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PERSPECTIVES ON PILOTS' FATIGUE RISK MANAGEMENT IN ESTONIAN SHORT-HAUL PASSENGER AIRLINES

Master's Thesis

International Business Administration

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I hereby declare that I have compiled the thesis independently, and all works, important standpoints and data by other authors have been properly referenced, and the same paper has not been previously presented for grading.

The document length is 16730 words from the introduction to the end of the conclusion.

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LIST OF ABBREVIATIONS AND DEFINITIONS

Abbreviations:

ANOVA	Analysis of Variance
AOC	Air Operator's Certificate
EU	European Union
EASA	European Aviation Safety Agency
ECA	European Cockpit Association
FAA	United States Federal Aviation Administration
FDP	Flight Duty Period
FRMS	Fatigue Risk Management System
FSS	Fatigue Severity Scale
FTL	Flight and Duty Time Limitation
HFMP	Human Factor Monitoring Program
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
SARPS	Standards and Recommended Practices
SD	Standard Deviation
SMS	Safety Management System
TRAM	The Estonian Transport Administration
MEL	Minimum Equipment List
NTSB	National Transportation Safety Board
WOCL	Window of Circadian low

Definitions:

1. Air Operator's Certificate (AOC) – "*certificate that authorises air operator to perform commercial air operations, as defined in the attached operations specifications, in accordance*

with the operations manual, Annex V to Regulation (EU) No 2018/1139 and its delegated and implementing actions." (European Parliament, 2018)

2. Commander's Discretion may be used to *"modify the limits on the maximum daily FDP (basic or with extension due to in-flight rest), duty and rest periods in the case of unforeseen circumstances (e.g., adverse weather, equipment malfunction or air traffic delay) in flight operations beyond the operator's control, which start at or after the duty time."* (EASA, 2018)
3. Duty period – "*any task that a crew member performs for the operator, including flight duty, administrative work, giving or receiving training and checking, positioning, and some elements of standby.*" (European Commission, 2014)
4. Disruptive roster (schedule) – "*a crew member's roster which disrupts the sleep opportunity during the optimal sleep time window by comprising an FDP or a combination of FDPs which encroach, start or finish during any portion of the day or of the night where a crew member is acclimatised. A schedule may be disruptive due to early starts, late finishes, or night duties.*" (European Commission, 2014)
5. Flight duty period (FDP) – "*a period that commences when a crew member is required to report for duty, which includes a sector or a series of sectors, and finishes when the aircraft finally comes to rest and the engines are shut down, at the end of the last sector on which the crew member acts as an operating crew member*." (Commission, 2012)
6. Flight sector – "*the segment of an FDP between an aircraft first moving for the purpose of taking off until it comes to rest after landing on the designated parking position*." (European Commission, 2014)
7. Minimum Equipment List (MEL) – "*a list which provides for the operation of aircraft, subject to specified conditions, with particular equipment inoperative (which is) prepared by an operator in conformity with, or more restrictive than, the MMEL established for the aircraft type*". (European Commission, 2012)
8. Micro-sleep – "*a short period of time (seconds) when the brain disengages from the environment (is stops processing visual information and sounds) and slips uncontrollably into light non-REM sleep. Micro-sleeps are a sign of extreme physiological sleepiness.*" (ICAO, 2020)

9. Roster – "*a scheduled arrangement of flight time (inclusive of proficiency flying, simulator and positioning), sign-on, sign-off times, standby periods and days off for a specific period.*" (Law Insider, 2023)

ABSTRACT

Fatigue is a recognised safety risk in commercial aviation that accounts for several incidents and accidents in previous years. Fatigue can significantly impair pilots' cognitive abilities, reaction times, decision-making abilities, and overall performance, which increases the risk of accidents and incidents. To ensure flight safety, fatigue risk management (FRM) is essential for effective surveillance and observation of safety-related fatigue risks. Over the years, fatigue and FRM have been studied from different angles and methods in European commercial aviation. However, the focus has been primarily on long-haul and/or ultra-long-haul flight operations leaving the short-haul operations with the gap in academic and industry-level studies. In addition, more study in the Estonian commercial airline sector needs to be done. The current thesis analyses pilots' fatigue-contributing causes and FRM concerns related to Estonian short-haul passenger airlines. To achieve the research aim, a sequential explanatory research strategy was used with a survey among 80 pilots working in Estonian short-haul passenger airlines, followed by a focus group interview with eight pilots from the same sample set to verify and complement the data received from the survey. Results of the study showed significant fatigue among survey participants. The correlational analysis of four age groups and six work experience categories revealed no statistically significant differences. The survey results revealed various fatigue-inducing factors, the most prevalent of which were sleep deprivation, circadian disruption, high workload, short turn-around times, inadequate rest time, disruptive rosters, duty extensions, unexpected roster changes, and sleep quality during layovers. Findings indicate that pilots do not consider fatigue protection effective and are sceptical about the efficiency of the current EASA FTL as a prescriptive FRM approach. The research revealed that insufficient fatigue hazards identification, lack of real-time data collection (e.g., turn-around time calculations), inadequate crew work and rest time planning, insufficient preparedness for the FRMS implementation, lack of authority oversight as the main FRM-related concerns on the company level as well as industry-wide for pilots working in Estonian short-haul passenger airlines.

Keywords: pilots, fatigue, fatigue risk management, FRMS, short-haul flight operations, Estonian passenger airlines.

INTRODUCTION

Since the beginning of the 21st century, civil air transportation has considerably changed and undergone comprehensive deregulation, resulting in today being one of the most safety-related and highly regulated sectors in the transpiration industry (Melin *et al*., 2018). Although air transport is one of the safest means of transportation, incidents and accidents still occur (IATA, 2018). Human error accounts for up to 80% of incidents and accidents in aviation industry (Shappell & Wiegmann, 2000; Wingelaar-Jagt *et al*., 2021; NTSB, 2022). Previous studies found that fatigue notably impacts pilots' performance and flight safety, being recognised as a common contributor to aviation incidents and accidents (National Transportation Safety Board (NTSB), 1994; Powell & Broadbent, 2007; Williamson *et al*., 2011; Houston *et al*.,2012; Venus *et al*., 2021). The airline business is part of a safety-sensitive industry where the risk of pilots' fatigue is high due to 24/7 operations resulting in irregular working shifts, switches between morning and night flights, circadian disruptions, unforeseen operational irregularities (e.g., adverse weather conditions, aircraft technical defects, delays etc.) and other hazards increasing the risk of pilots' fatigue. When pilots are fatigued, their cognitive abilities, reaction times, decision-making skills, and overall performance can be significantly impaired, increasing the risk of accidents and incidents (Houston *et al*., 2012). Therefore, fatigue risk management (FRM) is vital for effectively monitoring and surveilling safety-related fatigue risks to ensure safe flight operations.

Despite many topics related to fatigue and FRM in aviation being studied in the previous years, there are still uncovered areas that warrant future or more in-depth research. For example, while most previous studies focused on fatigue and FRM in long-haul flight operations, studies in short-haul operations from academic and industry-level perspectives are scant, especially in the European aviation sector. (Powell & Broadbent, 2007; Kiik, 2019; Wingelaar-Jagt *et al*., 2021; Hilditch *et al*., 2023) In addition, previous studies focused mainly on single factors or groups of factors related to pilots' fatigue risk: sleep and stress (Venus *et al*., 2021), time awake (Vejvoda *et al*., 2014), sleep and circadian phase (Gander *et al*., 2015), duty periods (Roach *et al*., 2012), work schedules and work tasks (Kiik, 2019). Wingelaar-Jagt *et al* (2021) suggest the importance of the study with a holistic approach where many fatigue-contributing factors will be studied more extensively. Moreover, previous studies used primarily quantitative study methods (Bourgeois-Bougrine *et al*., 2003; Gregory *et al*., 2010; Melin *et al*., 2018; Venus et al., 2021; Hilditch & Flynn-Evans, 2022), whereas fewer qualitative studies of fatigue have been published over the recent years (Hilditch *et al*., 2023).

Relatively scant studies focusing on fatigue and FRM in the Estonian airline sector encouraged the author to choose the current topic of the research. Identifying the signific fatigue-contributing causes and a better understanding of the FRM concerns from the pilots' perspective would bring more clarity for airline managers and possible changes to the enhancement of the fatigue risk management processes in Estonian short-haul passenger airlines.

The current thesis aims to analyse pilots' fatigue-contributing causes and FRM concerns related to Estonian short-haul passenger airlines. Based on the aim of the current study, the author formulated the following research questions:

1. What is the level of fatigue among pilots working in Estonian short-haul passenger airlines?
2. What are the most significant fatigue-contributing causes for pilots working in Estonian short-haul passenger airlines?
3. How do the fatigue-contributing causes affect pilots' perception of the fatigue management approaches in the airline industry?
4. What are pilots' perceptions of current fatigue risk management in their airline of employment?

The current thesis is divided into three chapters. The first chapter presents the theoretical background of the passenger airline business aspects, accidents theories and their link to safety management in airline business. It also provides a literature review of fatigue and fatigue management in the aviation sector. Chapter two describes the research strategy and introduces the sample set information. The author used a sequential explanatory strategy as a mixed-method study design. The author presents a detailed overview of the survey design and describes the procedure of the focus group interview. The final third chapter serves for the research results presentation and discussion. It contains the triangulation of the survey results and the focus group interview. The conclusion and discussion parts of the present thesis follow the third chapter.

The author believes that this thesis's results could yield benefits to the Estonian commercial airline business and shed light on the importance of robust fatigue risk management for safe and possible changes that need to be considered on the state level. The topic choice arose from the author’s interest in the abovementioned field of study and the connection to the Estonian aviation industry.

1 THEORETICAL BACKGROUND AND LITERATURE REVIEW

In this chapter, the theoretical framework of the current thesis is presented. The author suggests that the first chapter serves as the basis for the empirical part of the research as it includes the fundamentals of the theoretical background. The first chapter gives an overview of the flight operations aspect of a passenger airline as well as the role of the safety management system as one of the core elements in the airline management system. The author further describes the fatigue phenomena in aviation (causes, effects and safety-related outcomes). The last subchapter presents the concept of fatigue management with a detailed overview of different approaches used in the aviation sector. Prior most significant previous scientific studies and industry-specific documents are analysed and presented.

1.1 Airline industry

Passenger airline flight operations can be categorized into four groups based on flight duration: short-haul, medium-haul, long-haul, and ultra-long-haul. Short-haul flights are those under 3 hours that cover a distance of up to 1,500 kilometres. These flights are typically operated by regional airlines and are mostly domestic or international within a particular region, such as Europe, North America, or Asia. Medium-haul flights are between 3 to 6 hours, covering a distance of 1,500 to 3,500 kilometres. National or low-cost carriers typically operate these flights and may be regional or international, such as between Europe and the Middle East. Long-haul flights are defined as flights from the departure airport to the arrival airport of 3,500 to 6,500 kilometres over 6 hours. National carriers typically operate these flights and are usually international, such as flights between Europe and North America. Ultra-long-haul flights are over 16 hours and cover a distance of more than 6,500 kilometres. National carriers operate these flights, usually non-stop international flights, such as flights between Sydney and London or New York and Singapore. Longer flights require more crew members, with short-haul flights typically using two pilots, while ultra-long-haul flights may require up to four pilots to comply with fatigue regulations. In such cases, pilots may only be able to fly a limited number of monthly flights to avoid exceeding monthly work hour limitations. (Levo, 2016)

The type of flight operation also determines the necessary supporting functions. European Aviation Safety Agency (EASA) has mandated that an operations centre be handled whenever there are ongoing operations for aircraft operated by an airline with an air operator's certificate (AOC) (European Commission, 2012). Usually, commercial flight operations require 24-hour operational capability, constant monitoring and support for flight, maintenance, crew rotation, flight planning, and passenger flow due to continuous aircraft presence throughout the day. (Levo, 2016)

The composition of aircrew rosters varies significantly depending on the type of operations being conducted (Levo, 2016). Crew members on intercontinental flights experience layovers in different time zones, while those on short-haul flights stay in the same time zone each day. Nowadays, aircraft rotations are organized to avoid long idle periods for crew members away from their home base. In the past, flight crews would often have to stay in hotels for several days waiting for the return trip of the aircraft due to limited flight networks and fewer daily flights, particularly in long-haul traffic. (*Ibid*, 2016) Short-haul flights offer more flexible utilization of crew since the distances are shorter and aircraft rotations (turn-arounds) are faster, which airlines to schedule crew for up to several flights throughout the day with aircraft changes in between, creating some challenges for the crew.

1.1.1 Estonian airline industry

Notwithstanding its limited geographical expanse, Estonia boasts a thriving aviation industry, exemplified by the substantial upsurge in passenger traffic through Tallinn Airport during the first four quarters of 2022. Specifically, the number of passengers reached 2,748,266, denoting a 111.2% growth compared to the previous year (Tallinn Airport, 2023). The aviation sector in Estonia operates under the regulatory oversight of the Estonian Transport Administration (TRAM), an authoritative body tasked with monitoring and enforcing civil aviation laws and rules within the country. Its purview extends to various matters, including safety, security, aircraft maintenance activities, aircraft airworthiness continuity, and airport and ground handling services. As a member of the European Union, Estonia must comply with the EU's aviation standards and regulations mandated by the EASA, which TRAM is responsible for enforcing. Additionally, for any air operator seeking registration in Estonia, the TRAM is vested with the prerogative to issue the AOC that enables the operator to engage in passenger transportation activities while complying with the requisite operating conditions (TRAM, 2023).

As of March 2023, eight Estonian-registered air operators are offering domestic and international flights for passenger transportation. Five commercial short- or medium-haul airlines offer regular and non-regular (charter) flights. The rest three operators' activities fall into the business/corporate aviation domain. See for a list of air operators to which TRAM has issued AOC enabling commercial air operations with the type of passenger transportation in Appendix 1.

1.2 Fatigue in aviation

Fatigue is generally associated with various physical, psychological, socioeconomic, and environmental factors. According to Sadeghniiat-Haghighi & Yazdi (2015), in any safety-sensitive industry, fatigue is one of the most critical risks linked the human errors and accidents. There is no standard consensus definition of fatigue; it is defined in numerous ways with different classifications and types (e.g., acute fatigue, chronic fatigue, cognitive fatigue, physical fatigue, mental fatigue, perceptual fatigue etc.) (Dawson *et al*., 2009; Yung *et al.*, 2022). For example, Aaronson *et al.* (1999) state that "*fatigue is a universal symptom not only associated with most acute and chronic illnesses but also with normal, healthy functioning and everyday life*." From a solely physiological perspective, Berger *et al.* (1991) defined fatigue as "*functional organ failure*". On the other hand, Lee & Kim (2018) highlighted the physical aspect of fatigue and linked fatigue with mental decline and rest defects. Other researchers suggest that fatigue could be defined in the form of a group of contributors (e.g. sleep deprivation, insufficient rest times, sustained physical or mental effort, circadian disruptions) and outcomes (e.g. declined alertness, degraded task performance, etc.) (Bendak & Rashid, 2020) Nonetheless, fatigue of any kind is linked to worker's health, wellbeing, and assigned tasks performance (Yung *et al.*, 2022).

It is common for pilots to work around the clock in the aviation industry, which poses many challenges. Various studies by aviation professionals and scientists concluded that pilot fatigue is one of the safety-related concerns, particularly in short-haul operations (Bourgeois-Bougrine *et al.*, 2003; Powell & Broadbent, 2007; Vejvoda *et al.*, 2014; Sallinen *et al.*, 2017; Åkerstedt *et al.*, 2021; Hilditch *et al.*, 2023). Pilots working in short-haul operations are often challenged by irregular tight schedules that include consecutive early starts, late finishes, night duties long working days with 10 to 12-hour duty periods, which cause sleep-related problems such as circadian rhythm disruptions and the loss of sleep (Vejvoda *et al.*, 2014; Sallinen *et al.*, 2017;). Therefore, pilots usually experience fatigue caused by schedule-driven sleep loss. (Caldwell, 2012) According to ICAO, pilots' fatigue in aviation is mainly linked with sleep deprivation, extended wakefulness, circadian phase and workload (numbers and duration of flight duties, length of rest between duties, unforeseen operational errors etc.)

Hu & Lodewijks (2020) conclude that mental fatigue and drowsiness (i.e., sleepiness) are the most common forms of fatigue for civil aviation pilots. However, it is essential to distinguish these two forms of fatigue as they have different causes and physical and psychological responses (*Ibid.*, 2020). Cognitive workload and time spent on a task are the primary causes of mental fatigue. It confirms the results of previous studies (Powell & Broadbent, 2007; Roach *et al.*, 2012; Åkerstedt *et al.*, 2021) indicating that the main contributing factors to fatigue in pilots working on short-haul flights are long duty periods and early duty start times (which mean even earlier wake-up times). Furthermore, some researchers suggest that sleep-related factors – circadian rhythm, time awake and amount of prior sleep – are the leading causes of fatigue in a healthy human (Venus & grosse Holtforth, 2021). However, some studies (Williamson *et al.*, 201, p.499) associate fatigue mainly with the lack of rest rather than sleep, stating that fatigue is "*a biological drive for recuperative rest. This rest may or may not involve a sleep period depending on the nature of the fatigue.*" In addition, Venus & grosse Holtforth (2022b), confimed those pilots who reported higher fatigue levels also reported higher stress levels and higher scores of positive depression screenings.

1.2.1 Fatigue causes and contributing factors

There are different fatigue-contributing factors in a person's day-to-day life routine, like diet, number of physical activities, presence of stress etc. In this study, the author bases on physiological factors that contribute to pilots' fatigue acknowledge by ICAO and essential factors in short-haul flight operations, including the relevance of rostering aspects.

Circadian disruptions

Pilot work is commonly described as irregular work schedules that interfere with regular sleeping hours. According to Zhou *et al.* (2011), circadian rhythm disruptions can arise from working night shifts (shift work) or abrupt time-zone transitions, commonly known as jet lag, shifting the natural sleep-wake pattern. A critical consequence of circadian disruption is the misalignment of the window of circadian low (WOCL), "*a time in the circadian body clock cycle when subjective fatigue and sleepiness are greatest, and people are least able to do mental or physical work.*" (ICAO, 2020). The primary WOCL occurs at night, roughly from 2 AM to 6 AM, a time when physiological drowsiness is at the greatest level and physical capabilities are at the lowest level. Pilots' cognitive performance and alertness decrease during flight operations, particularly during the WOCL; moreover, it can cause impaired sleep due to the displacement of sleep to daytime when the quality and quantity of sleep are compromised. (Caldwell, 2012; Åkerstedt, et al., 2021)

Sleep loss

The optimal amount of sleep required per night can differ from person to person; however, adults generally aim for 7 to 8 hours of sleep. Studies have demonstrated that the quantity of sleep obtained in the past 24 hours is an independent predictor of an individual's ability to manage threats and errors while operating a jet aircraft in the simulator (Wingelaar-Jagt *et al.*, 2021). Conversely, insufficient sleep, defined as less than 5 hours, has been linked to sleepiness and loss.

An individual may lose sleep acutely, for example, by having extended periods without sleep (also known as sleep deprivation), or chronically, by losing one or two hours of sleep each night (also known as sleep restriction) (*Ibid*, 2021). This is of great concern to short-haul pilots who experience alternating morning and evening duties with minimum rest time, often insufficient to adjust their body clock and develop standard sleeping patterns (Reis *et al.*, 2016; Hu & Lodewijks, 2020). That can lead to an accumulation of sleep debt (having an hour of less sleep for several days), recovering from which needs a series of days with more sleep for a person and usual to entirely recover from sleep loss (Zhou *et al*., 2011). Apart from that, sleep quality may also be impacted by unfamiliar or uncomfortable sleep environments (e.g., noisy hotel rooms), circadian rhythm disruptions, or situational stress after a working day may complicate sleep during layovers. (Caldwell, 2012)

Time of wakefulness

The drive to sleep is linked to the time of wakefulness. This can be attributed to a homeostatic mechanism where an increased awake time increases sleep pressure. (Zhou *et al*., 2011) According to the findings of a study that was carried out by the National Transportation Safety Board (NTSB), crews that had been awake for shorter amounts of time (specifically, 5.3 hours for captains and 5.2 hours for first officers) committed four times more errors than crews that had been awake for longer amounts of time (13.8 hours for captains and 13.4 hours for first officers). (NTSB, 1994) Wakefulness that lasts longer than the regular 16 to 18 hours is associated with increased sleep pressure and subjective tiredness, leading to a gradual and more pronounced reduction in cognitive function). (Wingelaar-Jagt *et al*., 2021)

Workload

The effects of high and low workload scenarios can differ in several ways, with a low workload typically resulting in reduced motivation and task engagement, while a high workload may cause distress and potentially impair sleep. Due to the significant amount of mental effort required, situations with a high workload may exceed the capacity of tired individuals, whereas concerns with a low workload may not provide sufficient stimulation, revealing underlying drowsiness. (Wingelaar-Jagt *et al.*, 2021) According to Hu & Lodewijks (2020), "*both high and low workload scenarios can lead to a decline in performance, categorised as active and passive fatigue*."

Rostering aspects

Pilots frequently report work planning and scheduling as a cause of potentially inducing fatigue. For example, according to Houston *et al*. (2012), the work schedule was related to more than a quarter (27%) of all fatigue reports in commercial airlines. That has been supported by various studies analysing the link between flight duty period (FDP) and fatigue of aircrew (Bourgeois-Bougrine *et al.*, 2003; Powell *et al.*, 2007; Vejvoda *et al.*, 2014). Numerous studies have shown that duty duration is an important indicator of tiredness, alongside certain studies demonstrating that it is the most significant factor in fatigue. Apart from the duration of actual flight time, the complete duty length (total time starting from pre-flight briefing till the end) is a crucial factor contributing to pilots' fatigue (Wingelaar-Jagt *et al*., 2021). Moreover, the start time of FDP can impact the amount of sleep pilots can attain the night before, with an early start time being linked to considerably reduced sleep the previous night (Wingelaar-Jagt *et al*., 2021). According to Vejvoda *et al*. (2014), the late night or early morning hours may result in heightened fatigue levels. The study's results showed that short-haul pilots with late-ending FDPs were more fatigued than pilots with early-beginning FDPs, although their prior sleep duration was 1.1 h longer (*Ibid*, 2014). The cause of this may be an extended duration of being awake or operating an aircraft during the WOCL (Powell & Broadbent, 2007). In addition, some researchers have concluded that the high number of flight sectors can significantly increase fatigue at the end of the last duty sector (Roach *et al.*, 2012).

1.3 Accidents theories

1.3.1 Domino Theory

There is a well-established link between pilot fatigue and aviation safety. As fatigue is a broad subject that encompasses many different factors and aspects, they can be imagined as pieces of the "puzzle" that comprise the sequence of events leading to incidents and accident. Herbert W. Heinrich (1931) formulated the Domino Theory that illustrates the steps of disaster causation (see Figure 1). In his theory, Heinrich demonstrates that accidents are typically the result of a series of prior events, such that when one domino falls, it triggers the others to fall, resulting in an injury/accident.

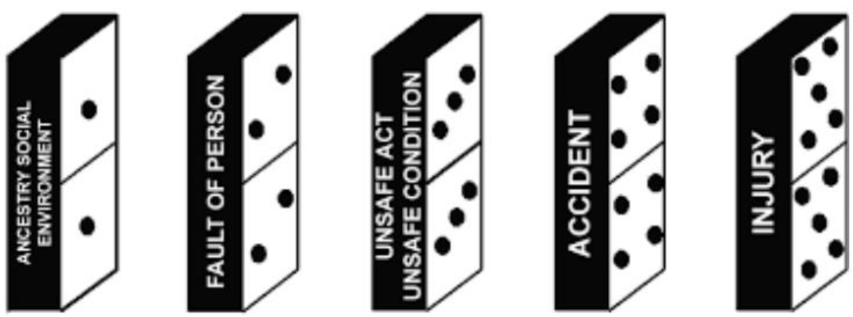

Figure 1. Heinrich's domino model of accident causation
Source: (Heinrich, 1941 cited in Barkhordari *et al.*, 2019)

After Heinrich's 1931 research and the introduction of the domino model, the concept that the human factor contributes the most crucial part in the occurrence of accidents became apparent. In this theory, Heinrich classifies fatigue as a potentially hazardous condition or action whose elimination could avert an accident. (Heinrich, 1941 cited in Barkhordari et al., 2019) During the critical phases of take-off and landing, even a brief disruption in concentration in an aircraft flying at hundreds of miles per hour can have catastrophic consequences.

1.3.2 Swiss Cheese Model

Similarly, James Reason (1990) demonstrates with his “Swiss Cheese model” (see Figure 2) that accidents are frequently the result of a combination of factors. Reason’s Swiss cheese model, which is considerably more recent than Heinrich’s Domino Theory, shares some similarities but is better developed and contains organisational factors as one of the latent threats. This model is widely used as a base concept in risk analysis and risk management in various safety-sensitive industries.

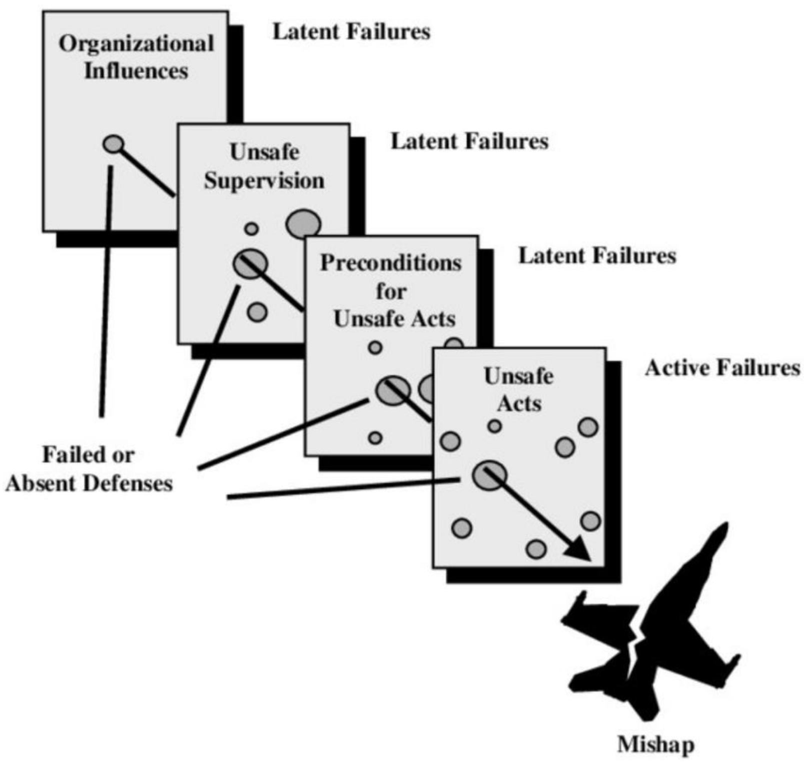

Figure 2. The "Swiss cheese" model of human error causation
Source: (Adopted from Reason (1990) by Shappell, S., & Wiegmann, D. A. (2000))

In the “Swiss cheese model” model, fatigue lies within the range of risks for unsafe acts. If left uncontrolled, it leads to involuntary unsafe acts ranging from microsleep to disruptions in attention, impaired decision-making, and loss of situational awareness.

According to the European Organisation for the Safety of Air Navigation (EUROCONTROL), fatigue is likely to be a factor in 30-90% of serious incidents or accidents (EUROCONTROL, 2018). In some aircraft incidents and accidents, fatigue has been identified as a primary or contributing factor.

Table 1. Comparison between different fatigue root-cause factors and the number of accidents/incidents in civil aviation between 2012 and 2021

Fatigue root-cause factors	**Accidents (n)**	**%**	**Incidents (n)**	**%**	**Total (n)**	**%**
General acute fatigue	5	24.0	10	50.0	15	37.0
Lack of sleep	8	38.0	6	30.0	14	34.0
Fatigue due to work schedule	5	24.0	4	20.0	9	22.0
Circadian rhythms or jetlag	3	14.0	0	0.00	3	7.0
Total	21		20		41	

Source: (National Transportation Safety Board, 2022)

For example, according to the National Transportation Safety Board (NTSB), there were 41 accidents by investigative findings (21 non-fatal and 20 fatal) regarding fatigue/alertness occurring between 2012 and 2021. According to Table 1, half of the non-fatal fatigue/alertness-related incidents were triggered by the pilots' general acute fatigue, followed by lack of sleep (30%) and fatigue due to work schedules (20%). Notwithstanding this, regarding the accidents that did cause fatalities, the most significant reason behind fatigue was the lack of sleep (38%), followed by general acute fatigue and fatigue due to work schedules (24% each).

1.4 Safety management system (SMS)

Historically, the aviation industry's approach to ensuring safety centred on examining the root causes of incidents and accidents. However, over the last decade, there has been a shift towards emphasizing the influence of working conditions, as well as management and organizational factors, on safety outcomes (ICAO, 2013a). Consequently, greater attention is now paid to how these factors affect employees' ability to act safely.

In November 2013, the International Civil Aviation Organisation (ICAO) adopted Annex 19, a document with the standards for systematic safety management system (SMS). The document entails that "*all companies operating within aviation (i.e., airports, airlines, air navigation and other organizations that can affect safety) must have a built-in system in their management for improving* *safety*" (ICAO, 2013a). Introducing a standardized and systematic method for enhancing flight safety requires significant alterations and higher expectations for the airline sector. Rather than relying on reactive measures that focus solely on identifying mistakes, incidents, or accidents, the aviation industry must now adopt a more proactive approach. This requires demonstrating to regulatory bodies a systematic effort aimed at preventing such occurrences. From the management point of view, safety is now treated as an integrated element of the organisation's core management system. Airline management should constantly ensure that all aspects of an airline's operations are conducted to minimise the risk of accidents and incidents. (ICAO, 2013b) This includes everything from aircraft maintenance to the training and qualifications of pilots, the procedures used to operate flights, and compliance with regulatory requirements.

The SMS includes a series of defined, organisation-wide structures, accountabilities, policies, and procedures (ICAO, 2013b). These are, for example:

- The identification of hazards
- The collection and analysis of safety data and safety information
- Safety performance measurement
- Set of the safety policy and objective
- Continuous assessment of safety risks (*Ibid*, 2013b)

The risk assessment method takes into account all relevant factors that may have an impact on aviation safety risks, including technological, human, organizational, environmental, financial, legal, or economic issues. Another risk that can be included in risk management is a risk to one's health and safety. Hazard identification combine reactive and proactive approaches for collecting and analysing safety data that identify present hazards and forecast future risks to aircraft operations. (ICAO, 2013b) According to ICAO, "*…an SMS ensures that hazards are analysed to determine corresponding safety risks to aircraft operations and safety risks are assessed to determine the requirement for risk mitigation action(s)".* Therefore, by proactively identifying and addressing safety risks, airlines can prevent accidents and incidents, enhancing their safety performance and reducing the likelihood of costly legal liabilities and reputational damage (ICAO, 2013a; 2013b).

In Europe, EASA is responsible for regulating and executing civil aviation safety. It works alongside national aviation authorities and is mandated to establish standards throughout the European Union (EU). The initial EASA SMS requirements have been implemented through the European Commission Regulation (EU) 965/2012 in air operations and organization requirements (EASA, 2012). Therefore, since October 2014, SMS has been a mandatory "element" of air operator's management system; the SMS is also a regulatory requirement for most civil aviation authorities worldwide, for example, the Federal Aviation Administration in the United States of America or the Civil Aviation Safety Authority (CASA) in Australia.

1.5 Fatigue risk management

According to ICAO (2015), fatigue risk management refers to the means by which aviation service providers mitigate the safety risks associated with fatigue. The ICAO Standards and Recommended Practices (SARPs) propose two approaches for managing fatigue risks (Figure 3).

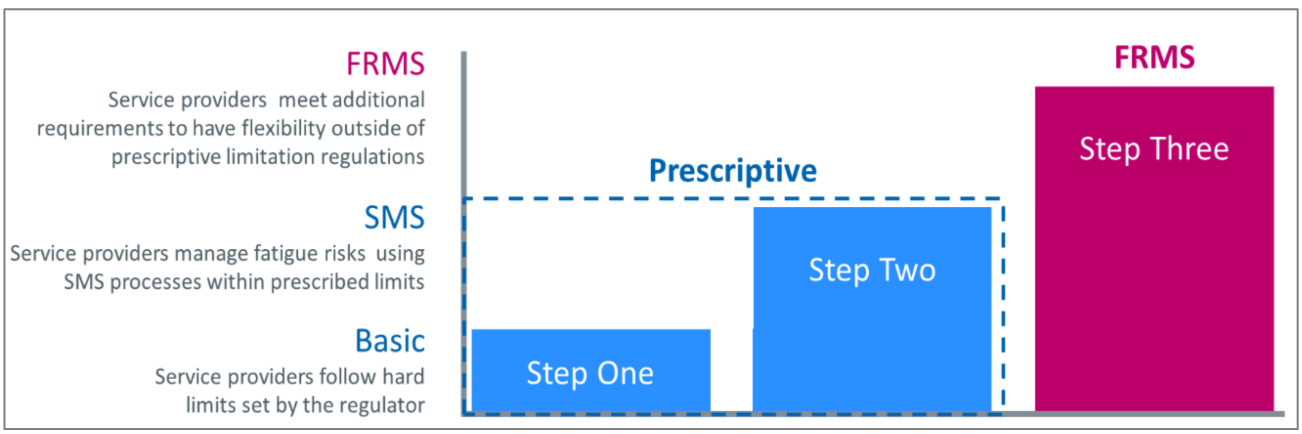

Figure 3. Fatigue management approaches
Source: (ICAO, 2020)

First, a prescriptive approach is when countries must have prescriptive fatigue management regulations which describe flight and duty time limits (FTL). This approach requires airlines to manage fatigue-related hazards and risks using SMS processes. According to (Wingelaar-Jagt *et al.*, 2021), this set of FTL regulations responds to fatigue concerns in general. However, this is solely an illustration of reality. As a result, these limits and this strategy have been criticised due to the significant discrepancies between regulations, the restrictive character of the limits and the lack of a foundation in modern fatigue science. Therefore, although suitable for some types of operations, the "one-size-fits-all", approach does not consider all possible causes of fatigue that can result in degraded pilots' performance in the cockpit (van den Berg, 2019). For example, Canada, Australia and New Zealand have started implementing less prescriptive and more performance-based fatigue management approaches allowing operators to define the upper limits of work and lower limits of rest required by employees. They are included in employment contracts or collective agreements. (Banks *et al.*, 2009, cited in Wingelaar-Jagt *et al*., 2021).

The performance-based approach is when countries may establish regulations allowing airlines to propose a Fatigue Risk Management System (FRMS) as an alternative compliance method (ICAO, 2020). Suppose an airline intends to increase its operational flexibility by utilising an FRMS or alternative approach instead of solely adhering to FTL rules. In that case, an airline must prove to its national aviation authority that it can ensure the same level of safety as it would be following the FTL rules in regulation. For example, the EU regulations allow variations without a full FRMS; however, airlines are still expected to provide a safety case to persuade the regulator that they can manage the fatigue risk. (Gander *et al.*, 2017)

In contrast to other occupational risks, fatigue is influenced by both work-related and non-work-related factors. The employer and employee must therefore share responsibility for fatigue management. Therefore, the airline must present a roster that allows sufficient rest, ensures adequate resource management and providing fatigue management training. Meanwhile, the crew member is accountable for arriving at work in a condition suitable for duty and identifying any fatigue hazards at the workplace. (Gander *et al.*, 2017; ICAO, 2020)

1.5.1 Flight and duty time limitations

The level of fatigue experienced by pilots is significantly influenced by their flight and rest times. Since duty times can differ depending on the type of flight, it is crucial to schedule them within the permissible limits to prevent crew fatigue. Initially, FTL rules aimed to avert fatigue among pilots working on long-haul flights, who have to deal with disruptions to their circadian rhythms, overnight stays in different time zones, frequent night flights, and extended flight duty periods (Venus & grosse Holtforth, 2021). However, many short-haul pilots have also reported elevated fatigue levels, reduced sleep opportunities, and increased on-duty drowsiness due to long work shifts and greater workloads, which require more take-offs and landings during each flight duty period. (Bourgeois-Bougrine et al., 2003; Reis *et al*., 2013; Roach *et al*., 2012; Vejvoda, *et al*., 2014)

Following the implementation of Commission Regulation (EU) 83/2014 in February 2016, the European airline industry adopted a completely unified set of FTL rules (European Commission, 2014). The FTL rules, however, are prescriptive rules that do not consider the fatigue experienced by individuals. These regulations specify the minimum duration of rest periods and establish upper limits on the number of flight hours per day, month, and year. However, considering the high prevalence of severe and very high fatigue among European pilots, EU FTL rules are considered less successful than expected. (Bendak & Rashid, 2020; Bourgeois-Bougrine, 2020; Efthymiou *et al.*, 2021) Therefore, European pilots continued to experience abnormally high fatigue levels, threatening flight safety despite European legislation to combat this problem. In 2017, the European survey of 15,680 pilots and cabin crew highlighted certain "fatigue hot spots" that warranted further investigation from the EASA side to determine whether the EU FTL regulations effectively managed the fatigue risk. Two years later, in 2019, a study titled "Effectiveness of Flight Time Limitation" was conducted on behalf of the European Commission and EASA to evaluate the FTL rules based on the current operations of 24 airlines. It revealed significant shortcomings in the current FTL regulations. According to the results, night flights and disruptive rosters have very high fatigue levels. (EASA, 2019)

For example, according to the current FTL part "Flight time and duty periods" (ORO.FTL.210) (Appendix 2), it is permissible for a flight duty to last for 12 hours, but exceeding this by just a minute is considered illegal. Although this distinction is insignificant when evaluating fatigue, the rules are in place as a bureaucratic measure and barely protect crew members against fatigue. These FTL rules are applied uniformly across all European airlines without considering significant variations such as long-haul versus short-haul flights (Efthymiou *et al*., 2021). However, the FRMS recognises these limitations. It emphasises the importance of maintaining adequate alertness, which depends on the situation, rather than just complying with the FTL rules. (Gander *et al.*, 2017; Starr, 2017; Wingelaar-Jagt *et al*., 2021).

1.5.2 Fatigue risk management system (FRMS)

The ICAO defines FRMS as a "*data-driven means of continuously monitoring and managing fatigue-related safety risks, based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness*". (ICAO, 2020)

The fundamental elements of FRMS comprise fatigue risk management processes, forming a self-contained loop for continuous fatigue management, as depicted in Figure 4. These processes are data-driven and include continuous monitoring of fatigue levels to determine occurrences where fatigue may be a hazard, evaluate the risk associated with a fatigue hazard, and mitigate the fatigue risk when necessary. Continuous monitoring is also required to evaluate the efficacy of newly implemented fatigue mitigations and to identify new fatigue hazards. This approach enables the maintenance of balance between productivity, costs, and safety in the organisation (Levo, 2016).

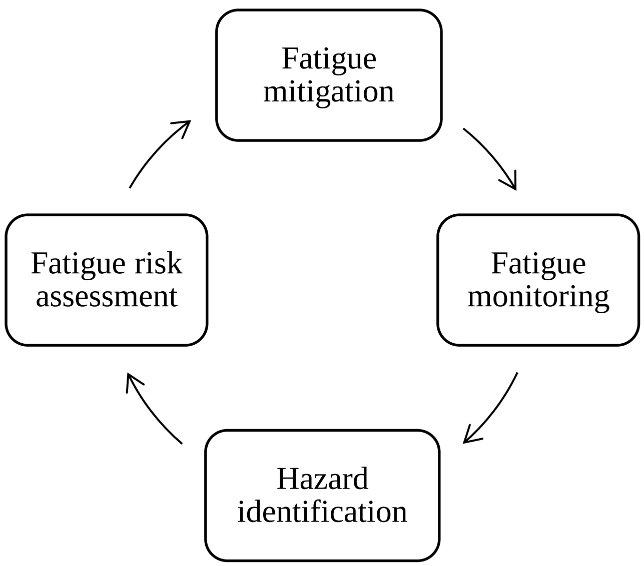

Figure 4. Fatigue risk management process cycle
Source: Gander *et al.*, 2017, author's interpretations

Further monitoring is needed to evaluate the implemented fatigue mitigations' efficacy and identify any new fatigue hazards through predictive, proactive, and reactive phases. Methods for predicting fatigue hazards may include operational experience and collected data, evidence-based scheduling practices, and bio-mathematical models, which are an approved but not mandatory means of forecasting potential fatigue hazards. (Levo, 2016; Gander *et al.*, 2017; ICAO, 2020)

However, the collection and analysis of data are essential for the successful implementation of FRMS. This involves measuring crews' fatigue and the airline's operational performance (Gander *et al.*, 2017). Proactive measures can be taken to identify and address fatigue risks through self-reporting, crew performance assessments, scientific studies, fatigue surveys, and comparison of actual real-time rosters versus preliminarily planned rosters (ICAO, 2020; Levo, 2016). This process requires collaboration between flight crew members, managers, and all other relevant personnel.

An influential safety reporting culture is also crucial for the success of FRMS, and it relies on operating personnel reporting observed hazards. The airline must differentiate between intentional and unintentional errors to make this work. ICAO (2013b) suggest that unintentional human errors be seen as opportunities for safety improvement rather than reasons for punishment to promote a positive safety culture. This necessitates adopting a non-punitive *Just Culture* policy that allows pilots and cabin personnel to report about occurrences without the fear of punishment, so long as they were not caused by negligence or deliberate disregard for safety. This encourages a reporting culture where flight crew members (pilots primarily) will report incidents and issues without fearing consequences. (*Ibid,* 2013b)

2 METHODOLOGY

The second chapter presents the research strategy of the current study. It introduces the study's primary aim and describes research questions. In addition, this chapter focuses on the techniques of data collection and sample set information. Primary quantitative data was acquired through an online survey, and the semi-structured focus group interview was used for the qualitative research. The author describes the in-detailed overview of the survey composition and the focus group interview preparation and process.

2.1 Research strategy

The present research aims to analyse pilots' fatigue-contributing causes and risk management concerns related to Estonian short-haul passenger airlines. The author has formulated the following central research questions to achieve the aim of the study:

1. What is the level of fatigue among pilots working in Estonian short-haul passenger airlines?
2. What are the most significant fatigue-contributing causes for pilots working in Estonian short-haul passenger airlines?
3. How do the fatigue contributing causes affect pilots' perception of the fatigue management approaches in the airline industry?
4. What are pilots' perceptions of current fatigue risk management in their airline of employment?

To achieve the research objective, the author decided to use a sequential explanatory research strategy, a common mixed-method design strategy typically used to "*explain and interpret quantitative results by collecting and analysing follow-up qualitative data*" (Creswell, 2009, p. 194). The first stage of the design consists of quantitative data collection and analysis, followed by qualitative data collection and analysis in the second phase, which builds on the initial quantitative results (*Ibid.*, p. 195).

Figure 5 illustrates the study design sequence. A survey was conducted as a part of a quantitative part of the present study to examine the level of fatigue and the causes contributing to pilots' fatigue levels. The reliability and validity of the answer scales were measured by

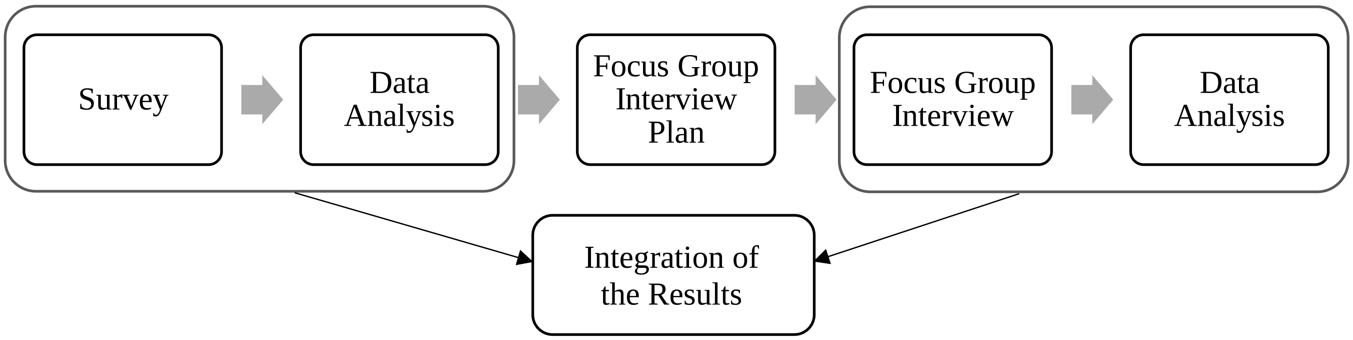

Figure 5. The study design process of the current research
Source: Author's interpretation of the study design process

In order to complement and verify the data received from the quantitative part of the study and get an in-depth understanding of how fatigue-related concerns identified in survey affect pilots' perception of fatigue risk management on the company level as well as industry-wide, the author decided to conduct a focus group interview with several survey participants as a part of a qualitative study.

2.2 Quantitative research

2.2.1 Data collection and sample description

Before the survey was carried out, a systematic literature review was described in the first chapter, which identified previous research with relevant question areas to design the questionnaire. Additionally, specific questions in the survey came from previously conducted surveys and were embedded in this survey, in some cases somewhat modified to be relevant to commercial air operations. The questionnaire consisted of 32 questions and was composed using the web-based survey platform *Google Forms*. This platform automatically generates answers into an *Excel* table and creates graphic drawings (Microsoft, 2023). The complete list of survey questions and answer alternatives is presented in Appendix 4.

The questionnaire used in this study consisted of a total of eight parts. The first part consisted of the question related to the socio-demographic information of the pilots participating in the survey. This part was followed by the Fatigue Severity Scale (FSS), which aimed to identify the fatigue level of the participants. The next module consisted of questions related to the causes of fatigue. Next, pilots were asked about safety outcomes due to fatigue-caused errors, reporting incidents and accidents linked with fatigue. Further, questions were posed about sleep quality and sleep-related problems. In addition, pilots were asked to assess the hotel outside their home base and the availability and quality of nutrition provided there. The final section of the survey focused on questions related to pilots' workload and work schedules. For all questions' scales Cronbach's alpha was calculated to confirm that they are respectable and internally consistent. Below in sub-chapter 2.2.2 the author presents a detailed description of each survey module.

The target group of the survey were pilots working in Estonian-registered short-haul passenger airlines. An email letter with the survey link was distributed through short-haul Estonian-registered commercial passenger airlines. In this email letter, participants were informed about the aim of this research, the length of the survey and that their data would not be shared, and answers would be treated with complete confidentiality. Participation in the survey was upon participants' personal acceptance. They were informed that they could drop out anytime during the survey. The survey period was two weeks in January 2023.

Table 2 summarises the sample structure of survey participants. A total of 162 pilots started the online survey, of whom 80 finished the survey. Thus, 46 captains and 34 first officers (second pilot) participated, with no significant gender differences in rank between 3.8% female, 92.5% male and 3.8% non-binary pilots. Most respondents belong to the age group between 35 and 44 years old (n=29, 36.3%).

Table 2. Demographical information of the participants

Variable	**Category**	**N**	**%**
Age	18–24	1	1.3
	25–34	23	28.8
	35–44	29	36.3

	45–44	16	20
	55–65	11	13.8
Gender	Female	3	3.8
	Male	74	92.5
	Non-binary	3	3.8
Rank	Captain	46	57.5
	First officer	34	42.5
Total flight time experience (hours)	<1000	11	13.9
	1000–3000	23	29.1
	3001–5000	13	16.5
	5001–10000	20	25.3
	10001–15000	9	11.4
	>15.000	3	3.8
Working experience at the workplace (years)	<1	12	15
	1–2	7	8.8
	2–3	8	10
	3–4	10	12.5
	4–5	20	25
	>5	23	28.8
Workload	Full-time	64	80.0
	Part-time	16	20.0

Source: Author's calculations and interpretation
Note: N = Number; % = Proportion

Respondents reported, on average, 5971.1 (SD=5307.5) total flight hours of experience in civil air transport operations. Most pilots (N=64, 80%) have a full-time employment contract in the companies where their work, 15 of whom have been employed in one company for more than five years and 20 pilots who have joined the company of employment within the last two years.

2.2.2 Measurement instruments and analysis

1. Fatigue levels

In order to evaluate fatigue levels among participants, the author used the Fatigue Severity Scale (FFS), a self-report questionnaire (see Appendix 3) designed to measure the severity of fatigue experienced by individuals with various medical conditions, including chronic fatigue syndrome, multiple sclerosis, and fibromyalgia (Krupp *et* al., 1989). The scale was developed by Krupp *et al.* (1989) and consists of nine items, each of which asks respondents to rate their level of agreement with a statement using a seven-point Likert scale (ranging from 1 = strongly disagree to 7 = strongly agree), with higher scores indicating more severe fatigue. The total score is calculated by summing the responses and dividing them by the number of items. In this study, a total score of 4 or higher is considered as significant fatigue, as suggested in the literature for the full scale (Valko *et al.*, 2008). The FSS has been shown to have good reliability and validity in measuring fatigue in various medical conditions (Krupp et *al*., 1989; Krupp *et al*., 1995; Jacobsen *et al*., 1999).

FSS has been chosen as it is a widely used tool and it has been proven effective in the measurement of pilots' subjective fatigue in commercial air operations. For example, Rosekind *et al*. (1994) used the FSS to measure fatigue levels in commercial airline pilots. The study found that pilots who reported higher fatigue levels on the FSS also reported more errors and performance problems during simulated flight tasks (*Ibid*, 1994). Another study involving airline pilots and pilots using FFS was conducted by British Airline Pilots Association (Steptoe & Bostock, 2011). Reis *et al*. (2013) used FSS to test the hypothesis that medium/short-haul pilots may present different fatigue levels from long-haul pilots.

The statistical procedure of comparing the means of a variable across several groups of individuals was performed using the correlational analysis of variances (ANOVA test). The comparison between fatigue levels, four age groups, and six work experience (years). The statistical analysis was carried out with the add-in application *Real-Statistics* in *Microsoft Excel*.

2. Causes and effects of fatigue

In total, there were two related causes of fatigue and three questions related to the effects of fatigue. The first two questions related to the causes of fatigue during the climb (stage of flight when aircraft climbs after take-off) and decent (pre-final stage of flight when aircraft descends before approaching for landing), and related to different events during the flight, which contribute to pilots' fatigue were examined through modified questions from the study by Bourgeois-Bougrine *et al*. (2003) “Perceived Fatigue for Short-and Long-Haul Flights: A Survey of 739 Airline Pilots”. The question “During climb and descent, to what extent do the following situations make you tired?” was paraphrased to “During climb and descent, to what extent do the following situations contribute to your fatigue?”. In contrast to the original study (Bourgeois-Bougrine *et al.*, 2003), nine statements were included regarding fatigue during climb and decent (added statement: interruption during activities by air traffic controller). The pilots were asked to rate each statement on a 5-point Likert scale (1 = no contribution; 5 = major). Cronbach’s alpha of 0.82 was acceptable and confirmed that the scale is respectable and internally consistent. The next question in this section, “In general, what is the impact of the following operational irregularities on your level of fatigue?” was modified by the author, adding two more statements (‘short turn-around times with an aircraft change’ and ‘operations aircraft with technical defects listed in the minimum equipment list (MEL)’) which constructed in total eight statements. Each statement was rated on the 5-point Likert scale (1 = no impact; 5 = severe impact). Cronbach’s alpha of 0.81 showed acceptable reliability. The effect of fatigue on pilots’ task performance during the flight was examined through three questions. The first question, “In what ways has fatigue affected your flight performance?” was obtained from the research by Gregory *et al.* (2010) “, Pilot Fatigue Survey: Exploring Fatigue Factors in Air Medical Operations”. The author modified the question by asking the participant to reflect on the previous five months. Answer alternatives: cannot concentrate; alertness degraded; performance degraded; impaired memory; all mentioned. The last two questions of this section concerning fatigue and declaring unfit to fly or taking a sick with reference to the last five months were developed by authors.

3. Safety-related outcomes of fatigue

Safety-related outcomes were examined through five questions used in the study by Melin *et al.* (2018), “High-flying Risks: Variations in working conditions, health, and safety behaviours among commercial airline pilots about safety climate” – two questions about fatigue and serious mistakes/incidents, two questions about serious mistakes/incidents and reporting, and one question about self-reporting fatigue. In the source (Melin *et al.*, 2018) abovementioned questions were formulated with time reference of the previous 12 months. In this study, the author changed the questions regarding the last five months.

4. Sleep patterns and problems

In order to examine sleep patterns and sleep-related problems, participants were asked a total of four questions in this module. The first two questions from research by Gregory *et al*. (2010) were about the average hours of sleep that pilots between their working days prior to the start of the new duty to feel completely rested and alert, and the second question focused on the actual average hours of sleep that participants get in the same working conditions. The question included multichoice answers: less than 5; 5–6h; 7–8h; 9–10h; more than 10 h. One question was taken from the study by Venus & grosse Holtforth (2021), "How Duty Rosters and Stress Relate to Sleep Problems and Fatigue of International Pilots". The author modified this question, shortening it from 14 statements to 8. Pilots were asked to rank each statement on the 5-point Likert scale (1 = never; 5 = always). The reliability coefficient of Cronbach's alpha was acceptable at 0.79. The last question in this section focused on how pilots improve the quality of their sleep, where participants were given alternatives of six different answers alternatives.

5. Work–rest environment

Regarding pilots' work-rest environment, the module consisted of the first two questions obtained from the study by Gregory *et al*. (2010). It was posted concerning the availability of the rest facilities during layovers outside of their home base and environmental factors and conditions of the rest facilities. As in the commercial aviation pilots rest in hotels during a layover, the author paraphrased two questions "Does your current employer provide a suitable rest environment?" and "How would you best describe the environmental conditions (lighting, temperature, and noise) for the secluded rest area you identified in the previous question?" (Gregory *et al.*, 2010) into the following questions: "Does your current employer provide a suitable hotel room during a layover?" and "How would you best describe the environmental conditions (lighting, temperature, and noise) for the hotel room area you identified in the previous question?". Further in this module, the author composed two questions about the availability and quality of the nutrition provided in the hotel during a layover.

6. Workload and rostering

Four questions were in the module to examine pilots' workload and fatigue-related rostering concerns. First, pilots were asked to describe their current situation regarding their work schedule in their current airline. In the question with seven statements. (Melin *et al.*, 2018) Each statement was rated on the 5-

point Likert scale (1 = strongly disagree; 5 = strongly agree). Cronbach's alpha of 0.92 showed acceptable reliability. Following that, pilots were asked to indicate what fatigue severity caused the listed types of duties. The question included ten statements with an answer rating based on a 5-point Likert scale (1= no fatigue to 5 = severe fatigue). Cronbach's alpha for types of duty questions was 0.82. The next question examined what situations connected to rest amount and duration during or/and between the duties contribute to pilots' fatigue. Six statements were included in the question with the answer alternative based on a 5-point Likert scale (1 = no fatigue to 5 = severe fatigue). Cronbach's alpha was 0.84. Lastly, participants were asked to take a stand rating level of fatigue in relevance to different rostering patterns (duty duration on a daily, weekly and monthly bases), marking an answer alternative to each of the five statements based on the 5-point Likert scale (1 = no fatigue to 5 = severe fatigue). The reliability coefficient Cronbach's alpha for this question was 0.85.

7. Fatigue risk management

The effectiveness of current fatigue risk management in their company was examined through the question with four statements where pilots were asked to express their level of agreement with each statement based on the 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). Cronbach's alpha of 0.70 showed acceptable reliability. Also, participants were asked to express to what extent fatigue is a concern among pilots in their current company and how good the protection of pilots against fatigue is in their current company through two separate close-ended questions. Answer alternatives for both questions were based on the 5-point Likert scale.

2.3 Qualitative research

2.3.1 Participants and focus group interview

In order to in order to complement and verify the data received from the survey and get an in-depth understanding of how fatigue-related concerns identified in questionnaire study results affect pilots' perception of fatigue risk management on the company level as well as industry-wide, author decided to conduct a focus group interview with the group of survey participants. The invitation for the focus group interview was distributed through the same communication channel as the survey. The only inclusion criterion was to be a survey participant. Interested pilots were scheduled for an online focus group interview hosted through the *Zoom* online conference platform and, in the interview, participated in a total of seven pilots. The total sample profile of participants is described in Table 3 below. During the interview, pilots were asked to use their cameras and only their first name when joining the meeting. However, the names of the participants have not been disclosed in this study; instead, generic codes such as “Participant 1”, “Participant 2”, etc., have been assigned to identify individual participant quotes when applicable.

Table 3. Description of focus group interview participants

Variable	**Category**	**N**
Age	18–24	1
	25–34	2
	35–44	3
	45–54	1
Rank	Captain	5
	First Officer	2
Working experience at the workplace (years)	≤ 1 year	1
	2–4 years	1
	≥ 5 years	5

Source: Author’s calculations
Note: N = Number

Before the interview, pilots were asked for consent for an audio and visual recording of the session. Responses were recorded using the *Zoom* auto-generated transcript and notes taken by the author during the interview. The time limit was prescribed as 1 hour; however, the interview duration was 1 hour and 25 minutes. At the end of the interview session, pilots were asked to indicate their age, rank and working experience. The focus group interview plan is enclosed in Appendix 5.

2.3.2 Content analysis

Qualitative data obtained from the focus group interview was analysed using a conventional qualitative content analysis approach using an open coding in a qualitative data analysis software *ATLAS.ti*. Conventional qualitative content analysis is the systematic classification of text data into codes, themes and categories by identifying relevant text, quotes and repeating ideas (Milne & Oberle, 2005). As shown in Table 4 first coded the transcript by highlighting relevant text, quotes and repeating ideas. Next, these codes were grouped into themes. Then, themes were used to categorise data and triangulate the survey and interview results. The complete list of codes can be found in Appendix 6.

Table 4. Example of conventional content analysis process

Relevant text, quotes, repeating ideas	**Code**	**Theme**	**Category**
"*... circadian cycle is also a big matter, and nobody thinks about it. Take it into account because, for instance, when you wake up at 5 o'clock, two days in a row, you have to switch to the night flights, with respect to the minimum rest written in regulations, of course, but your body is going crazy.*" – Participant 4 "*…in a short-haul operation early starts of the shift in the morning, like getting up at 4 AM one day and then finishing duty in the afternoon the same day, and the next day, you can start working at the time when you have finished working the previous day and finishing duty early in the morning and having to go to bed like at 2 AM.*" – Participant 1	Circadian switches; Early wake-up/report; Early starts	Circadian disruption; Early duties;	Sleep patterns and problems

Source: Author's interpretation

3 RESULTS AND DISCUSSION

This chapter introduces the results of quantitative and qualitative data analyses based on the research strategy described in Chapter 2. The survey results are presented in percentage terms and numerically, partially illustrated with tables.

3.1 Research results

1. Fatigue levels

A significant level of fatigue (FSS ≥ 4) was identified among 62 pilots (78%). The average FSS score among all participants was 4.46 (SD 0.42). Table 5 shows the average scores and SD for each of the nine statements of the FSS questionnaire. According to the results, six out of nine statements had a score of ≤ 4.0, among which four had scores of ≥ 5.0. According to the results, the highest scores among the statements were “My motivation is lower when I am fatigued” and “Fatigue interferes with my work, family or social life”, where mean = 5.8 (SD 1.25) and mean = 5.5 (SD 1,31) respectively. Followed by “Fatigue interferes with carrying out certain duties and responsibilities” (mean = 5.3, SD 1.16).

Table 5. FSS scores by statements

Item	Statement	Mean	SD
1	My motivation is lower when I am fatigued	5.8	1.25
2	Exercise brings on my fatigue	3.0	1.17
3	I am easily fatigued	2.8	1.27
4	Fatigue interferes with my physical functioning	5.2	1.38
5	Fatigue causes frequent problems for me	3,9	1.54
6	My fatigue prevents sustained physical functioning	4.4	1.42
7	Fatigue interferes with carrying out certain duties and responsibilities	5.3	1.16
8	Fatigue is among my most disabling symptoms	4.4	1.56
9	Fatigue interferes with my work, family or social life	5.5	1.31

Source: Authors’ calculations based on the FSS questionnaire results
Note: SD = Standard deviation

Regarding the relationship between fatigue level and age groups, ANOVA analysis uncovered no significant statistical differences ($p = 0.36$).

The author asked focus group interview participant about the possible root cause of the relatively high levels of fatigue according to the results of the FSS questionnaire. Interviewees agreed that the post-COVID-19 period put them in a situation where "… *operation is pushed to the limits and the companies are trying as much as they can to be on the same operational level as before COVID. Nevertheless, pilots are pushed to their limits, so results are as they are…*"– interview Participant 5. Participants expressed their concerns about airlines taking advantage of pilots' desire to keep their jobs in the aviation sector: "… *all of our terms and conditions have been squeezed significantly compared to before Covid, including fatigue and issues. So, before Covid, if you felt fatigued, you could maybe feel better and happier to offload yourself. However, now you are just like much more inclined to do whatever it takes to keep your job…"* – interview Participant 4. Other interviewees believe that airlines "*have taken the back of that*" and "*great advantage*" – interview Participants 4 and 5. They consider it cynical and unfair that very little attention is paid on such significant safety risk as fatigue. One of the participants highlighted that "*pilot pushing*" leads to the high-stress levels, insecurity, mental fatigue and burnout that all affects pilots' performance: "*... I studied the topic of pilot mental health out of my interest and found out that rates of depression and rates of suicide ideas are higher in the pilot body than it is in the general population."* – interview Participant 2.

2. Causes and effects of fatigue

Results regarding the causes of fatigue have shown that among the nine items listed in the question, sleep deprivation remained the most important factor generating fatigue during aircraft climb and descent stages of flight. The vast majority of pilots (n=73, 91%) considered that lack of sleep moderately (n=45, 56%) or majorly (n=28, 35%) contributes to their fatigue. Avoiding adverse weather conditions and high workload, which characterise the climb and descent flight phases, gained the second and third highest scores, respectively (see Figure 6). Interview revealed that pilots feel as if there is a perception of them as "*superhumans*" if they simply know how to fly an aeroplane: "*... people forget that we are not superhumans and we can make mistakes. Furthermore, in the cockpit during the most important stages of flight, I mean after take-off and during landing, you need to be concentrated to your maximum, you need smooth communication with your co-pilot, everything needs* *to work like a clock before you can engage the autopilot. And now imagine that you did not have enough sleep the night before and your concentration is scattered, or your co-pilot is not on the same level of preparation for the flight as you are...”* – interview Participant 1. All participants highlighted the importance of having sufficient rest (importantly sleep) before the flight as they consider it to be the “*core-base element*” of their physiological well-being.

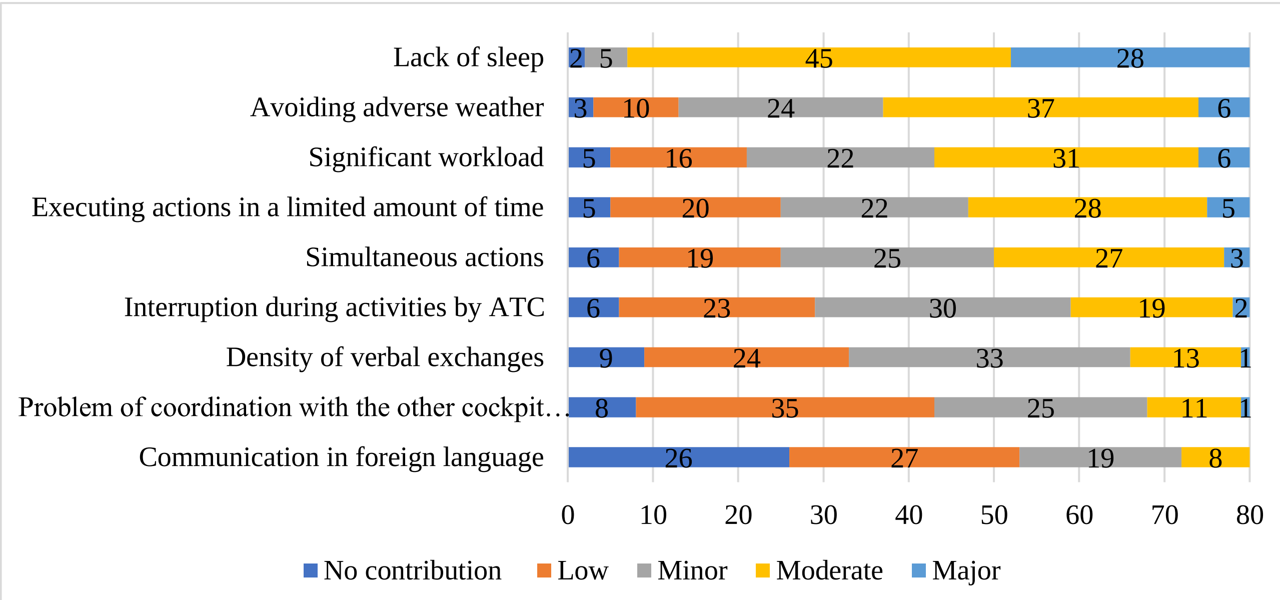

Figure 5. Causes of fatigue during climb and descent
Source: Authors’ interpretation of the survey results

Figure 7 represents the impact of seven operational irregularities on participants’ fatigue. The highest scores attributed to these seven items remained lower than that due to sleep deprivation in the previous question. The impact on fatigue was scored “major and severe” by 50% or more of pilots ($n \geq 40$) for one statement: short turn-around time with the aircraft change, followed by extension of duty via Commander’s Discretion (n=32, 40%) and compliance with time constraints (n=21, 27%), respectively. Whereas flight delay, operating an aircraft with defects, dissension among crewmembers and operations to/from unknown airports had minor to minor impacts on pilots’ fatigue. Participants of the interview also highlighted the problem of short turn-around times and the direct link to the duty extensions via Commander’s discretion: “… *you fly 4 sectors, and they would show the turnaround at being 20 min or 25 min, or maybe 30 min, and throughout my 6 years in that company, I never achieved a turn-around time like that. Not even once. So, my planned roster is lying to me. Like there is no way we are going to do a 20 min turn-arounds, it is unrealistic.*” – interview Participant 3. Pilots mentioned that, theoretically, it is possible to do the aircraft turn-around in a minimum of 25-minute time. However, suppose something goes out of line (delays or other irregularities such as technical problems). In that case, the turn-around times get extended, and as a result, the whole duty time gets extended as per Commander's Discretion: "*So, I could look at that and say, I am rostered to within 30 min of duty extension by Commander's Discretion, and I know that those turn-arounds will take 45min.*" – interview Participant 5.

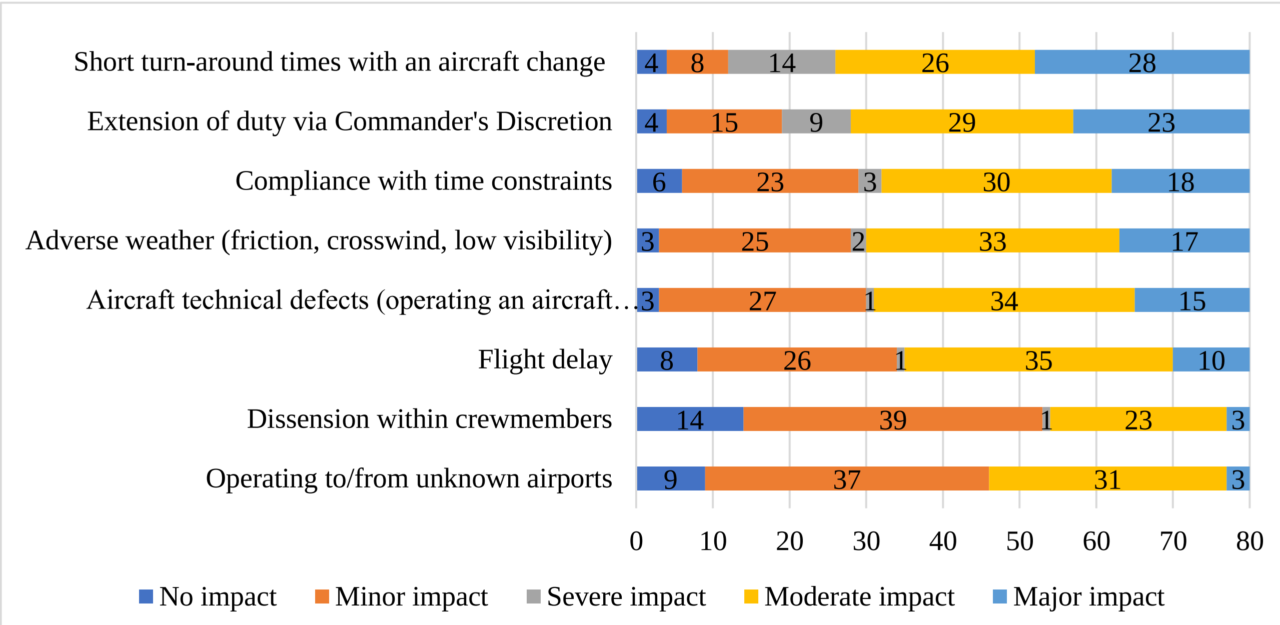

Figure 6. Impact of operational irregularities on aircrew fatigue
Source: Authors' interpretation of the survey results

As a root cause, pilots highlighted the lack of real-time turn-around observations from the airline side: "*…airlines could track it and say that, in fact, for example, statistically, is a 35-minute turnaround. If they input that data back into their system, we would be unable to complete those days. The fatigue, like predictively, would be much, much higher. And again, the data is there, and you can track it. You can go to an airport, and you can stand with a stopwatch and watch the aircraft do a turn-around and see that it took 40 min, and it was scheduled for 20 in the beginning*" – interview Participant 1. Another participant said that airlines must be involved in that process, and the authority should take more proactive steps to oversee how realistic the turn-around times planned by the airlines are.

Concerning fatigue outcomes, results show that fatigue has affected most of the pilots (n=60, 77%), such as an inability to concentrate, decreased alertness, degraded task performance, and impaired memory. This was also confirmed by a survey of pilots (Gregory et al., 2010), with >80% reporting that fatigue affected pilots' flight performance. Similar reductions in performance have been observed in several other studies that showed significantly declined flight performance after 24h of wakefulness (Caldwell *et al*., 2004; Previc *et al*., 2009). It could be concluded that inadequate sleep is one of the significant causes of fatigue root causes that affect a pilot's ability to execute his/her duty in the cockpit.

3. Safety-related outcomes of fatigue

The reporting of aviation events and incidents is a regular way of measuring safety, and reports are often made both within the airline and to the Estonian Administration. According to Melin *et al*., 2018 previous studies, as well as the authorities' side, point out that there are many unknown cases in the formal registers of reported events where fatigue is one of the root-cause factors. Results insulated below show that because of feeling fatigued more than two-thirds of pilots (n=55, 69%) at least once or a few times have made a mistake without an immediate flight safety effect within the previous five months. Whereas 15% of pilots (n=12) frequently experience errors in the cockpit due to fatigue (see Figure 8).

Finding shows that the number of pilots who reported not making mistakes without an immediate flight safety effect is relatively low (n=13, 16%). Less than half (n=23) of pilots reported making a mistake in the cockpit without an immediate flight safety effect due to fatigue, whereas the rest (n=43) who experienced such an occurrence while on duty refused to report it. Pilots who reported making a mistake were asked to indicate whether this mistake had been reported to the company.

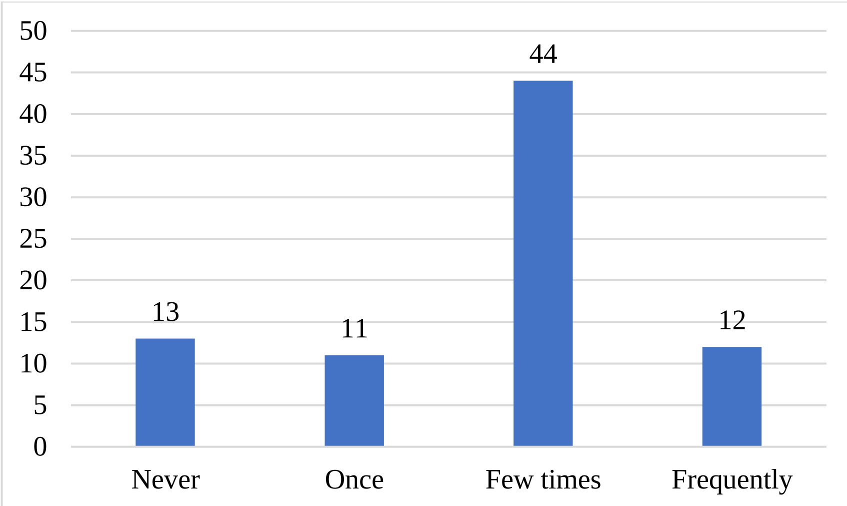

Figure 7. Mistakes without an immediate flight safety effect within the previous five months
Source: Authors' interpretation of the survey results

The majority of respondents (n=66, 83%) have not been involved in an incident nor made a severe mistake where fatigue was a contributory factor within the previous five months (see Figure 9). Slightly less than one-fifth of participants (n=14, 18%) have been involved in an incident or made a grave mistake due to fatigue once or a few times. A notable finding is that similarly to reporting a mistake in the cockpit without an immediate flight safety effect where fatigue was a contributory factor, less than half of pilots who have been involved in an incident or made a severe mistake reported it.

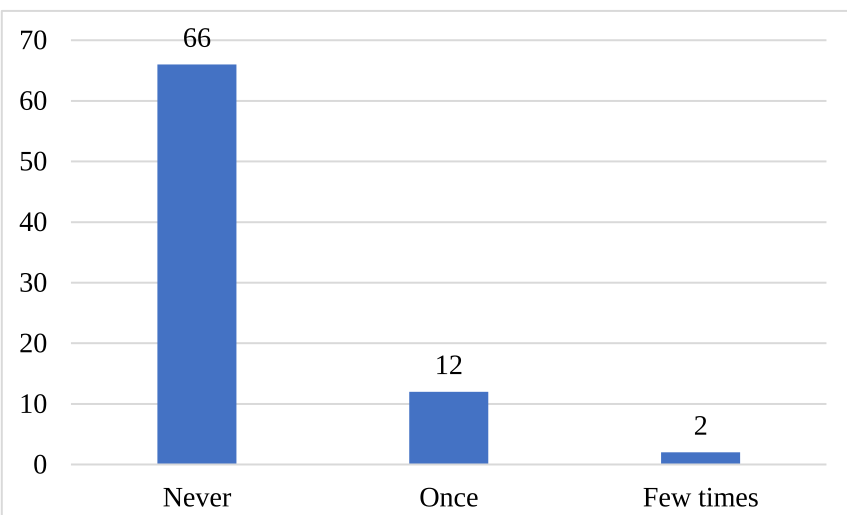

Figure 8. Incidents or serious mistakes due to fatigue within the previous five months
Source: Authors' interpretation of the survey results

It is worth noticing that the number of pilots who called in sick, taking an official sick leave off work to combat their fatigue, is slightly higher (n=15, 19%) than the number of pilots who have turned down the flight (reported "unfit to fly") (n=12, 15%) without the need to turn to the doctor. In both cases, the prevailing number of pilots have not reported as unfit to fly nor taken sick leave to combat fatigue.

Pilots were asked to comment on these results during the focus group interview. Three of seven participants refused to give any comments, and the rest of the participants came to the consolidated conclusion that the fatigue reporting and fatigue-caused-mistakes and/or errors reporting come down to the effectiveness and trustworthiness of the *Just Culture*: "*... if I, as a pilot feel confident that my airline management will not use this against me in the future, I do not have any problems admitting my mistake...*" – interview Participant 4. In addition, pilots spoke about the importance of using the reports as a data source for the fatigue risk management system: "*…well fatigue reports are subjective, I agree, but how else will airlines know about our problems? And we as pilots want to be heard, and well, let's also admit we must report about this, this is safety, after all and we all know about it. No one wants to lose his license and job…*" – interview Participant 5. Another participant spoke up about the shared responsibility in fatigue questions between employees (pilots) and employers (airlines): "*…However, we need to understand that fatigue is always a shared responsibility, and the bad outcome must also be a shared responsibility. If my company rosters me to fly up to 6 sectors with minimum rest time, short-turn arounds, and layovers in hotels with unacceptable conditions and all of that means they put me in that extreme conditions that do contributes to my physical and well-being. Of course, it is easy to say for industry to put all the responsibility to be fit to fly on pilot's shoulders, but airlines create this fatigue-inducing work environment in first place…*"– interview Participant 7.

4. Sleep patterns and problems

Most pilots (n=78, 97%) reported that, on average, they require at least 7 hours of sleep between their working days before starting the new duty to feel completely rested and alert. However, Figure 10 shows that only 31% (n=25) of pilots obtain the required amount of sleep (up to 8 hours) before duty. The majority of the participants (n=55, 69%) reported sleeping 6 or less hours of sleep between their working days before the start of the new duty. Focus group interview results revealed that pilots who have been off flying for different reasons in general needed several weeks to restore a regular sleeping routine: "…*it took me again a month and a half to develop just a normal sleep rhythm.*" – interview Participant 7, "… *when COVID started and I got grounded, at first it was very hard for my physical and mental health to adjust to the new reality. You know, only later I realised how messy my sleep was, so basically, it took me 2 months to start sleeping like a normal human and feel a 100% fit again.*" – interview Participant 4.

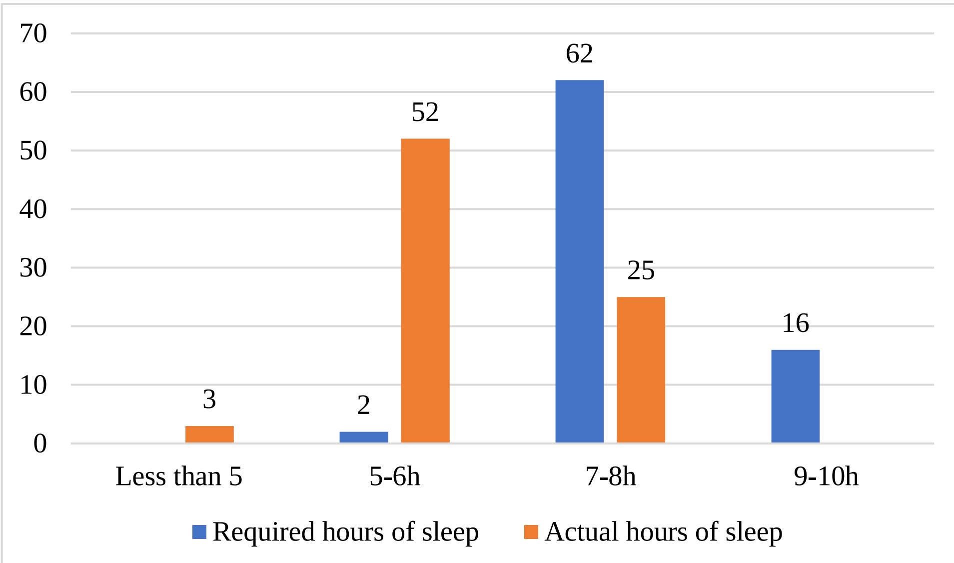

Figure 9. Pilots' required amount of sleep (average hours) versus the actual amount of sleep (average hours) between working days
Source: Authors' interpretation of the survey results

According to Figure 11 below, the majority of participants (n=50, 63%) reported that they have never experienced a micro-sleep(s) in the cockpit or have they (n=46, 58%) experienced falling asleep during the flight while being on duty over the previous five months. However, slightly less than half of the respondents rarely or sometimes have experienced micro-sleep(s) in the cockpit (n=28, 36%) or fallen asleep during the flight (n=33, 41%).

Approximately 65% of respondents (n=52) always or often find it more difficult to fall asleep before an early morning duty. These results are complemented by the fact that most pilots (n= 64, 80%) always or often experience a lack of sleep before an early morning duty. In addition, only 5 pilots (6%) never experience sleep deprivation during layover time.

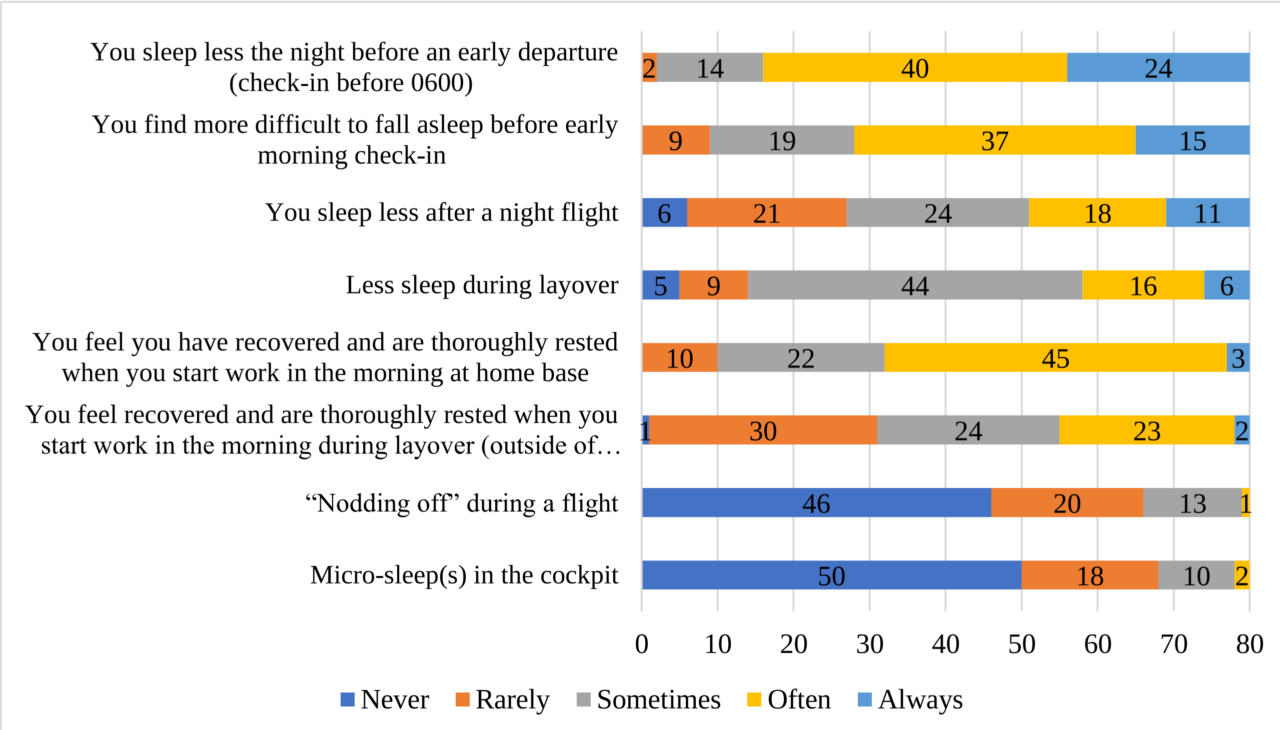

Figure 10. Pilots' sleep-related problems over the last five months
Source: Authors' interpretation of the survey results

When discussing the topic of sleep-related fatigue and problems, one pilot commented that when discussing fatigue as a risk, it is essential to draw a link between fatigue and the causes of fatigue and look at it as a bigger picture: "*…otherwise that is a poor fatigue risk management. Due to lack of sleep, any human essentially drops below the arousing level to the point that he or she is semi-asleep or asleep. And as we know the high fatigue level can make pilots drop all the way down to basically switching off and falling asleep in the cockpit and that has happened in commercial aviation… that fatigue issues affect us all but the Black Swan event, that we are trying to prevent, where crew fall asleep, and aircraft flies past the destination and runs out of fuel, or they forget to retract the gear and attempt to land.*" – interview Participant 6.

Approximately 9% (n=7) indicated that they use non-prescriptive or alternative medicine (e.g., melatonin) to help them fall asleep. Nine participants (11%) take prescribed medications (e.g., sleeping pills) to improve the quality of their sleep. Lastly, 80% (n=64) of the participants indicated that they do not take any substances to improve their sleep quality.

5. Work-rest environment

Results show that for most (n=67, 84%) respondents' the company does provide a suitable hotel room where they can get proper rest during the layover. However, 13 respondents (16%) were reluctant to say that the hotel room provided by the company was satisfactory. Figure 12 presents results on how the hotel room's environmental conditions (lighting, temperature, and noise) affected pilots' sleep. Approximately half (n=42, 53%) of the pilots answered that these conditions interfere with their sleep ability. Only roughly 5% of pilots (n=4) indicated that the conditions made sleeping very difficult. Slightly less than half (n=34, 43%) of the respondents indicated that hotel conditions do not affect their ability to sleep.

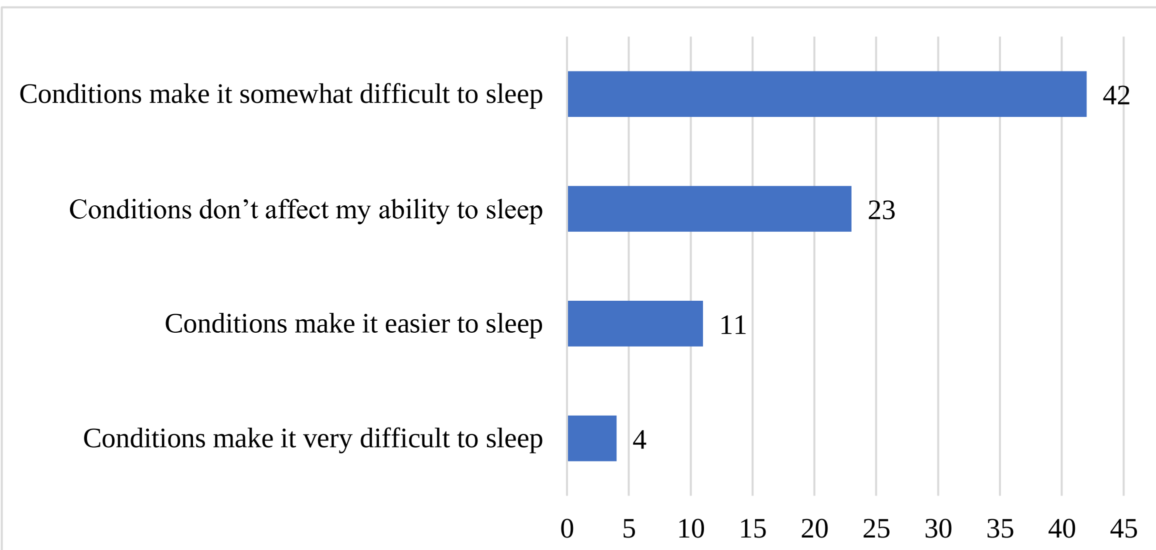

Figure 11. Number of participants who assessed hotel room environmental conditions (lighting, temperature, and noise)
Source: Authors' interpretation of the survey results

Less than half of the pilots (n=32, 40%) reported always or often receiving the proper nutrition in the hotel during the layover. At the same time, more than half (n=46, 57%) of respondents reported getting nutrition sometimes or rarely. Regarding the quality of the nutrition, almost half of the pilots (n=36, 45%) expressed their satisfaction as neutral, 34% of pilots (n=27) stated that they are either very satisfied or very satisfied with the quality of the nutrition, whereas 21% (n=17) considered the quality of the nutrition as unsatisfied or very unsatisfied.

6. Workload and work rostering

Regarding the perception of work scheduling (rostering) at the workplace, Figure 13 below illustrates the results of the statements in the questions. Only a quarter of respondents (n=16, 20%) strongly agree or agree that they feel that they can influence their roster, while 37% (n=30) of pilots disagree that they can influence their roster. However, the prevailing part of participants (n=34, 43%) neither agree nor disagree that they feel like they can influence their roster. Over half of the respondents (n=45, 56%) disagree or strongly disagree with the statement. *My roster and work are planned in such a way that I can recover from work during my free time*. Approximately the same percentage of pilots (n=44, 55%) reported their disagreement about the stability of their roster (i.e., rosters are changed too often or with a short notice), which does not allow them to plan their life outside of work. In the focus group interview, one of the pilots mentioned how an unpredictable roster contributes to his work-life disbalance: "*Due to constant roster changes, I may end up spending 20 nights per month away from home. Even when you are off the duty, you still cannot be doing the activities you would like to do in your free time because you are in a random airport in a random hotel anywhere. That also generates more mental fatigue for me. If you can only dedicate maybe 8 days a month to your personal life.*" – interview Participant 1.

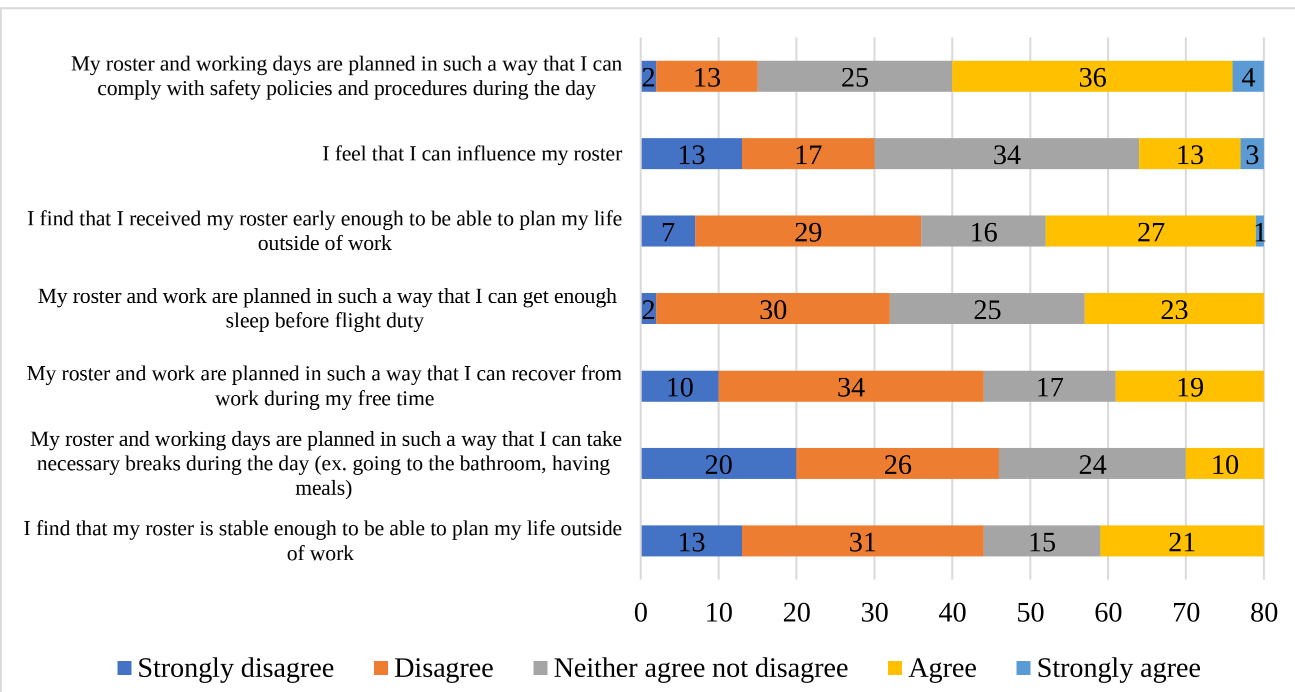

Figure 12. Participants' perception of rostering at the workplace
Source: Author's interpretation of the survey results

In addition, almost half (n=36, 45%) of the participants report receiving a roster not early enough to be able to plan their life outside of work. Nevertheless, over half (n=44, 55%) of the pilots neither agree nor disagree, agree or strongly agree that they receive their work rostering early enough to plan their life outside work. During the focus group interview, pilots exchanged views about other transportation industry sectors and how, for example, sailors spend more time at home than pilots do: "*…sailors have 50/50, you know, if they are away, after the operation they spend more or less the same time at home. Of course, shift patterns again differ from company to company but aviation. Yes, we have this tiny number of days prescribed by the regulation that we must be at home. And, as we all said definitely nobody accounts for all the time spent in the hotels or airports…*" – interview Participant 7. Another participant has an awareness of the truck driving industry in Spain where truck drivers "*have much more flexible rosters and they are able to plan their lives much better than pilots"* – interview Participant 2. It is essential to highlight that participants did agree that in other transportation industries across Europe, there are different regulatory requirements for work schedules.

Regarding the balance between the rostering and the amount of sleep, just over a quarter of pilots (n=23, 29%) agree that their roster and work are planned in such a way that they can get enough sleep before the duty, while just under a half (n=32, 41%) do not get enough sleep before duty with the current rostering procedures in their companies. During the focus group interview, participants mentioned that sleep-related problems mainly start when they experience circadian switches: "*… circadian cycle is also a big matter, and nobody thinks about it. Take it into account because, for instance, when you wake up at 5 o'clock, two days in a row, then you have to switch to the night flights, with respect to the minimum rest written in regulations, of course, but your body is going crazy.*" – interview Participant 6. The switches from one sleeping pattern to another with inadequate body clock adjustment has been acknowledged to be the biggest problem in short-haul operations:"*… There is a, you know, 6:00AM duty start and then a 2:00PM start the next day, and the 6:00AM duty start again, and that is what I find to be most fatiguing because your body never catches up with these changes does not understand what it is doing. And this is worse than any 12-hour jet lag, to be honest.*" – interview Participant 1.

As to whether the roster and working days are planned in such a way that pilots can take necessary breaks (e.g., going to the bathroom, having meals), only 13% (n=10) agreed with that, whereas more than half (n=46, 58%) of respondents reported either disagreement or strong disagreement with the statement *My roster and working days are planned in such a way that I can take necessary breaks during the day (ex. going to the bathroom, having meals)*. During the focus group interview, the challenges pilots faced regarding their roster planning and breaks were also discussed. According to one of the participants, unlike most other industries, pilots do not have regulated breaks and are only provided with the opportunity to eat and use the restroom. This can be particularly difficult during short flights and turn-arounds where time on the ground is limited: "… *if we are talking about short-haul, operation short flights, short turn-arounds, everything needs to be as quick as possible because airlines do not want to waste any minute on the ground that will cost them money. But you as a pilot do not stop working when aeroplane comes to the gate, you need to do so many other tasks already on the ground and with short turn-around time you often do not get that spare minute for your physical needs."* – interview Participant 3. On the other hand, half (n=40, 50%) of the participants agreed or strongly agreed with the statement: *My roster and working days are planned so that I can comply with safety policies and procedures during the day*. Only 15 pilots (19%) disagree or strongly disagree with the mentioned statement (see Figure 13).

When it comes to the most fatigue-causing types of duties among pilots in short-haul operations, most of the respondents reported that early morning duties (n=39, 49%), as well as long duties starting early in the morning (n=50, 63%), have moderate to severe impact on their level of fatigue. These results are supported by the results illustrated in Figure 14, which shows that the overall proportion of participants (n=52, 65%) reported that alternating morning and evening duties with insufficient time to adjust have moderate or severe fatigue effects on them. Focus group interview results revealed that pilots do not consider existing EASA FTL rules applicable for both short-haul and long-haul operations due to the fact that regulation "*does not take into account the specification of the airline flight operations and regulation was not adjusted the sufficiently towards the short-haul operations. Basically, that is why we have the same duty and rest time limitations [EASA FTL rules] which can be used by airlines to the maximum without taking into consideration so many important fatigue-related factors. Again, there is a huge difference between rostering patterns in long-haul operations and short-haul operations.*" All participants of the focus group interview agreed that the main problem is rooted in regulation: "… *I think that the airline I work for looks at current FTL rules not so much as limitations, but rostering limits. If changes do not come from the regulatory level, companies will use these rules in their favour*." – interview Participant 7. Also, results show that the minimum amount of rest between work periods and minimum rest rotations between duties have a moderate or severe impact on participants' fatigue. Almost half of the pilots (n=39, 49%) consider low number of days off per month as the factor moderately or severely contributing to their fatigue.

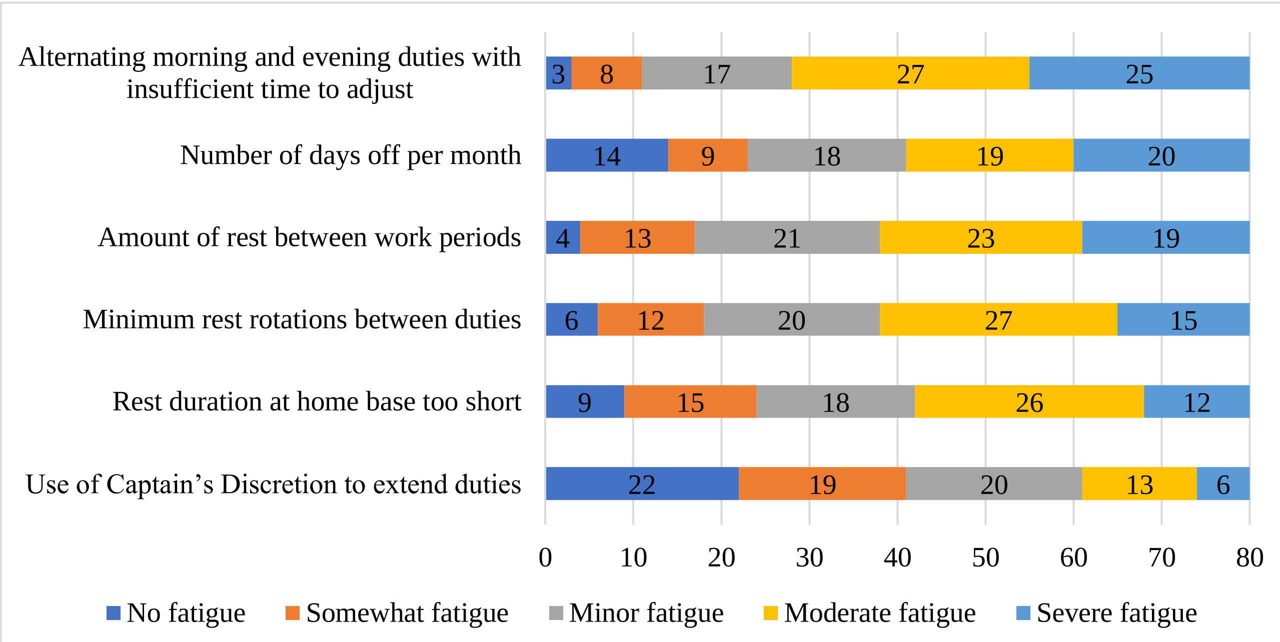

Figure 13. Fatigue-causing factors associated with duty and rest
Source: Author's interpretation of the survey results

Regarding the workload combined with rostering, 82% (n=65) of pilots reported moderate or severe fatigue impact due to a high number of sectors combined with early starts and long days. Also, the vast majority of respondents (n=54, 71%) have identified maximum lengths of duty days moderately or severely impacting their level of fatigue. Another important aspect of the discussion is the importance of dividing and differentiating the fatigue levels of pilots working in short-haul operations and those who fly long-haul flights. One of the participants shared his experience: "… *in a long-haul operation the usual practice, with any flights usually longer than 8-9h, crew management starts adding additional crew members already and for the long/ultra-long-haul operations, it is basically 2 separate crews' compositions. So, you always have a certain backup. There is nothing like that in short-haul operations*." – interview Participant 3. When discussing the difference between short-haul and long-haul pilots, participants shared their concerns regarding the EU regulation and EASA FTL rules (as well as FRMS) being more effective in long-haul operations than short-haul, whereas most of the European airline industry is focused on the short-haul and/or medium-haul flight operations type (flying within European continent). Moreover, one participant shared his experience showing his roster to his doctor and asking for a professional opinion about the adequacy of the planned rest time and time to adjust the regular body clock from the morning to evening duties: "*I discussed it with my doctor who is a clinical physiatrist in addition, and he was shocked how badly does the legal rostering according to FTL rules affects the circadian cycle and normal body lock. He said if I continue working like that with constant sleep debt, I will most probably end up burnet out in 10 years*" – interview Participant 5. The same participant added that: "… *even the fighter military pilots in France right now are shocked about the kind of rosters we [short-haul pilots] do, and how that produces fatigue and influences the awareness.*" – interview Participant 7. Another comment made about rostering highlighted the significant difference between the planned roster "on the paper" and the reality of 24/7 flight operations in commercial passenger airline where unforeseen situations (e.g., delays, aircraft changes, technical defects, unpredictable weather etc.) are a part of pilots' daily routine which often result duty extensions and higher workload, therefore "…*when the airline prints the roster and shows it to the TRAM, they are like "yeah, that is that is fine, all legal" but this a lie and both know that. Because in reality, rosters change in real-time with duty extensions applying Commander's Discretions, the rosters they plan within the limitations end up being absolutely different in the end, and airlines do not want to confront that."* – interview Participant 1.

7. Fatigue risk management

The last module of the survey was dedicated to fatigue risk management. The results show that 57 respondents (71%) consider fatigue risk a significant concern among pilots working in short-haul airlines based in Estonia. The rest of the respondents think fatigue possesses a low (n=9, 11%) or moderate level (n=14, 18%) problem. Focus group interview results revealed that most participants do not firmly believe that fatigue is a significant safety risk and overall concern: "… *it seems they do not take it into account real threats like pilots and cabin crew being fatigued and pushed to their limits. They do not take into account the human factor and the resources as long as everything matches on Excel for them…*" – interview Participant 7.

Regarding the protection against fatigue in the company, results reveal that more than half (n=46, 49%) of pilots consider the protection poor or very poor. Only 6 participants (8%) find the protection of fatigue in their airline on a good level. The rest of the respondents (n=28, 35%) assess the protection against fatigue as fair. Pilots in the interview shared very different opinions about protecting against fatigue on both regulatory and company levels. Some argued that there no protection at all and there is little chance anything on the higher level (meaning the European regulations) will change since big and authoritative European airlines support current FTL rules and even have contributed to their creation: "… *this is definitely because of big financial capabilities and lobbying capabilities of big European airlines.*" – interview Participant 2. Pilots also consider local authority (TRAM) not being proactive enough.

On the other hand, several other participants disagreed with the absence of protection: "*I think it is not fair to say that there is no protection. I think that is not right. Because we do have flight time limitations. We have minimum rest periods. We have the ability to offload ourselves if we are fatigued, but the issue is that the protection is not going far enough.*" – interview Participant 7. Another pilot supported this idea by adding that the central question lays down to the costs: "…*the protection is decreased by 10%, by flight duty periods, by the limitations, by the minimum rest, the circadian rhythm - they all need to be taken accounting too far, and that will cost. And if you ask them [airlines] how much cost they are willing to accept, we can start talking about a real solution. But until they are not willing to spend more money or increase the costs like nothing will ever change, and as long as all these rosters are legal – we are good to go.*" – interview Participant 4.

Figure 15 presents the result of the question about fatigue risk management at participants' airlines of employment. According to the results, 27 pilots (34%) believe that the management in their company is making an effort to identify fatigue-related risks associated with their work. However, almost half (n=39, 49%) of the pilots reported disagreement or strong disagreement with the idea that their management is attempts to recognise the fatigue-related risk, "… *from management's perspective everything seems to be just is fine. That is how it should be because, you know, they are not stupid, and they know what they are doing. It is their goal to operate like that. It is not that it happened by mistake or that they overlooked something. Their goal is to make money at all costs by squeezing the maximum of these FTL rules and closing their eyes on fatigue.*" – interview Participant 1.

That is supported by the results of the next statement, where only 11% (n=9) of pilots agree that the fatigue risk is adequately managed in their current company, whereas over half of the respondents (n=46, 58%) disagree or strongly disagree with that.

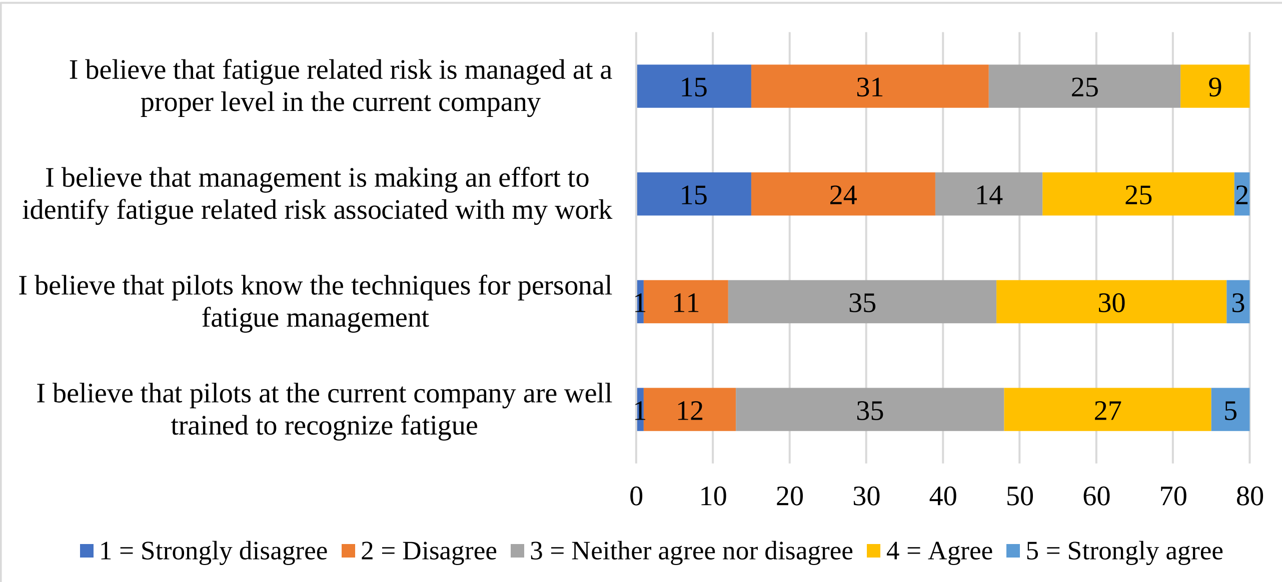

Figure 14. Participants' perception of fatigue risk management in the airline of employment
Source: Author's interpretation of the survey results

Nevertheless, regarding fatigue management training, the results show that half of the participants (n=40, 50%) agree or strongly agree with the statement "*I believe that pilots at the current company are well trained to recognise the fatigue*". Focus group interview results support the results of this survey questions. Pilots explained that in their companies there is a mandatory fatigue awareness training for pilots and cabin crew. Two pilots highlighted the importance of this training to be recurrent every year and involve trainers and even doctors with occupational health background. On the other hand, just under half (n=35, 44%) have a neutral position regarding this statement. The results are complementary to the following statement "*I believe that the pilots know the techniques for personal fatigue management*" where the same number of respondents (n=40, 50%) reported agreement or strong agreement with that; and only 15% (n=12) of pilots do not know the techniques for personal fatigue management.

3.2 Discussion

The aim of this study was to analyse pilots' fatigue-contributing causes and fatigue risk management (FRM) concerns related to Estonian short-haul passenger airlines. Until now, the little was known about the fatigue and FRM in Estonia short-haul airline industry. The results of this study among Estonian short-haul pilots provide a valuable insight into fatigue-related causes and pilots' perception of current FRM. The FSS has been used to measure pilots' subjective fatigue. During the evaluation of the fatigue level about pilots the 78% of the participants showed a significant level of fatigue (FSS ≥ 4). Current study results are in a line with the results of the previous studies (Reis *et al.*, 2013; Venus & grosse Holtforth, 2021) where the same fatigue level evaluation tool was used. The correlational analysis of variances across four age groups and six work experience groups uncovered no significant statistical differences. Therefore, results of the current study confirm that not age nor the length of service have a correlation with the level of pilot's fatigue.

The results of the survey revealed a range of fatigue-contributing causes, the most common of which were related to lack of sleep, circadian disruption, high workload, short turn-around times, inadequate rest time, disruptive rosters, duty extensions, unexpected roster changes and quality of sleep during laovers. Qualitative data results, together with a complementary focus group interview, provided rich insight into these hazards, allowing author to better understand the complexities of fatigue in short-haul airline operations. Considerable sleep problems related primarily to the lack of sleep and circadian disruption showed similar effects on fatigue as in various previous studies (Reis *et al.*, 2016; Åkerstedt *et al*., 2021; Hilditch *et al.*, 2023). The results show that 69% of pilots sleep six or less hours during the regular work week, whereas the required amount of sleep to feel completely rested and alert is eight or more hours for 97% of the participants. The qualitative results of the study complemented the questionnaine results by explaining that, for example, on third day in a row of waking up during their WOCL (around 4-5AM), pilots start feeling that they start feeling a sleep debt and as a consequence parformance degrades and more time to concentrate is needed. Despite crossing fewer time zones relative to long-haul operations, results also show that short-haul pilots are still exposed to circadian disruption through multiple changes in duty start times within the short period of time (e.g., a week) that leads to insufficient time for inner body clock adjustment from one sleeping pattern to another. High workload, short turn-around times and inadequate rest time were the second most common fatigue-contributing causes indentifies in this study. These results complement the findings of recent study conducted among US short-haul commercial pilots (Hilditch *et al.*, 2023). As one pilot highlighted, while unforseen operational irregularities (e.g., go-around due to adverse weather conditions, delays, aircraft swaps) in long-haul operations occur less frequently as they may occur during one or two flights withint one working day, in short-haul operations pilots may face them on each flight sector during the duty day. In addition, a short turn-around time with limited time for the basic physiological needs and access to meal breaks leads to the fatigue. Similar to the study by Hilditch *et al.* (2023), pilots pointed out that there is a great gap between the comprehension of the legally prescribed rest times and turn-around duration and the real-life operations where these rest times and turn-around times are almost impossible to achieve. Another important findings, that are in the line with the recent studies (Bourgeois-Bougrine *et al.,* 2023; Venus & grosse Holtforth, 2021; Hilditch *et al.*, 2023), show that fatigue-contributing causes among short-haul pilots are rooted within the pilots' disruptive rosters. Another unique challenge inherently tied to the disruptive rosters is unpredictability due to unexpected roster changes. Unpredictability in rosters is a known fatigue factor in business aviation (Wollmuth, 2017). However, the results of this study are in a line with recent study (Hilditch *et al.* 2023), suggest that unexpected roster changes are the prevalent in regularly scheduled commercial passenger flight operations as well. This study indentified that high number of early flights, high number of sectors within one FDP, duty extensions via Commander's Discretion and minimum rest roatation between duties lead to physical and mentahl fatigue. This particular findings justify the need to introduce FRMS as part of the implementation process of FRM described in the sub-chapter 1.4.2. Furthermore, the quality of sleep in hotels during layovers was raised as fatigue hazard, with noise being the most significant complaint in line with previous studies (Hilditch *et al.*, 2023; Gregory *et* al., 2010). It is crucial to protect both the duration and quality of sleep during layovers in order to allow pilots to return to their next duty adequately recuperated.

The present findings suggest that the pilots working in Estonian short-haul passenger airlines consider fatigue to be a significant risk in the European commercial aviation sector. Findings revealed that pilots do not consider the protection against fatigue on the effective level and are reluctant to the efficiency of currently implemented EU-wide EASA FTL rules that by the book aim to help to manage fatigue-related risk by restricting the amount of hours spent in on duty and regulate the required amount of time for rest, however interview results suggested that the perception of the current FTL rules is rather with the negative undertone. Previous study by European Cockpit Association (ECA) (2012) also found the EASA FTL rules are insufficient in combating fatigue. In addition, as addressed in sub-chapter 1.4.1, a study in (2019) conducted on behalf of the European Commission and EASA, revealed significant shortcomings in the current EASA FTL regulations.

On the company level, results revealed that almost half of the pilots consider existing FRM at their airlines rather than poorly identifying the fatigue hazards and mitigating fatigue risks. On the other hand, survey results regarding mistakes and errors in the cockpit show that a high percentage of pilots (69%) have made a mistake at least once or a few times without immediate safety effects. Important is that only 18% have been involved in an incident or made a serious mistake where fatigue was a contributory factor. The research results are similar to the findings of the research carried out by the ECA (2012), where more than 70% of participants reported making mistakes in the cockpit due to fatigue. A notable finding is that similarly to reporting a mistake in the cockpit without an immediate flight safety effect where fatigue was a contributory factor, less than half of pilots who have been involved in an incident or made a severe mistake reported it. The focus group interview results suggest that the root cause could lie in poor fatigue reporting culture as an essential part of the FRM data collection process. The reason for that could be linked to the company's immature *Just Culture*, and because of that, pilots feel insecure about reporting fatigue associated with errors in the cockpit. It is crucial to facilitate the development of an environment in which incidents are reported. It may be advantageous to implement preventative measures to support such an approach.

Interview results revealed insufficient preparedness and a need for recourses for the FRMS implementation on the company level. Some interview participants argued that in short-haul operations, the efforts and costs associated with the FRMS are not worthwhile as the root problem lies on the regulatory side, and it is not the FRMS that needs to be implemented; it is the regulation that needs to be changed; while other pilots argued that the benefits of FRMS can be amplified in short-haul airlines with the existing EASA FTL rules. However, most participants agreed that their underlying point of discussion involves the necessary investments from both the regulatory and company sides. The introduction of FRMS involves considerable investments in areas such as carrying out different studies, robust crew rostering practices, effective human resource management, and implementing bio-mathematical models. A good example of a European (UK) short-haul passenger carrier with an established FRMS for fatigue related safety risks is easyJet (Stewart *et al.*, 2009). According to EUROCONTROL (2012) easyJet, the first airline in Europe to implement an FRMS successfully is one of the most advanced practitioners of FRMS in the world. Following the example of the easyJet FRMS processes practises, the author suggests that the Estonian short-haul airlines' implementation of the FRMS including the Human Factors Monitoring Programme (HFMP) as a part of the FRM process cycle illustrated in sub-chapter 1.4.2 Figure 4. The HFMP is accompanied by real-time data collection as a step of hazard identification and fatigue risk assessment (see Figure 4) based on the current operational performance. For example, using smartwatches to measure and monitor the sleep between duties when rostered to the maximum allowed FDP lengths with minimum rest times. By doing so, there will be a much more precise calculation of the needed rest time to avoid avid circadian switches with insufficient time for the crew to adjust their body clock to the new sleeping patterns. Another recommendation is to use real-time turn-around time calculations on different routes to identify the fatiguing planning patterns when crews need more time to rest. Therefore, specific routes need to be recalculated with extended turn-around time or with the needed time buffer for pilots to have a guaranteed rest time. The needed buffer could provide more flexibility and potentially decrease the duty extensions leading to an increased risk of crew fatigue. According to Stewart *et al* (2009), fixed rostering practice introduced in easyJet has resulted the decrease of fatigue reporting by 12% over 5-month test period. In addition, based on the study results, the author recommends introducing optimised rostering practices as part of the FRM. All rosters, including at least one disruptive schedule element, are run through a defined process before publication if rosters with a particular fatigue score are unacceptable and require re-rostering.

3.3 Limitations and future research

Despite valuable results and thought-provoking insights, current research has several limitations. The most critical limitation is the relatively small sample set. Nevertheless, a small number of pilots is justified by the relatively small size of the Estonian airline industry; a larger number of participants should be considered in future studies for studies in Estonia or other countries. In future studies, researchers could address similar survey questions and focus group interview discussions for more airlines in the aviation Estonian market or expand the research, including airlines from other neighbouring countries (for example, Latvia, Finland, and Sweden) and analyse the comparison. In addition, this study did not consider the identification of fatigue that is directly attributed to psychological factors. The evaluation instrument of the quantitative study (survey) was used to collect the data and in this study author did not attempt to control the timing for each individual response (during the duty, after the duty, during the day off). This presents inherent subjectivity and limitations. As the author has referred to fatigue following the ICAO definition, the main focus has been on physiological causes rather than psychological factors related to fatigue. Future research could focus more on either phycological factors or a combination of both psychological and physiological ones. Also, in the future, the sample set could be expanded from pilots solely to cabin crew. For instance, the comparison study pilots versus cabin crews.

CONCLUSION

Fatigue can substantially influence pilots' cognitive abilities, reaction times, decision-making skills, and overall performance, increasing the risk of accidents and incidents. The airline industry is a safety-sensitive industry where the risk of pilot fatigue is high due to 24/7 operations resulting in irregular working shifts, switches between morning and night flights, circadian disruptions, unanticipated operational irregularities and other hazards that increase the risk of pilot fatigue. Therefore, fatigue risk management (FRM) is essential for effective monitoring and observing safety-related fatigue risks to ensure flight safety.

The current thesis aims to analyse pilots’ fatigue-contributing causes and fatigue risk management (FRM) concerns related to Estonian short-haul passenger airlines. To answer the research questions in the methodological part of the paper, the author chose a mixed-method study design with a survey for quantitative data collection and a focus group interview to complement the survey results. The level of pilots’ fatigue has been measured using Fatigue Severity Scale self-evaluating questionnaire included in the main survey. The sample set consisted of 80 pilots working for Estonian short-haul passenger airlines. Focus group interviews consisted of a total of seven survey participants.

During the evaluation of the fatigue level of pilots, 78% of the participants showed a significant level of fatigue (FSS≥ 4). The correlational analysis of four age groups and six work experience categories revealed no statistically significant differences. Therefore, the current study confirms that neither the pilot's age nor service duration correlates with their fatigue level. The survey results revealed various fatigue-inducing factors, the most prevalent of which were sleep deprivation, circadian disruption, high workload, short turn-around times, inadequate rest time, disruptive rosters, duty extensions, unexpected roster changes, and sleep quality during layovers. The author gained a deeper understanding of the complexities of fatigue in short-haul airline operations with the help of qualitative data results and a complementary focus group interview.

The present findings indicate that pilots employed by Estonian short-haul passenger airlines view fatigue as a significant threat to the European commercial aviation industry. Findings indicate that pilots do not consider fatigue protection effective and are sceptical about the efficacy of the currently implemented EU-wide EASA FTL. Even though the commercial airline sector is highly regulated, a prescriptive approach to managing fatigue risk with sole compliance with “one-size-fits-all” flight and duty time limitations (FTL) rules does not always guarantee an effective way of managing fatigue and safety-related risks associated with it, especially in short-haul flight operations, where there is more opportunity for airlines to solely stick to the FTL rule to maximise profitability by increasing the operational density rostering pilots to fly a high number of sectors in maximum flight duty periods (FDPs) with minimum rest times and multiple switches from morning to evening rostering patterns. The vast majority of pilots consider the protection against fatigue to be either inadequate or very poor, according to the current study's findings. Less than half of pilots involved in an incident or made a significant error disclosed it. The results of the focus group interviews suggest that the primary cause may be a subpar fatigue reporting culture, which is an essential component of the FRM data collection procedure. The results of the interviews also disclosed a lack of readiness and a need for additional resources for the FRMS implementation at the company level.

The significance of the study's findings stems from the fact that they reflect the pilots' perspectives on the topic of FRM in short-haul flight operations. These findings are essential for illuminating the perspectives of FRM in Estonian short-haul commercial passenger airlines. These particular findings justify the need to introduce performance-based FRM implementation. Therefore, airlines should be aiming to implement a fatigue risk management system (FRMS), a data-informed risk management approach to fatigue combined with FTL; however, it includes scientific principles and knowledge, real-time data collection and analysis.

The study clarifies the various fatigue-contributing causes for pilots working for short-haul passenger airlines. The study identified the pilot fatigue "hot spots" in the Estonian passenger airline industry. The study provides recommendations for future company-wide enhancements. In the future, comparable research could be conducted globally with pilots from neighboring nations and all over Europe. The current study designed and validated a questionnaire that can be used as a stand-alone data collection instrument in academic research on FRM.

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APPENDICES

Appendix 1. List of Estonian-registered passenger air operators

AOC Operator Registered Name	Doing Business As	AOC Number	ICAO three-letter designator	Type of operations
Pakker Avio AS	Pakker Avio	EE-002	PKR	Business/ corporate
Panaviatic AS	Panaviatic	EE-010	VPC	Business/ corporate
Smartlynx Estonia OÜ	Smarlynx Estonia	EE-015	MYX	Commercial
Regional Jet OÜ	Xfly	EE-020	EST	Commercial
Diamond Sky	Diamond Sky	EE-021	DMS	Business/ corporate
NyxAir OÜ	NyxAir	EE-022	NYX	Commercial
Nordic Aviation Group AS	Nordica	EE-023	NDA	Commercial
Marabu Airlines OÜ	Marabu	EE-025	MBU	Commercial

Source: Estonian Transport Administration, 2023

Appendix 2. ORO.FTL.210 Flight times and duty periods

(a) The total duty periods to which a crew member may be assigned shall not exceed:

(1) 60 duty hours in any 7 consecutive days;

(2) 110 duty hours in any 14 consecutive days; and

(3) 190 duty hours in any 28 consecutive days, spread as evenly as practicable throughout that period.

(b) The total flight time of the sectors on which an individual crew member is assigned as an operating crew member shall not exceed:

(1) 100 hours of flight time in any 28 consecutive days;

(2) 900 hours of flight time in any calendar year; and

(3) 1 000 hours of flight time in any 12 consecutive calendar months.

(c) Post-flight duty shall count as duty period. The operator shall specify in its operations manual the minimum time period for post-flight duties

Source: European Commission Regulation (EU) No 83/2014

Appendix 3. Fatigue Severity Scale

Item	Statement	Answer scale
1	My motivation is lower when I am fatigued	1 = Strongly disagree 2 = Disagree 3 = Somewhat disagree 4 = Neither agree nor disagree 5 = Agree 6 = Somewhat agree 7 = Strongly agree
2	Exercise brings on my fatigue	
3	I am easily fatigued	
4	Fatigue interferes with my physical functioning	
5	Fatigue causes frequent problems for me	
6	My fatigue prevents sustained physical functioning	
7	Fatigue interferes with carrying out certain duties and responsibilities	
8	Fatigue is among my most disabling symptoms	
9	Fatigue interferes with my work, family or social life	

Source: (Krupp, LaRocca, Muir-Nash, & Steinberg, 1989)

Appendix 4. Survey questions

Nr.	Questions	Answer alternatives
1. Domegraphical information		
Q1	Please indicate your age	18-24 25-34 35-44 45-54 55-65
Q2	Please indicate your gender	Male/ Female/ Non-binary
Q3	Your current rank?	CP = Captain/ FO = First Officer
Q4	What are your total flight hours in commercial aviation (h)?	Opean answer - number of hours
Q5	For how long have you been employed into the current company?	Less than 1 year 1-2 years 2-3 years 3-4 years 4-5 years More than 5 years
Q6	Are you currently working full--time or part-time?	Full-time / Part time
2. Levels of fatigue – Fatigue Severity Scale		
Q7	Please rate each of the following statements: 1. My motivation is lower when I am fatigued 2. Exercise brings on my fatigue 3. I am easily fatigued 4. Fatigue interferes with my physical functioning 5. Fatigue causes frequent problems for me 6. My fatigue prevents sustained physical functioning 7. Fatigue interferes with carrying out certain duties and responsibilities 8. Fatigue is among my most disabling symptoms 9. Fatigue interferes with my work, family or social life	1 = Strongly disagree 2 = Disagree 3 = Somewhat disagree 4 = Neither agree nor disagree 5 = Agree 6 = Somewhat agree 7 = Strongly agree
3. Causes and effects of fatigue		

Q8	During climb and descent, to what extent do the following situations contribute to your fatigue? Statements: 1. Significant workload 2. Executing actions in a limited amount of time 3. Simultaneous actions 4. Interruption during activities by ATC 5. Problem of coordination with the other cockpit crewmembers 6. Density of verbal exchanges 7. Adverse weather conditions 8. Communication in foreign language 9. Lack of sleep prior the flight	1 = No contribution 2 = Low 3 = Minor 4 = Moderate 5 = Major
Q9	In general, what is the impact of the following operational irregularities on your level of tiredness/fatigue? Statements: 1. Flight delay 2. Short turn-around times with an aircraft change 3. Operating to/from unknown airports 4. Dissension within crewmembers 5. Operating an aircraft with open MEL items 6. Extension of duty via Commander's Discretion 7. Compliance with time constraints	1 = No impact 2 = Minor impact 3 = Moderate impact 4 = Major impact 5 = Severe impact
Q10	In the past 5 month, in what ways has fatigue affected your flight performance?	Cant' concentrate/ Alertness degraded/ Performance degraded/ Impared memory/ All of mentioned/ Other - open answer
Q11	In the past 5 month, have you turned down the flight (reported unfit to fly) due to fatigue/tiredness?	Yes/No
Q12	In the past 5 months, have you called in sick because you were too tired/worn out/fatigued?	Yes/No
4. Safety-related outcomes of fatigue		
Q13	Over the past 5 months, has it happened that, because you felt fatigued, you have made a mistake (without immediate flight safety effect) in the cockpit while on duty?	Never Once Few times Frequently
Q14	If so, have you reported about the mistake?	Yes/No/ I have not made a mistake

Q15	Over the past 5 months, while on duty, have you been involved in an incident or a serious mistake had been made, where fatigue was a contributory factor?	Never Once Few times Frequently
Q16	If so, have you reported about this incident or a serious mistake had been made, mentioning fatigue/tiredness as a contributing factor?	Yes/No I have not been involved into an incident or a serious mistake
Q17	In average, how many fatigue reports have you made over the past 5 months?	Open answer - number of times
5. Sleep patterns and problems		
Q18	How many hours of sleep do you typically require to feel completely rested and alert between your working days prior the start of the new duty?	Less than 5 5-6h 7-8h 9-10h More than 10h
Q19	How many hours of sleep do you actually get during duty days (in average)?	Less than 5 5-6h 7-8h 9-10h More than 10h
Q20	Over the last 5 months, how often did you experience any of the following sleep-related problems: 1. You feel you have recovered and are thoroughly rested when you start work in the morning at home base 2. You feel recovered and are thoroughly rested when you start work in the morning during layover (outside of your home base) 3. Less during layover 4. You sleep less the night before an early morning duty 5. You find more difficult to fall asleep before early morning duty 6. Micro-sleep(s) in the cockpit 7. “Nodding off” during a flight 8. You sleep less after a night flight	1 = Never 2 = Rarely 3 = Sometimes 4 = Often 5 = Always

Q21	Do you use any substances to help you fall asleep and/or improve your sleep quality?	Prescription medicines by a doctor (e.g., sleeping pills, antidepressants, anti-anxiety medications, etc.)/ Non-prescription/free sale medicines (e.g., melatonin)/ Alternative medicine (herbal therapy, homeopathic medicine, etc.)/ Alcohol/ Drugs/ Nothing
6. Work–rest environment		
Q22	Does your current company provide a suitable hotel room for layover?	Yes/No
Q23	How would you best describe the environmental conditions (lighting, temperature, and noise) for the hotel room area you identified in the previous question?	Conditions don't affect my ability to sleep/ Conditions make it easier to sleep/ Conditions make it somewhat difficult to sleep/ Conditions make it very difficult to sleep
Q24	How can you assess the availability of nutrition provided at the hotel during your layover time?	1 = Never 2 = Rarely 3 = Sometimes 4 = Often 5 = Always
Q25	How can you assess the quality of nutrition at the hotel during your layover time?	1 = Very unsatisfied 2 = Neutral 3 = Unsatisfied 4 = Satistfied 5 = Very satisfied
7. Workload and rostering		

Q26	For each of the following statement, please select the response which best describes you work situation 1. I find that I received my roster early enough to be able to plan my life outside of work 2. I find that my roster is stable enough to be able to plan my life outside of work 3. My roster and working days are planned in such a way that I can take necessary breaks during the day (ex. going to the bathroom, having meals) 4. My roster and working days are planned in such a way that I can comply with safety policies and procedures during the day 5. My roster and work are planned in such a way that I can recover from work during my free time 6. My roster and work are planned in such a way that I can get enough sleep before flight duty 7. I feel that I can influence my roster	1 = Strongly disagree 2 = Disagree 3 = Neither agree not disagree 4 = Agree 5 = Strongly agree
Q27	Please rate to what extent do the following duties cause fatigue for you: 1. Early morning duty 2. Evening duty 3. Long duty starting early 4. Long duty during the day 5. Long duty starting in the evening 6. Standby 7. Reserve 8. Split duties 9. Positioning flights 10. Calling out from off-days (FDO)	1 = No fatigue 2 = Somewhat fatigue 3 = Minor fatigue 4 = Moderate fatigue 5 = Severe fatigue
Q28	Please rate how the following situations connected to rest amount and duration during or/and between the duties contribute to your level of fatigue: 1. Minimum rest rotations between duties 2. Amount of rest between work periods 3. Use of Captain's Discretion to reduce rest or extend the duty 4. Alternating morning and evening duties with insufficient time to adjust 5. Rest duration at home base too short 6. Number of days off per month	1 = No fatigue 2 = Somewhat fatigue 3 = Minor fatigue 4 = Moderate fatigue 5 = Severe fatigue
Q29	Please rate to what extent do the following rostering patterns cause fatigue for you: 1. High number of sectors in a duty day 2. High number sectors combined with early starts and long days 3. Maximum length of duty day 4. High number of duty hours in a week 5. High number of duty hours in a month	1 = No fatigue 2 = Somewhat fatigue 3 = Minor fatigue 4 = Moderate fatigue 5 = Severe fatigue
8. Fatigue risk management		

Q30	To what extent do you agree or disagree with the following statements about current company's fatigue risk management system? Statement: 1. I believe that management is making an effort to identify fatigue related risk associated with my work 2. I believe that fatigue related risk is managed at a proper level in the current company 3. I believe that pilots at the current company are well trained to recognize fatigue 4. I believe that pilots know the techniques for personal fatigue management	1 = Strongly disagree 2 = Disagree 3 = Neither agree not disagree 4 = Agree 5 = Strongly agree
Q31	In your opinion, to what extent is fatigue a concern among pilots at your company?	1 = Not at all 2 = Low 3 = Moderate 4 = High 5 = Very high
Q32	According to your personal opinion how good is the protection of flight crew against fatigue in your company?	1 = Very poor 2 = Poor 3 = Fair 4 = Good 5 = Very good

Source: Author's interpretation

Appendix 5. Focus group interview plan

Preamble: Permission for audio and video recording

Section 1 – Introduction

- Interviewer's introduction (author, thesis topic, thesis aim, interview objectives)
- Participants' introduction (age, rank, working experience in company of employment)

Section 2 – Interview topics

- Pilots' definition of fatigue and how does it affect their health, motivation, well-being, work-life balance etc.: discussion of the significant survey results;
- European commercial airline industry: high commercial competitiveness;
- Fatigue management in the European aviation industry: exchange of experiences and main concerns from pilots' perspective;
- Protection against fatigue: regulatory vs company level;
- Regulatory level: effectiveness of the current EASA flight time limitations (advantages and disadvantages);
- Authority oversight;
- Perception of current FRM in the company: solutions and suggestions to be introduced on the management level;
- Advantages and disadvantages of the FRMS.

Section 3 – Conclusion

- Round the table
- Questions from participants
- Interviewer's gratitude word

Appendix 6. Interview coding table

Category	Theme	Code
Causes and effects of fatigue	Roster induced fatigue	Physiological needs during the turn-around
		Insufficient time to switch from morning to night duties
		Roster changes
	Mental health	Pilot pushing
		Stress
		Burnout
		Work-life balance
	Outcomes	Personal factors
		Mental fatigue
		Recovery from fatigue
The safety-related outcome of fatigue	Accidents/incidents	Perception of fatigue as a contributing factor
Sleep patterns and problems	Sleep disruptions	Lack of sleep
	Circadian disruptions	Circadian switches
		Jet lag
	Early duties	Early starts
		Early wake-up/report
Work-rest environment	Hotel conditions	Noisy hotel rooms
		Poor hotel conditions
		Absence of proper nutrition
Workload and rostering	Rostering	Fixed rosters
		Night flights
		Commander's discretion
		Workday length
		Multiple legs
		Long duty days
		Check-in time
		Long FDPs with short rest time
	High workload	Aircraft switches
		Poor weather conditions
		Operating aircraft with MELs
		A high number of sectors
	Short turn-around time	Real-time observations
Fatigue risk management	Authority	Lack of actions to influence airlines' management

		Lack of oversight
	Airlines	Poor or lack of actual actions
		Fatigue training
		Tools to measure fatigue in real-time
		Commercial pressure
		Safety = efficiency
		Lack of financial investment
		Managers tin cockpit
		Resource management
		Inadequate perception of pilots' work
	EU regulations	Lobbying of regulations among bigger EU airlines
		FTL no adequate for LH and SH operations
		FTL limits long-haul vs short-haul
		No protection against fatigue

Source: Author's interpretation of interview results

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