senses of sight, hearing, touch, smell and taste and direct their behaviors accordingly. However, the two most important senses in aviation activities are sight and hearing. Most of the data required to evaluate the position and balance of a flier in the sky or to direct the interaction and behavior of aviation workers, such as air traffic controllers and maintenance technicians, with the environment is obtained through the eyes and ears. There is a certain threshold point for the sensory organs to activate. For example, a minimum light level is required for the eyes to see. Ears, on the other hand, cannot hear sounds below a certain pressure level. The sensory threshold can vary from sense organ to sense organ and from person to person, and can also be affected by environmental factors. Incorrect or misleading data transmitted to us by our eyes and ears is a significant source of concern for aviation sector workers (Campbell & Bagshaw, 2002). Both the need for a certain threshold point for the senses to be activated and the fact that the sensory threshold is affected by individual factors and environmental conditions can be considered as factors limiting individual performance.

As in many aviation activities, maintenance technicians must have a certain level of vision to perform maintenance tasks that rely on visual inspection safely. Many maintenance tasks require the use of both distance and near vision. However, eye defects such as myopia, hyperopia, astigmatism, and cataracts, which personnel experience especially due to the aging process, can cause limitations in performance (CAP 715, 2002). In addition to visual performance, some factors affect hearing performance. The hearing performance of the human ear varies according to the frequency and intensity of the sound. The sound frequency range that a young person can hear varies between 20-20,000 hertz, while the highest sensitivity is approximately 3,000 hertz. However, people can normally hear between 20-120 decibels. However, sounds between 50-70 decibels are the sound intensity that is more easily heard by the ear. Ear infections, earwax, eardrum damage, and especially the aging process are important factors that limit hearing performance caused by the person. However, noise is an important environmental factor that limits hearing performance (Campbell & Bagshaw, 2002).

Data provided by the sensory organs is analyzed through the information processing process and converted into meaningful information. Information processing is a process consisting of five stages: detection, perception, decision making, behavior, and feedback. According to information processing theory, people not only react to stimuli from their environment, but also process the data they receive. The scope and capacity of the brain and nervous system are extremely effective in the information processing process (Wang, Liu & Wang, 2003). In the aircraft maintenance sector, where there are many risks and complex tasks, information processing is a process in which personnel are prone to making mistakes. In addition to cognitive problems such as memory problems, lack of attention, and insufficient perception, many factors such as lack of education, inexperience, anxiety, psychological problems, physical illnesses, lack of communication, lack of motivation, and environmental conditions can limit the information processing of personnel in aircraft maintenance tasks (Salas, Jentsch & Maurino, 2010). If maintenance technicians ignore these limitations and try to quickly evaluate environmental inputs and take action, and therefore overlook a small detail, the consequences can lead to serious accidents.

One of the reasons behind aircraft maintenance technicians' refusal to accept their physical and cognitive limitations may be their professional mindset. Aircraft maintenance technicians are known for having an **"I can do this"** mindset that motivates them to perform exceptionally due to the challenging tasks and environmental conditions they face. *"I didn't receive proper training in this subject. However, I have a lot of experience. I can figure out how to do this job without formal training. How difficult can this job be? After all, I have a maintenance license. Having a license shows that I can do this. I am strong. I can work for days, months, and long hours without much sleep. I will sleep only when I am dead"* is a dominant mindset that often motivates aircraft maintenance technicians regardless of the difficulties they face while doing their job. However, this mindset can backfire in some cases and cause the maintenance technician to go beyond their limits (Maggie & Grower, 2016).

The reason why aircraft maintenance technicians do not accept limitations may also be due to national and professional culture. In a qualitative study conducted by Bükeç and Çoban (2023) on aviation employees on the factors affecting a just culture, it was observed that the fatalistic approaches ***(God willing, nothing will happen to me***) exhibited by employees in Turkish and Middle Eastern cultures due to their national culture and religious beliefs encouraged aircraft maintenance technicians to go beyond the rules; at the same time, aircraft maintenance technicians tried to solve unsafe situations within themselves due to their professional culture and therefore avoided reporting behavior. Aircraft maintenance employees often perform by being exposed to intense physical and cognitive workload in a work environment dominated by challenging environmental conditions, time pressure, shift work, sleeplessness, fatigue and insufficient resources (Çoban, 2019). When working in challenging work conditions and organizational and individual resources are insufficient, technicians may take the initiative and go beyond existing limits. The successful completion of the performance exhibited by going beyond the limits will prepare the ground for the maintenance technician to go beyond the limits again in similar situations and will increase their self-confidence. As a result, in such a situation, the maintenance technician will probably tend to go beyond the limits. In this context, for aircraft maintenance tasks to be

performed effectively and safely, employees must be transparent and honest, free from ego in accepting their limits. Not accepting the limits can decrease individual performance and can cause serious damage to teammates and expensive aircraft and equipment in various, risky and crowded work environments such as aircraft maintenance hangars and flight lines (https://skybrary.aero).

The examination and analysis of the physical, emotional and cognitive limits of humans are a vital part of human factors training. According to the EASA Part-147 regulation in the European Union countries and the Aircraft Maintenance Training Organizations Instruction (SHT-147, 2022) in Turkey, to obtain an aircraft maintenance license, it is necessary to take Module 9-Human Factors Training specified in the Aircraft Maintenance Personnel License Instruction (SHT-66, 2013). The second part of this module addresses the physical and cognitive performance and limits of a person and covers topics such as vision, hearing, information processing, attention, perception, memory, claustrophobia and physical access.

In addition to human factors training, aircraft maintenance technicians themselves can take some precautions to accept their individual and environmental limitations. *"Being aware of physical, cognitive and technical limitations; watching for warning signs from your body while working; keeping your ego under control; accepting your lack of knowledge about your job; always working according to correct work procedures; taking breaks while working; getting work-related support when needed and living a healthy lifestyle"* can help an employee accept and manage their limitations at work (https://skybrary.aero).

2.2. Lack of Operational Integrity

Integrity is a virtuous person characteristic that includes behaviors such as expressing the truth by leaving individual interests aside and prioritizing social benefit, doing the right thing under all circumstances, being reliable and avoiding harm (Selim, 2022). Integrity means doing the right thing every time, regardless of whether others are watching or not. Operational integrity, or in other words, "business ethics," generally refers to being aware of what is right and wrong in the workplace and always doing the right thing. Business ethics also reveal what is right and wrong in the process of producing goods and services by businesses (Doğan, 2009). In an approved maintenance organization, business ethics means complying with the regulatory requirements and approved maintenance procedures of international and national authorities that guide the aviation sector, and also strictly adhering to moral values (Maggie & Grower, 2016). Deviating from these procedures, rules and values can be defined as a lack of operational integrity.

Lack of operational integrity and business ethics can lead to routine and spontaneous situational violations, which are frequently seen in maintenance technicians. In cases where challenging organizational conditions such as time pressure, insufficient equipment, lack of resources and excessive workload arise, an approach lacking in operational integrity such as ***It was a little out of tolerance last time but it worked; I can go out of tolerance again, no problem"*** will bring about violations and unsafe behaviors (Maggie & Grower, 2016). In the aircraft maintenance sector, it is common for maintenance technicians and engineers to take part in more than one task and be responsible for those tasks without knowing whether they have been completed completely. For example, a technician may have a control task in

another maintenance task while performing a maintenance task. Often, due to personnel and time constraints, the responsible technician may tend to risky behavior such as approving the maintenance exit without checking how the work done in control tasks has been completed. In such a case, due to operational integrity, the technician must fully check whether the work has been done according to the procedures. In this context, business integrity can be seen as a professional employee characteristic that eliminates risky behavior (CASAA, 2013).

There may be different reasons that lead employees to unethical behavior in commercial organizations. The pressure to achieve certain organizational goals due to commercial concerns, the failure of the top management of the organization to prioritize ethical values, conflicts of interest between functional departments and employees within the organization, excessive self-confidence and arrogance seen in employees, etc. may cause both the organization itself and the employees individually to deviate from ethical rules and honesty (Doğan, 2009). In this context, when because aircraft maintenance organizations, as commercial organizations, have certain organizational goals and profit expectations, often work under time pressure, and maintenance technicians may act in line with their interests, it should not be forgotten that behaviors that deviate from business ethics and may put safety at risk may be seen in the aircraft maintenance sector.

In the aircraft maintenance sector, the negative consequences of behaviors that are far from organizational procedures and ethical values may not be immediately visible, as they are in the flight crew. The flight crew's work environment is extremely variable during the flight process, from the aircraft leaving the apron to completing its flight and parking on the apron again. During this process, the flight crew's mistakes can be actively and immediately seen, while the consequences of their mistakes and violations can be extremely fatal. Compared to the flight crew, maintenance technicians work individually or as a team, especially in maintenance hangars, in more stable environmental conditions (Sian, Robertson & Watson, 2017). The fact that they are mostly alone while performing maintenance on a part or device can cause the technicians' possible mistakes and violations to be overlooked and remain hidden. The consequences of technicians' unsafe behaviors are mostly hidden, as they can be seen either during quality checks at the end of maintenance or during flight. In addition, if maintenance errors are noticed in a process before the aircraft is released for flight, these errors are easier to compensate for and less damaging in terms of their consequences, and erroneous behaviors can be tolerated. The nature of aircraft maintenance tasks can lead to complacency, overconfidence, and the belief that deviation from organizational and ethical rules poses little risk to maintenance technicians. In this case, deviation from operational integrity can insidiously permeate maintenance technicians' behaviors.

In aircraft maintenance organizations, measures can be taken against a lack of operational integrity at both organizational and individual levels. At the organizational level, organizations should determine their own business and ethical values and share them with their employees. When the corporate websites of many traditional and low-cost airlines such as United Airlines, Air France, Air China, Japan Airlines, Turkish Airlines, Lufthansa, Easy Jet and Southwest are examined in the aviation sector, it is possible to see that business and

ethical values are shared with both society and employees. However, simply sharing these values is not enough. In the next process, whether employees act according to these values should be checked by organizational control mechanisms. For this mechanism to work, a senior management approach that prioritizes ethical values and strong organizational policies and processes is needed. According to Maggie and Grower (2016), employees can take some individual measures to ensure operational integrity in the aviation sector. *"Knowing what integrity is and displaying honest behavior, being consistent with what is said and what is done, reporting mistakes honestly, always thinking about the safety and security of those we are in contact with and responsible for, and acting according to organizational and correct procedures under all circumstances"* are some of the measures.

2.3. Lack of Professionalism

The third human factor that HPA included in the Filthy Fifteen is a lack of professionalism. Professionalism can be defined as the expertise, knowledge, skills and behaviors exhibited in a certain field. The nature of professionalism includes dynamism and effort. In addition, professional employees are people who do a job for money. To evaluate whether a person is a professional, it is necessary to look at whether they meet certain criteria in the field they are interested in (Altıok & Üstün, 2014). According to Pavalko (1971), theoretical knowledge load, connection with basic social values, commitment to the profession, education period, cooperation awareness, serving the community and work ethics are defined as the basic criteria of professionalism. Professionalism can develop as long as professional employees fulfill their job responsibilities at the highest level.

Although technological tools and equipment are widely used in aircraft maintenance tasks, the main determining factor in the correct and safe performance of maintenance and repair tasks is maintenance technicians (Padil et al. 2018). Individuals who want to work in the aircraft maintenance sector, after completing the training required by international or the aviation authorities of the country they are in, are authorized to work on a certain type of aircraft, engine or aircraft system with the license or certification they earn (Zaharevitz, 1980). SHY-66, SHY-145 and SHY-147 regulations published by the General Directorate of Civil Aviation in Turkey are the basic national regulations that guide the theoretical training, professional experience and licensing processes of aircraft maintenance technicians. Factors such as the fact that aviation operations are subject to strict international regulations, that safety and security are the two main priorities of aviation activities, that errors and violations lead to fatal and major financial consequences, that expensive technological tools are used in the aviation sector, and that aviation employees are required to perform their duties by receiving legal and valid training have turned aircraft maintenance technicians, as well as all aviation sector employees, into professional employees.

Many professional jobs have their rituals, cultures, norms and jargon. Since ancient times, taking an oath has been one of the rituals practiced to start many traditional and professional professions worldwide. Taking an oath means making a promise on a certain subject or confirming the truth of a certain statement by presenting a sacred value or being as a witness. In addition to public duties such as membership in parliament, presidency, and military service, taking an oath is frequently seen when starting traditional professions such as

lawyers, doctors and pharmacists. In many Western countries, doctors take the Hippocratic Oath as a symbol of their commitment to maintaining a set of ethical rules and standards when starting their profession (Avşar, 2012). Similar to the Hippocratic Oath of doctors, the *Maintenance Technician Oath*, written in 1941 by American Jerome Lederer, a pioneer in aviation safety, is known to be extremely effective in the professional behavior of technicians in the aircraft maintenance sector. The text of this oath first appeared on the back cover of the first issues of the Flight Safety Foundation's Aviation Technicians Bulletin in 1953 and became extremely popular. At that time, many technicians from Tokyo to Frankfurt, Canada to Puerto Rico wrote letters asking for copies of this oath to hang on the walls of their workplaces and offices. This can certainly be seen as evidence that aircraft maintenance technicians are a professional profession (Maggie & Grower, 2016). The text of the maintenance technician oath written by Jerome Lederer is presented below.

"Upon my honor, I swear that I shall hold in sacred trust the rights and privileges conferred upon me as a certified mechanic. Knowing full well that the safety and lives of others are dependent upon my skill and judgment, I shall never knowingly subject others to risks which I would not be willing to assume for myself, or for those dear to me. In discharging this trust, I pledge myself never to undertake work or approve work which I feel to be beyond the limits of my knowledge, nor shall I allow any non-certificated superior to persuade me to approve aircraft or equipment as airworthy against my better judgment, nor shall I permit my judgment to be influenced by money or other personal gain, nor shall I pass as airworthy aircraft or equipment about which I am in doubt, either as a result of direct inspection or uncertainty regarding the ability of others who have worked on it to accomplish their work satisfactorily. I realize the grave responsibility which is mine as a certified airman to exercise my judgment on the airworthiness of aircraft and equipment. I therefore pledge unyielding adherence to these precepts for the advancement of aviation and for the dignity of my vocation." (https://skybrary.aero).

Professionalism is a phenomenon that reveals the basic professional character of all aircraft maintenance workers, especially technicians. Professionalism is also a combination of expert skills, personal feelings and attitude towards the job for an aircraft maintenance worker. Professionalism in the aircraft maintenance sector can be interpreted as the desire to take responsibility for the safety of passengers traveling on aircraft and the airworthiness of aircraft above individual interests (CASAA, 2013). From this perspective, business integrity and professionalism are two concepts that are interconnected like symbiotic twins. Integrity is the cornerstone of professionalism, and it is not possible to achieve professionalism without integrity. The factors that can be seen as the basic components of professionalism in the aircraft maintenance sector are listed in Table 2.

Table 2. Basic Components of Professionalism in the Aircraft Maintenance Sector

1	Discipline	Following approved procedures to perform a given task.
2	Communication	Keeping team members informed of progress and developments.
3	Teamwork	Working together well to resolve problems and maintain control.
4	Knowledge	Having deep understanding of aircraft systems and their operation.
5	Expertise	Retaining and transferring knowledge and skills
6	Situational Awareness	Knowing what is happening around you.
7	Experience	Calling upon prior training and knowledge to assess new situations.
8	Decision Making	Taking correct decisive actions.
9	Resource Management	Allocating resources to ensure control of the larger situation while specific problems are being addressed.
10	Prioritization	Setting safety above personal concerns.

Source: (CASAA, 2013).

The physical and technical aspects of aircraft maintenance tasks seem relatively simple and can be easily understood. However, it can be difficult to define and understand the concept of professionalism that separates a superior maintenance worker from an average one. Professionalism is a situation that is obvious when seen. It is possible to understand the professionalism of an aircraft maintenance technician not only from their technical skills but also from their situational awareness, coordinated teamwork and ability to make the right decisions. Professionalism also emphasizes the individual's self-control over themselves to avoid and protect themselves from risky behaviors. Maintenance technicians with high self-control can make conscious and correct decisions for safety (Maggie & Grower, 2016).

Professionalism is of central importance for the integrity of aircraft maintenance processes, production quality, and safe and successful results. The **4C Concept**, which reflects four basic characteristics that stand out for aviation professionals, is taught in the human factors training provided by HPA. The components that make up the 4C Concept are: Having sufficient knowledge and skills in one's field (***Competence***), Commitment to a higher goal (***Commitment***), Being in control of one's work (***Control***), and Communication, whether written, verbal or in any form (***Communication***). HPA emphasizes that the internalization and application of these basic competencies are of vital importance and offers a series of recommendations to maintenance technicians to protect against a lack of professionalism. These recommendations are: "*Work with passion in your work, share your knowledge, use approved parts, materials and technical documents/data; use appropriate equipment, tools and vehicles; be extremely meticulous about quality and always follow the right procedures."* (Maggie & Grower, 2016).

A maintenance technician must know and apply the countermeasures that correspond to each item of the Filthy Fifteen while performing their job to be a complete professional. For example, the technician must not hesitate to be assertive and manage stress, as well as avoid distractions and complacency. A technician should not take any maintenance task for granted and should give each task the same attention and care as he does to complex tasks. It is known that most accidents in the aircraft maintenance sector are not caused by complex technical problems, but by simple and preventable mistakes, such as not tightening a nut enough. Professional technicians readily admit their mistakes. A technician who is trained

and licensed to perform maintenance tasks is disciplined and assertive in his work, which demonstrates his professionalism. In addition, a professional technician should share this situation with his managers without hesitation when he has doubts about whether he can perform his job safely and effectively. In this way, management can ensure that the technician receives the necessary support or training when needed. In this context, each technician is encouraged to always do their best through continuous learning and professional development (Maggie & Grower, 2016).

Professionalism is a charismatic situation that can both guide the safety culture of the maintenance organization and be guided by the safety culture, and adds value to the maintenance technician. Professionalism in aircraft maintenance operations can be developed in single-person maintenance tasks as well as in team or inter-team tasks. It is a sign of professionalism that each technician involved in maintenance tasks is aware of the stage of their task and how far they have progressed since the beginning of the task. Good communication among professional employees reduces the possibility of making risky decisions. However, making a risky decision should not be seen as a lack of professionalism. Because there is always a risk in the nature of aviation activities. What is important is to minimize these risks and carry out the activities safely. The trust that a professional employee has in his teammate should not replace good communication, situational awareness and control. A professional maintenance technician should always keep the motto ***"trust does not prevent control"*** alive in his mind. In this context, a professional technician should never sign a job that he has not done, examined or checked.

As a result, both operational integrity and professionalism should be important topics in the human factors training curriculum for aircraft maintenance technicians. However, the implementation of professionalism in the workplace is largely the responsibility of each individual. Maintenance technicians need to embrace operational integrity and professional values and take pride in their practice. This is a process that begins in the technician's heart and is instilled in his mind by the hands that touch and work on the aircraft and its components (Maggie & Grower, 2016).

3. DISCUSSION AND CONCLUSION

In the aviation sector, where the concept of safety is extremely important, aircraft accidents caused by the errors of aircraft maintenance technicians became an important agenda item worldwide in the early 1990s. In this context, as a result of studies conducted by Transport Canada employee Gordon Dupont and his teammates in 1993, 12 human factors that cause employees in the aircraft maintenance sector to make mistakes were identified, and these factors were named the Dirty Dozen. After the Dirty Dozen model emerged, it was accepted worldwide as a simple and widespread model for understanding and solving accidents caused by human errors, first in the aircraft maintenance sector and then in other sectors where safety and security are extremely important.

In the nearly thirty years since the Dirty Dozen model emerged, the conditions brought about by globalization and technological changes have also been reflected in the working environment and work behaviors of aircraft maintenance technicians. In this context, HPA,

one of the world's leading aircraft maintenance, repair and training organizations, has updated and expanded the factors that cause aircraft maintenance workers to make mistakes while doing their job and has proposed the Filthy Fifteen model. In this model, three more human factors have been added to the human factors in the Dirty Dozen. These factors are: *Not Admitting Limitations, Lack of Operational Integrity and Lack of Professionalism*.

It can be said that the human factors in the Filthy Fifteen cause aircraft maintenance technicians to make mistakes, and these factors are interrelated. First of all, aircraft maintenance tasks are an aviation operation based on teamwork and effective communication. Therefore, it is likely that a lack of communication will reduce the team performance of maintenance technicians and cause fatal errors. The experience that technicians gain over time can cause complacency in maintenance tasks, and complacency can reduce assertiveness and awareness, causing unsafe situations to be overlooked. Commercial concerns of airline companies and workplace norms that encourage unsafe practices will increase pressure, stress and fatigue in maintenance workers and cause errors. This fatigue can be physical and mental. Distracting factors commonly seen in the aircraft maintenance work environment can reduce the situational awareness of technicians and trigger erroneous behaviors. The variable structure of the aircraft maintenance work environment and constant exposure to technological changes can cause a lack of knowledge and awareness in technicians.

Human factors such as norms, stress, lack of resources, lack of knowledge, fatigue, pressure, and lack of assertiveness included in the Filthy Fifteen can mostly be seen as factors originating from organizational policies and commercial concerns. Human factors such as lack of communication, complacency, distraction, lack of teamwork and lack of awareness can mostly be seen as individual factors originating from technicians. However, it can be said that some human factors originate from both organizational and individual reasons. When the last three human factors that are added to the Dirty Dozen and form the Filthy Fifteen are examined, factors such as pressure, stress, complacency, lack of information and resources can cause technicians to go beyond their limits and compromise their work integrity. It is a fact that operational integrity forms the basis of professionalism. When a maintenance technician acts with awareness of the factors that cause them to make mistakes, they exhibit professional behavior.

Maintenance technicians can make their work environment safer by taking some precautions against the human factors in the Filthy Fifteen. Effective communication, emphasis on teamwork, working according to organizational procedures and maintenance documents, not signing a job that has not been done, paying attention to physical and mental health, sharing problems with managers, working within the framework of ethical rules and integrity, and always acting professionally can prevent or minimize the misconduct of aircraft maintenance technicians.

The Filthy Fifteen, which has offered a current perspective in recent years to explain human factors seen in the aircraft maintenance sector, can be updated according to the changes experienced in today's business life. In this context, *technostress* can be seen as a source of stress affecting the performance of many employees in the modern age and as a current

human factor that can cause aircraft maintenance workers to make mistakes. Technostress refers to the stress experienced by employees due to problems such as the effort to perform many tasks using information and communication systems, constant exposure to excessive workload due to these technologies, system updates, constant need for relearning, software and hardware failures (Tarafdar, Tu & Nathan, 2011). Factors such as technological complexity in the workplace, increasing workload, adaptation process to changing technology, age and experience of the technology user, organizational pressures, and changing job roles are among the factors affecting technostress (Türen, Erdem & Kalkın, 2015). Techno-overload, techno-invasion, techno-complexity, techno-insecurity and techno-uncertainty can affect the job performance of aircraft maintenance technicians as sub-dimensions of technostress (Tarafdar et al., 2011).

Aircraft maintenance technicians have to navigate more complex interfaces and dense data flows in maintenance tasks today due to developing technology. In addition, the flow of information from multiple sources through maintenance manuals, digital dashboards and communication tools can overwhelm technicians. In this context, overload and information flow resulting from the use of technology can create technostress in maintenance technicians and limit their ability to see critical maintenance stages and faults (Reason & Maddox, 1995; Çoban & Aydoğdu, 2020). When the literature is examined, it is possible to see studies on the relationship between technostress and job performance in the aircraft maintenance sector. In a study conducted by Alam (2016) on pilots and maintenance technicians in Pakistan, it was found that technostress reduces team performance; in a study conducted by Çoban and Aydoğdu (2020) on 177 aircraft maintenance technicians in Turkey, time pressure increased technostress; and in another study conducted by Türen et al., (2015) in Turkey, it was seen that 32% of employees in the aviation sector experienced technostress. In a quantitative study conducted by Erdem and Sökmen (2022) on 331 aircraft maintenance technicians working in four different cities in Turkey, it was reported that the technological complexity dimension of technostress negatively affected the work efficiency of the technicians. However, in another quantitative study conducted by Kızılcan, Hoşgör and Güngördü (2023) with the participation of 112 personnel working in ground services at Antalya Airport in Turkey, it was found that moderate perceived technostress did not affect work performance.

In addition to the technostress studies mentioned above, it has been observed that significant technological changes and innovations have recently been experienced in the aircraft maintenance sector to perform maintenance tasks more efficiently. One of these technological innovations, predictive maintenance, focuses on proactively predicting failures and increasing efficiency in maintenance tasks by using data analytics, machine learning, advanced algorithms and sensor technologies (Daily & Peterson, 2017). Aircraft maintenance companies face great difficulties, especially when examining aircraft exterior surfaces during the maintenance needs assessment process. The aircraft maintenance sector, which wants to solve this difficulty, equips maintenance hangars with specially designed robotics and automation systems. One of the notable developments is the use of drones for efficient and fast aircraft inspections. The use of drones in maintenance tasks can reduce maintenance times by up to 90%. Easyjet has saved significant time by using Blue Bear drones in maintenance tasks. Airbus uses visual cameras and obstacle detection sensors in

addition to special drones in maintenance tasks (Reed, 2019). Developed by New Zealand-based Invert Robotics, a versatile and crawling robot can cling to wet and dry aircraft surfaces and provide maintenance engineers with high-resolution images of the aircraft's condition. It is possible to see that the world's leading aircraft engine manufacturers and maintenance companies, such as Rolls-Royce, Pratt & Whitney, GE Aviation, and Lufthansa Technik, are turning to environmentally friendly robotic technologies in engine maintenance and inspection. In addition, big data analytics and blockchain technology are important technological innovations used in aircraft maintenance processes to make optimum resource allocation, reduce risks, perform safe maintenance, and provide transparent maintenance records (Olaganathan, 2024).

It is thought that the current and intense technological changes seen in the aircraft maintenance sector will contribute to the more effective, efficient and safe performance of maintenance tasks and that these technological changes will increase in the coming years. However, these changes are likely to create a need for more technological skills and training for aircraft maintenance technicians compared to the past. In this context, many factors such as not being able to follow rapidly changing and updated technological innovations, being constantly exposed to technological complexity, the need for frequent updates of technological tools, the need to analyze intensive data under time pressure, and software and hardware problems can come together to create technostress in maintenance technicians.

Technostress can indirectly lead to perceptions of excessive workload, cognitive fatigue, loss of motivation, burnout, low job performance, intention to leave the job, and job dissatisfaction in maintenance technicians (Tarafdar, Tu, Ragu-Nathan & Ragu-Nathan, 2007). Moreover, technostress can be related to many human factors included in the Filthy Fifteen. First of all, a maintenance technician experiencing technostress is likely to have problems with communication, teamwork, attention, and situational awareness. The time pressure caused by the commercial pressures of the airline company can increase technicians' perception of technostress. Constant exposure to intense technological processes and complexity can exhaust technicians mentally and physically, as well as push them beyond their limits and lead them to unprofessional behaviors.

Within the scope of the research in the literature, it is possible to see technostress in the aircraft maintenance sector as a human factor that is independent of other stress sources and negatively affects employee performance. In this context, the **"Dirty Sixteen"** model, which can be created by adding technostress to the Filthy Fifteen, can be a current approach to understanding errors caused by human factors in the aircraft maintenance sector. The development of the Dirty Sixteen model, including the Dirty Dozen and Filthy Fifteen, is presented in Figure 2.

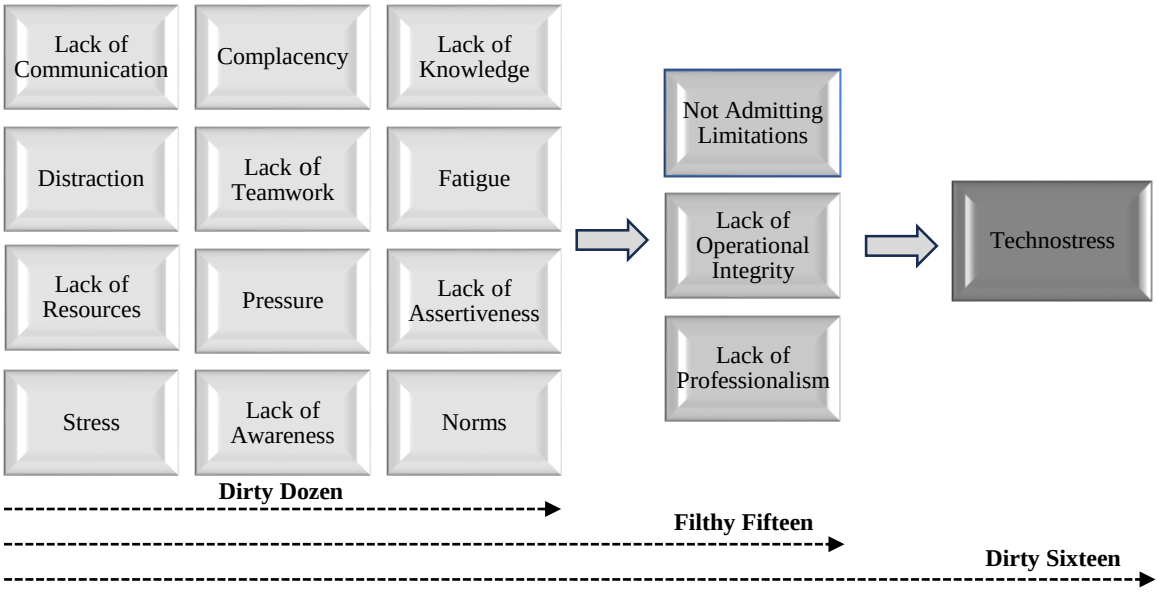

Figure 2. Dirty Sixteen Model in Aircraft Maintenance Sector

The Dirty Sixteen model, which also includes technostress, can be an important human factors examination model not only in the aircraft maintenance sector but also in the flight, maintenance and air traffic operations of civil and military aviation. The use of technology in both the civil and military aviation sectors is quite high. In particular, technological materials, devices and equipment are frequently used in military aircraft maintenance activities, where maintenance technicians are at the center (Çoban & Aydoğdu, 2020). In addition, the advanced avionics features of military jet aircraft and the high technology of today's advanced smart ammunition can create technostress in military aviation, especially in flight, maintenance and ammunition loading teams. It can be said that technostress is affected by many human factors and affects many human factors. In this context, apart from the aviation sector, the Dirty Sixteen model can be used as an important tool to examine human factors in sectors such as energy, software, automotive and health, which involve high technology and where employee errors have extremely serious negative consequences.

This study, which examines the Dirty Dozen and Filthy Fifteen models developed to examine human factors in the aircraft maintenance sector in light of literature review, may have limitations due to being a theoretical review. To overcome these limitations, this theoretical review can be supported by conducting quantitative and qualitative studies on the effects of the three new human factors added to the Dirty Dozen and current human factors, such as technostress, on aircraft maintenance technicians. In this context, which of the sixteen human factors, including technostress, affect the performance of maintenance technicians the most and whether technicians and maintenance managers are aware of the four newly added human factors to the model, can be investigated through face-to-face interviews. In addition, scale studies can be conducted on whether the Filthy Fifteen and Dirty Sixteen can be separated into dimensions within themselves. It is thought that this study will bring a current perspective to the literature on human factors in the aircraft maintenance sector and shed light on future research.

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