Guidelines Manual for Investigating Human Fatigue in Aeronautical Occurrences

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National Commission of Human Fatigue - CNFH

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Contents:

1. Foreword:

The modern commercial aviation industry brings great challenges for the management of human error and its consequences on operational safety. New on-board technologies have ensured high standards of reliability for components and systems, dramatically mitigating the incidence of material failures in aviation events [1]. On the other hand, however, the improvement of such systems and equipment may also result in an increase in complacency, as well as in the complexity in human-machine interaction [2]. Flying an aircraft nowadays means acting as a system manager and monitor, a task that requires great cognitive ability [3-5]. These factors, combined with a progressive increase in air transportation demand worldwide - with 24/7 daytime operations - demonstrate the need that aspects related to the human factors, including fatigue [6], are considered fundamental for risk management due to physiological aspects.

This Guidance Manual aims to update the methodology to investigate human fatigue in aeronautical events, published in a separate chapter in the Human Fatigue Investigation Guide in Aeronautical Occurrences (CNFH, 2017) [7]. The main goal was to produce a document with an operational approach that describes briefly and objectively the main aspects to be evaluated in aeronautical events in which the human factors may have contributed. The methodology presented herein was developed taking into account the recommendations prescribed by ICAO on DOC No. 9966 [8], as well as investigative practices adopted by other agencies such as the National Transportation Safety Board [9] and Transportation Safety Board [10].

This Guidance Manual is divided as follows: sections 2 to 5 present the scope and limitations of the methodology, as well as the factors that contribute to fatigue and the factors that influence the increase of cognitive demand in aeronautical activity; section 6 presents the research methodology, divided in two stages: (a) initial screening, and (b) detailed methodology; finally, sections 7 and 8 present the final considerations and references used throughout this document.

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2. Scope of the methodology:

The methodology presented in this document aims to improve the human fatigue investigation process in aeronautical events in which the human factor may have contributed. With this, it is expected that this Manual will assist investigators - especially those in the area of human factors - in conducting an investigative process aimed at preventing new occurrences, as recommended by the Brazilian Aeronautical Accident Investigation and Prevention System (SIPAER).

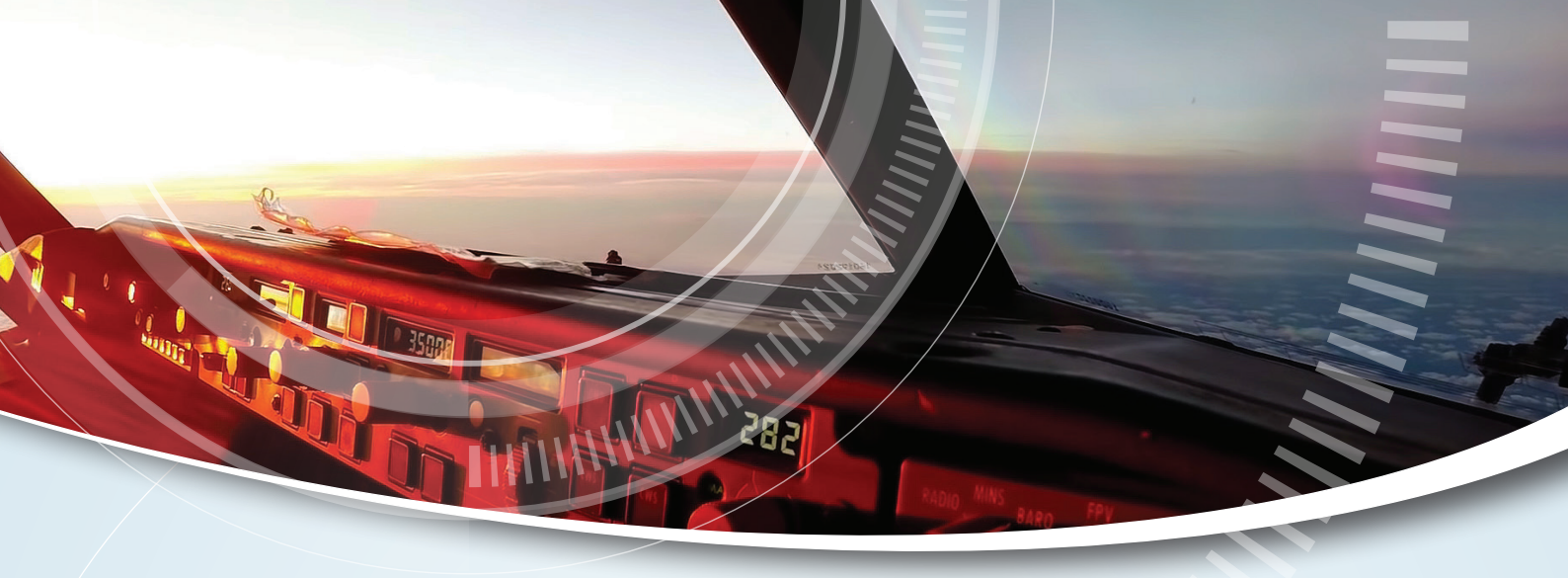
3. Limitations of the methodology:

The CNFH has made efforts to establish consistent metrics for assessing the influence of fatigue - especially that related to sleep - in aeronautical events. These metrics, based on scientific parameters, have the goal to support the analysis of the various factors that may trigger fatigue in aircrews. However, individual and environmental aspects (organizational or not) may not be completely identifiable during an investigation, which can hinder the analysis of fatigue and the possible conclusions after the investigative process.

Relevant individual characteristics include several factors, such as: (1) sleep habits, (2) sleep disorders, (3) use of psychoactive substances, (4) management of sleep opportunities, among others.

The characteristics of the environment include factors such as: (1) suitability of the rest facility, (2) the age of the children, (3) the special needs of close people, (4) concomitant involvement in extra-flight activities in general, (5) operator policies for sick leave or fatigue call, (6) organizational culture, among others.

Finally, it is important to emphasize that the methodology and all information contained herein has a guiding character and, as such, this document should always be used in the context of other relevant sources and regulations issued by the competent bodies.



4. Main contributing factors to fatigue susceptibility:

4.1 - Time of day: studies point to a greater sleepiness of human beings at night time, especially during the dawn, as well as in the early afternoon [11-14][1]. The times that characterize these sleepiness peaks are usually different for people with different chronotypes [8, 14], reinforcing the importance of assessing, whenever possible, the chronotype of the individual involved in the aeronautical event. Additionally, a study carried out in a large Brazilian airline using Flight Data Monitoring (FDM) data pointed out that the relative incidence of pilots' errors increased by 46% in the period between 0h00 and 06h00, in comparison with the other periods of the day [15]. Due to it, CNFH adopts this period - which is also defined as dawn, in the Federal Law [16] and in the Brazilian Civil Aviation Regulation 117 (RBAC 117) [17] - as the period of greatest fatigue susceptibility.

4.2 - Wakefulness: the duration of time since crew member woke up until the time of the event to be analysed is another factor that contributes to the fatigue susceptibility.

4.3 - Workload: the type of activity and the workload (physical and mental) associated with the task performed may impact performance over time. Thus, monotonous activities contribute to the increase in sleepiness and degradation of human performance. More complex or high-workload activities increase fatigue susceptibility [18].

4.4 - Sleep inertia: transient phenomenon, which may occur just after waking up from a period of sleep. It is understood as the time it takes an individual to restore his/her level of alertness after waking up.

4.5 - Desynchronization of biological rhythms (biological and social Jet Lag): both night work, shifting the wake-sleep cycle, and crossing of time zones (from east to west, and vice versa), cause changes in biological rhythm and, consequently, can cause difficulties in adapting to the new work schedules [19].

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[1] The sleepiness period that usually takes place in the beginning of the afternoon is known as the post-lunch dip and may affect crewmember performance.

4.6 - Specific characteristics of flight schedules: according to researches [20-22], the most fatiguing flight schedules include the following main characteristics: (1) night flights, (2) desynchronization of biological rhythms, (3) early-starts, (4) time pressure, (5) multiple sectors and (6) consecutive schedules without adequate recovery periods.

4.7 - Individual aspects: (1) irregular sleeping habits, (2) sleep disorders, (3) use of psychoactive substances, (4) insufficient use of rest opportunities, (5) extra-flight activities in general, (6) long commuting time from home to work and vice versa, (7) psychological issues, (8) family conflicts, (9) inappropriate eating habits, (10) irregular practice of physical activities, (11) health issues, among others.

4.8 - Aspects of the environment: (1) adequate rest facilities, both at home or at work, (2) the age of children, (3) the special needs of close people, (4) operator policies for sick leave or fatigue call, (5) operator policies regarding the predictability of published schedules, (6) organizational culture, (7) time pressure, among others.

4.9 - Regulatory aspects: the regulatory framework has a relevant role as the first protective barrier to the minimize fatigue risk. However, research shows [22-24], that, under certain circumstances, the prescriptive rules may not be sufficient for managing this risk properly. It is also recommended to use biomathematical models as a supporting tool to assess fatigue, even if the regulatory limits have not been exceeded.

5. Main contributing factors to the increase in the cognitive demand of crew members in aviation:

5.1 - Technical problem in the aircraft: mechanical failures in the aircraft that lead to: (1) performance limitations, (2) changes in usual procedures, (3) changes in configuration and/or use of systems, (4) changes in aircraft behaviour (handling) and consequent change in the piloting technique, (5) crew workload management, among others, may significantly increase the cognitive demands of the activities conducted by the crew.

5.2 - Adverse weather: adverse meteorological conditions may increase the crew's cognitive demands, requiring greater efforts to obtain an adequate management for the decision-making process.

5.3 - Heavy air traffic: heavy air traffic may cause an increase in crew's cognitive demand due to the need for greater attention and concentration. The language used in radio communications, the familiarity with the airspace overflown, and the air traffic regulations at the airports operated may also contribute to a greater cognitive demand.

5.4 - Non-precision procedures: non-precision procedures may increase the crew's cognitive demand requiring skills that may not be practiced frequently on a daily basis. The transition from instrument flight to the visual approach segment may also lead to an increase in the crew's cognitive demand, especially in regions around the aerodrome with unfavourable terrain topography (possibility of CFIT or black hole) [25-27].

5.5 - Manual flight: manual piloting may also increase the cognitive demand of the crew, requiring skills and the ability to crosscheck instruments, whose interpretation and performance may not be used on a daily basis.

5.6 - Go-around procedure: the go-around procedure significantly increases the crew's cognitive demand, with the possibility of causing spatial disorientation

if there is no visual reference with the terrain. Among the several types of spatial disorientation, it is worth highlighting the somatogravic illusion, which is caused by the sum of the gravitational force with inertial forces resulting from the aircraft's longitudinal acceleration [28].

5.7 - Instruction flights: en-route instruction flights may increase the cognitive demand of the crew.

5.8 - Automation: the use of aircraft automation in certain circumstances may lead to an increase in cognitive demand. The main relevant points are: (1) the level of automation used for performing a given task, (2) mode reversals, (3) pilots' mental model of the system logic [29], inoperability of certain autopilot system modes, "automation surprises" [30], among others.

6. Investigation methodology:

The absence of a standard and detailed methodology for investigating the influence of fatigue in aeronautical events in Brazil was considered a potential gap for considering fatigue as a contributing factor in an incident or accident. In response to this need, CNFH conducted studies and works aimed to develop a specific methodology, which is comprised of two parts:

6.1. an initial screening, which allows investigators to recognize that aspects related to fatigue may or may not be present in the investigated occurrence;

6.2. a detailed methodology, which allows investigators to identify whether or not there was sufficient factual data to indicate the contribution of fatigue to the investigated occurrence.

The identification of fatigue in aeronautical events contributes to data collection relevant to the improvement of fatigue management in the context of aviation. Based on the recognition of fatigue as a potential threat to human performance, the methodology presents itself as a useful tool, the use of which may result in mitigating actions for the current Brazilian aviation scenario.

6.1 - Initial screening:

6.1.1. Objective, method and conclusions:

Objective: to achieve a general assessment of the sleep and wake conditions of the crew involved in the aeronautical incident.

Method: it consists of six questions with dichotomous answers (YES or NO) to be used as an aid to conduct investigative work.

Conclusions: should the investigator obtain negative answers to all questions, it is recommended to interrupt the investigation from a fatigue standpoint. If at least one of the answers to these questions is affirmative, one should proceed to a more accurate investigation using the detailed methodology.

6.1.2. Questions:

Question 1 (sleep history): does the history of **past 72 hours** suggest that the individual slept less than 8 hours a day[2], or less than usual, if this pattern is known, or even if any of the sleep events were of poor quality?

Question 2 (wakefulness period): was the individual awake for **16 hours or more** at the time of the aeronautical event?

Question 3 (time of day): did the incident or accident occur during **more critical periods of sleepiness**, that is, between 0h00 and 06h00?

Question 4 (Jet Lag): is there evidence that the individual was not with his/her sleep-wake cycle synchronized with the legal time in the time zone of occurrence?

Question 5 (workload): is there evidence that the workload (physical or mental) was high during the duty period or that the cognitive demand to perform the tasks was high and/or unusual? Is there evidence that there was monotony or underload at the time of the occurrence?

Question 6 (performance): does evidence suggest that the aeronautical event was the result of inaction (lethargy/inertia) or that there was forgetfulness or even a reduction in the individual's attention capacity?

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[2] For the preliminary analysis of the accumulated sleep debt the investigator can apply a sleep credit system (+2 credits for each hour of sleep and -1 credit for each hour of wakefulness) [9]. There will be an accumulated sleep debt if the sleep credit drops below zero.

In case of one or more affirmative answers to the aforementioned questions, the analysis must be carried out using the detailed methodology It should be stressed out that, whenever a more detailed investigation is required, it is essential the involvement of human factors professionals in the case.

6.2 - Detailed methodology:

6.2.1 Objectives, method and conclusion:

Objective: to obtain information that allows establishing the proper correlations between the two main axes: (1) fatigue susceptibility conditions and (2) performance, behaviour and physiognomy of the individual consistent with the effects of fatigue.

Method: suggested questions for the composition of the interview script are presented as support, as well as two checklists, included at the end of this document, which summarize the guidelines for conducting the investigative work. These support materials may assist the investigator in the searching for possible associations of fatigue in the event, that is, if there was fatigue susceptibility (Checklist Axis 1) and if individual's (or crew's) unsafe behaviours or actions were consistent with the ones expected from an individual (or crew) under the effect of fatigue (Checklist Axis 2). For proper use of the suggested method, during the investigative work, there must necessarily be a human factor professional trained for investigating this issue in aeronautical occurrences.

Conclusion: after applying the proposed methodology, one should be able to conclude whether or not the fatigue of the individual(s) was a contributing factor to the aeronautical occurrence.

6.2.2 Axis I – Fatigue Susceptibility:

6.2.2.1 Sleep duration: check, if possible, if the individual had adequate sleep periods in the days preceding the occurrence. Use, if possible, information on sleep and awake time for at least 72 hours before the event, and compare this data with the individual's usual sleep time, if this pattern is known, including partial episodes of sleep during the day. Try to identify when was the last time that the individual had the opportunity to recover the sleep debt, considering, at least, two consecutive nights of sleep and totally adapted to the legal time of the aeronautical occurrence.

It is recommended to use biomathematical models as a supporting tool in order to make a more accurate estimate of the duration of sleep at the time of the occurrence, that is, if there was a significant sleep deficit.

The following questions may be used to compose the interview script:

- During your days off, assuming you can sleep normally at night, what time do you usually go to bed?
- During your days off, what time do you wake up?
- How much sleep do you think you should sleep to feel well?
- Inform, if possible, what time you went to bed and woke up in the last 3 days before the aeronautical event.

  • Main sleep before the event:

  Slept at ____:____

  Woke up at ____:____

  Sleep quality: ( )Excellent ( )Good ( )Regular ( )Poor

  In case of any response in the options of regular or poor, it is suggested to ask the reason.

  • Main Sleep the day before the event:

  Slept at ____:____

  Woke up at ____:____

  Sleep quality: ( )Excellent ( )Good ( )Regular ( )Poor

  In case of any response in the options of regular or poor, it is suggested to ask the reason.

- Main sleep two days before the event:

Slept at ____:____

Woke up at ____:____

Sleep quality: ( )Excellent ( )Good ( )Regular ( )Poor

In case of any response in the options of regular or poor, it is suggested to ask the reason.

- Was there a brief nap/sleep period in the last 24 hours prior to the event? ( )Yes ( )No
  - If yes:

When:_____

Where: _____

For how long: _____

6.2.2.2 Sleep quality: if possible, check whether the individual's sleep was fragmented (for example, several episodes of sleep over a 24-hour period) and/or restless (for example, waking up during sleep due to individual or environmental factors) in the days preceding the occurrence.

It is recommended to use biomathematical models as a supporting tool to estimate the crewmember's performance as a function of sleep quality, if the investigator can determine this variable.

If possible, the following questions are suggested to compose the interview script:

- Were there any factors in the resting environment that interfered with your sleep? For example: noise, light, phone calls, etc...?

- Was your sleep pattern different or was it interrupted in the days before the event?

- How do you rate your sleep at home? Poor, regular, good or excellent? Considering that your sleep at home is excellent, how do you rate your sleep at the rest facility provided by the company (poor, regular, good or excellent)?

- On the day of the incident, were you subjected to an environment or unusual tasks that may have caused excitement or drop in alert, such as:
  - Low lighting?
  - Operational delays?
  - Monotony or boredom?
  - Personal problems?

6.2.2.3 Wakefulness period: check how long the individual was awake at the time of the occurrence, using interviews or records to estimate the time of the most recent awakening before the event under investigation. Long periods of continuous wakefulness may impair human performance (alertness, memory, among others). When considering the existing variability in human beings with regard to their organism and physiological functioning, it is suggested that the period of 16 hours or more of continuous wakefulness be adopted as a reference for suspected fatigue susceptibility.

6.2.2.4 Factors associated with biological rhythms, jet lag and sleep inertia: check if the critical event occurred during the dawn, that is, from 0h00 to 06h00. Usually at this time most people are sleepy, which is why it is difficult to stay alert. This time interval is calculated from scientific data on performance [15], variation in body temperature, as well as from subjective reports.

Additionally, assess whether there is evidence that the individual did not have his biological rhythms, especially those associated with sleep and wakefulness, adapted to the legal time of the occurrence. The individual takes, on average, one day to adapt to each time zone crossed. Therefore, travelling west → east and east → west rotations should be carefully evaluated.

Check for evidence that the individual could be under the effect of sleep inertia at the time of the occurrence. According to the literature [31], this effect can degrade cognitive performance up to 120 minutes after awakening.

It is recommended to use biomathematical models as a supporting tool for a more accurate analysis of the degradation of the individual's cognitive performance caused by circadian factors, Jet Lag or sleep inertia.

The following questions are suggested to compose the interview script:

- In the past few weeks, have you experienced any of the following:
  - Crossing of three or more time zones (east → west or west→ east) without a period of at least three local nights for adaptation[3] ?
  - Starting or finishing work between 11 pm and 7 am?
  - Main sleep occurred during the day or during the afternoon?
  - Main sleep occurred at variable times?

[3] Local night means a period of 8 consecutive hours between 22h00 and 08h00, considering the legal time zone of the individual [17].

6.2.2.5 Workload: check if the workload to which the individual was subjected was high or if there was an underload in the period before the event. The cognitive demand for the activities that preceded the incident/accident must also be taken into account, in order to verify whether there are signs that the individual's performance was not good enough to deal with the complexity of the tasks required for the correct management of the presented circumstances.

If possible, ask the following question: Have you been subjected to an unusual environment or tasks that may have caused an underload or overload of work?

6.2.2.6 Individual and/or health aspects (sleep disorders or use of psychoactive substances): check if individual aspects or health problems (sleep disorders or use of psychoactive substances) were present in the individual's history. It is necessary to investigate the use of substances that affect sleep and/or alertness.

If possible, use the following questions to compose the interview script:

- Do you have difficulty to fall asleep or to stay asleep?
- Have you ever been diagnosed with a sleep disorder?
- Do you use drugs/medication regularly? Which are they? What is the frequency?
- Did you use drugs/medication on the day of the incident?
- Do you have any medical problems that affect sleep, such as, chronic pain, gastroesophageal reflux or sleep apnea?
- Check if the individual's eating habits are adequate, including stimulants (caffeine) and use of dietary supplements;
- Check if the individual practices physical activities regularly;
- Check for extra-flight activities in general, considering whether the individual:
    - Has any other activity not related to the flight (own business, informal work, social work, etc…);
    - Has and/or accumulates administrative functions within the company, if applicable;

- Check the average elapsed time that the individual takes to go from home to work and from work to home;
- Check if the individual has children and, if so, how old they are;
- Check for any relevant psychological issues or family conflicts that are compromising the individual's quality of rest.

6.2.2.7 Organizational and management aspects: the items presented below may contribute to fatigue susceptibility:

- Work schedules (planned and executed), mainly including the following factors:
  - Night flights;
  - Consecutive work schedules with alternating shifts without adequate recovery periods;
  - Early stars in the morning, typically between 06h00 am and 08h00 am;
  - Multiple flight sectors;
  - Successive schedules with a counterclockwise pattern (check-in times systematically anticipated in relation to the previous day), generating a feeling of shortening of the individual's day;
  - Significant changes between published and executed work schedules, including last minute changes of night shifts, without the necessary predictability to provide adequate rest.

- Check the transportation records to verify the amount of time spent from hotel to airport and vice-versa.

- Elapsed time between the check-in and the start of the block time: verify the check-in and check-out times for the duty period and whether the check-in is consistent with the actual check-in time at the hotel or at the airport. If there is a discrepancy, it is recommended to use the actual times for the purpose of analysing the wakefulness period;

- Check if the resting facility at the hotel or in flight was adequate to perform the schedule;

- Check the policies and procedures adopted by the company/organization related to Fatigue Risk Management, mainly including the following factors:
  - Non-punitive policies for sick leave or fatigue call;
  - Organizational culture, including fatigue reporting policies and procedures;
  - Incidence of reports on fatigue and mitigating actions performed by the organization;

  - Fatigue Risk Management training;
  - Risk analyses of the organization, if available. Some fatigue indicators recently obtained for the Brazilian airline industry [24] may help the investigator's analysis;

- If possible, check whether union or association representatives have received fatigue reports or complaints from the individual or other individuals on similar schedules;

- Regulatory aspects: check if there is evidence that current regulations may not have been sufficient to mitigate the fatigue risk [22-24]. Some fatigue indicators obtained recently for the Brazilian airline industry [24] may help the investigator's analysis.

- Verify if the the roster complied with the regulations (Law 13.475/17, RBAC 117, or specific operation, as applicable)

6.2.3 Axis II - Performance, behaviour and physiognomy of the individual:

6.2.3.1 Performance of the individual: assess whether the individual's performance was consistent with the effects of fatigue and whether the incident or accident was caused by inaction, lethargy, inertia, inattention or spatial disorientation. It is important to estimate if the individual had difficulty in paying attention to a stimulation field for a prolonged period of time, that might result in poor vigilance. In this way, attention may be directed towards stimuli that are not relevant to the situation, either due to the difficulty of keeping the focus oriented in a certain direction, or because of the distracting power of the non-relevant stimulus. For this reason, every human action/inaction related to the occurrence requires an accurate analysis.

Use available evidence to determine whether the individual's performance was deteriorating prior to the aeronautical event. For example:

- Was there evidence that the individual forgot or ignored tasks or parts of tasks?

- Did the individual's focus on a task exclude other important information?

- Was there evidence of delayed responses to stimuli or apathy?

- Was there evidence of impaired decision-making or inability to adapt the behaviour to new information?

- Was there evidence of altered speech or any kind of misunderstanding in the communication between the pilots and the ATC?

  6.2.3.1.1 Aspects of voice, speech and language: whenever possible, request a technical evaluation of the recorded speech data, in order to identify whether there were variations compatible with signs of fatigue or sleepiness [32]

6.2.3.2 Behaviour and physiognomy of the individual: analyse whether the individual's physiognomy or behaviour before the aeronautical event was suggestive of sleepiness or fatigue, based on:

- Individual report on perception of fatigue;
- Testimonials from other crewmembers, co-workers or observers;
- Audio files: Analyze, whenever possible, aspects of the pilots' communication with the ATC and audios stored in the Cockpit Voice Recorder (CVR) for performance evaluation;
- Videos (crew room, boarding, ramp, etc.).

6.3 Application of results and decision-making:

After applying this methodology, fatigue can be listed as a contributing factor to the investigated aeronautical occurrence only if it is possible to conclude that:

- The individual was susceptible to fatigue conditions, and
- The individual showed evidences of performance, behaviour or physiognomy consistent with fatigue.

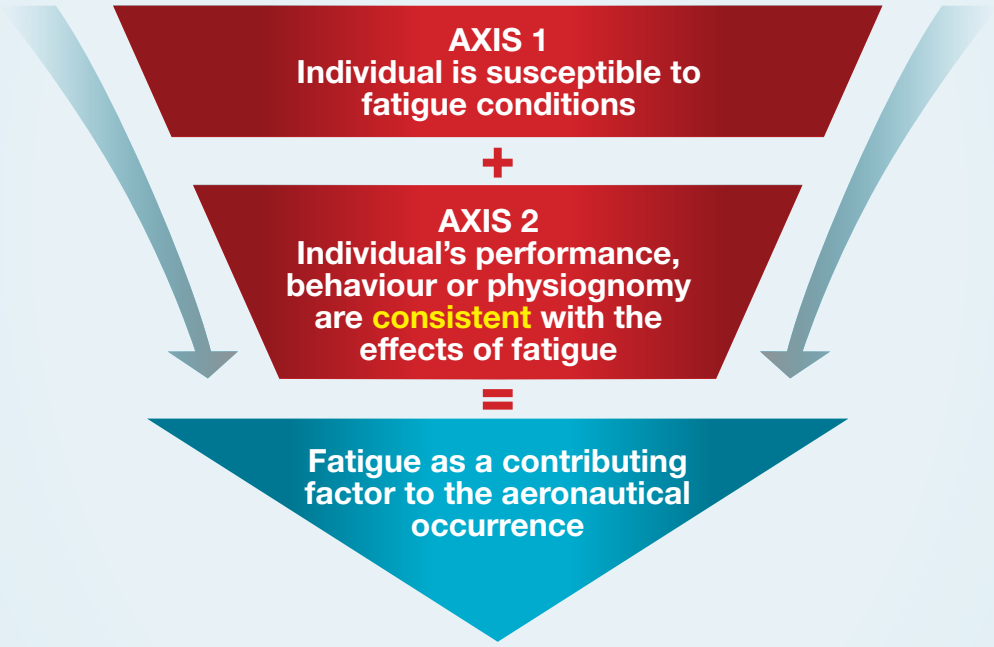

Figure 1: Flowchart for the detailed methodology with fatigue outcome as a contributing factor to the aeronautical occurrence. Details in the text.

The use of the methodology also allows concluding if the individual was susceptible to fatigue conditions, without finding evidence of performance, behaviours or physiognomy consistent with a state of fatigue. In such cases, fatigue should not be listed as a contributing factor to the aeronautical occurrence, but should be considered as an object of flight safety recommendation and proposition of mitigating actions.

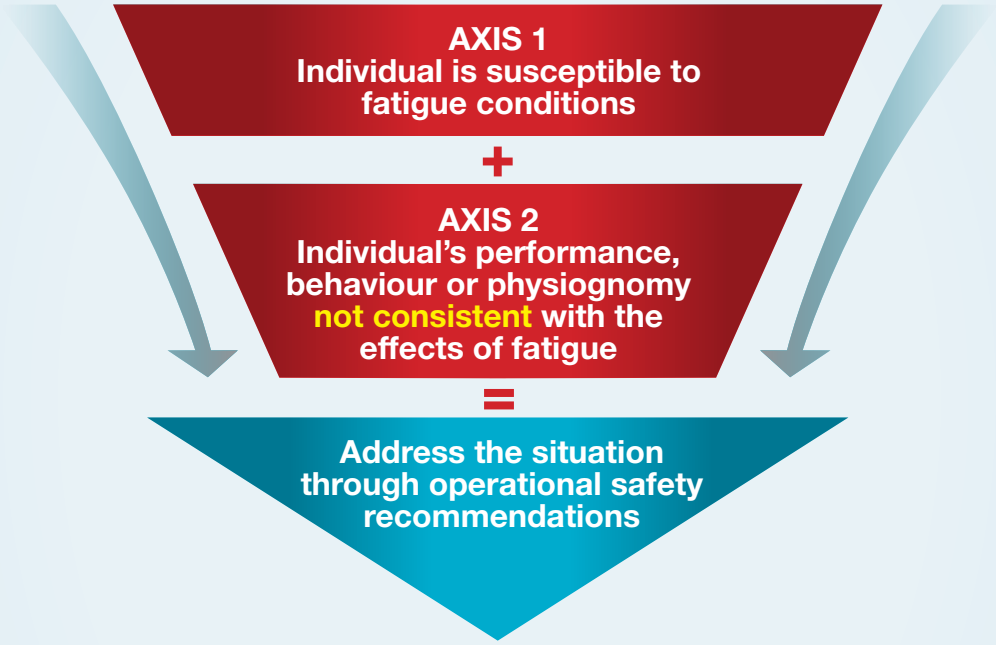

Figure 2: Flowchart for the detailed methodology with the outcome of proposing operational safety recommendations. Details in the text.

7. Final considerations:

According to ANAC [33], the Brazilian aviation industry had a 16% growth in the number of domestic and international flights between 2009 and 2018, reaching the mark of 967,000 of flight sectors in 2018. This increase, associated with major changes in the regulatory framework with the new fatigue rules from RBAC 117 [17], demonstrates the need for operators, the regulatory body, representative entities and other stakeholders, to seek effective mechanisms in the management and prevention of human fatigue in the aviation. Thus, there is a need for a joint effort by all stakeholders to deal with fatigue management - an increasingly important issue in modern society.

In line with these efforts, the methodology presented may support studies and the investigation of fatigue, aiming at identifying its occurrence and mitigating the risks associated with this factor.

This guide is, therefore, an important tool to increase reactive prevention actions in the aeronautical field. It is noteworthy, however, that this is only a portion of the possible preventive actions. Despite its relevance in obtaining a database that allows an analysis of trends in this aspect, it is healthy to highlight that proactive and predictive measures are fundamental for the success of the operational safety management.

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ANNEXES:

- **Initial Screening**
- **Checklist Axis 1: Fatigue susceptibility**
- **Checklist Axis 2: Performance**

INITIAL SCREENING

Topic	Guidance questions	YES	NO
Sleep history	Does the history of the past 72 hours suggest that the individual slept less than 8 hours a day, or less than usual, if this pattern is known, or even if any of the sleep events were of poor quality?		
Wakefulness period	Was the individual awake for 16 hours or more at the time of the aeronautical event?		
Time of the day	Did the incident or accident occur during more critical periods of sleepiness, that is, between 0h00 and 06h00?		
Jet lag	Is there evidence that the individual was not with his/her sleep-wake cycle synchronized with the legal time in the time zone of occurrence?		
Workload	Is there evidence that the workload (physical or mental) was high during the duty period or that the cognitive demand to perform the tasks was high and/or unusual? Is there evidence that there was monotony or underload at the time of the occurrence?		
Performance	Does evidence suggest that the aeronautical event was the result of inaction (lethargy/inertia) or that there was forgetfulness or even a reduction in the individual's attention capacity?		

CHECKLIST AXIS 1: FATIGUE SUSCEPTIBILITY

Topic	Guidance	Suggested questions
Sleep duration	Check, if possible, if the individual had adequate sleep periods in the days preceding the occurrence. Use, if possible, information on sleep and awake time for at least 72 hours before the event, and compare this data with the individual's usual sleep time, if this pattern is known, including partial episodes of sleep during the day. Try to identify when was the last time that the individual had the opportunity to recover the sleep debt, considering, at least, two consecutive nights of sleep and totally adapted to the legal time of the aeronautical occurrence.	1.During your days off, assuming you can sleep normally at night, what time do you usually go to bed? 2.During your days off, what time do you wake up? 3.How much sleep do you think you should sleep to feel well? 4.Inform, if possible, what time you went to bed and woke up in the last 3 days before the aeronautical event. 5.Was there a brief nap/sleep period in the last 24 hours prior to the event?
Sleep quality	If possible, check whether the individual's sleep was fragmented (for example, several episodes of sleep over a 24-hour period) and/or restless (for example, waking up during sleep due to individual or environmental factors) in the days preceding the occurrence.	1. Were there any factors in the resting environment that interfered with your sleep? For example: noise, light, phone calls, etc...? 2. Was your sleep pattern different or was it interrupted in the days before the event? 3. How do you rate your sleep at home? Poor, regular, good or excellent? Considering that your sleep at home is excellent, how do you rate your sleep at the rest facility provided by the company (poor, regular, good or excellent)? 4. On the day of the incident, were you subjected to an environment or unusual tasks that may have caused excitement or drop in alert?
Wakefulness period	Check how long the individual was awake at the time of the occurrence, using interviews or records to estimate the time of the most recent awakening before the event under investigation.	1. What was your wake-up time? (it is suggested that the period of 16 hours or more of continuous wakefulness be adopted as a reference for suspected fatigue susceptibility.).

CHECKLIST AXIS 1: FATIGUE SUSCEPTIBILITY

Topic	Guidance	Suggested questions
Biological rhythms, jet lag and sleep inertia	Check if the critical event occurred during the dawn, that is, from 0h00 to 06h00.	1. In the past few weeks, have you experienced any of the following: • Crossing of three or more time zones (east → west or west → east) without a period of at least three local nights for adaptation? • Starting or finishing work between 11 pm and 7 am? • Main sleep occurred during the day or during the afternoon? • Main sleep occurred at variable times?
	Assess whether there is evidence that the individual did not have his biological rhythms, especially those associated with sleep and wakefulness, adapted to the legal time of the occurrence.	
	Check for evidence that the individual could be under the effect of sleep inertia at the time of the occurrence.	
Workload	Check if the workload to which the individual was subjected was high or if there was an underload in the period before the event.	1. Have you been subjected to an unusual environment or tasks that may have caused an underload or overload of work?
	Check the cognitive demand for the activities that preceded the incident/accident in order to verify whether there are indications that the individual's performance was not good enough to deal with the complexity of the tasks required for the correct management of the presented circumstances.	
Individual and/or health aspects	Check if individual aspects or health problems (sleep disorders or use of psychoactive substances) were present in the individual's history. Check if substances that affect sleep and/or alertness were used.	1. Do you have difficulty to fall asleep or to stay asleep? 2. Have you ever been diagnosed with a sleep disorder? 3. Do you use drugs/medication regularly? Which are they? What is the frequency? 4. Did you use drugs or medication on the day of the incident? Which are they? 5. Do you have medical problems that affect sleep, for example, chronic pain, gastroesophageal reflux or sleep apnea? 6. Do you have children? How old are they?
	Verify that: the individual's eating habits are adequate and that physical activity is practiced regularly; extra flight activities in general; travel time from home to work and vice versa.	
	If possible, check for any relevant psychological issues or family conflicts that are compromising the individual's quality of rest.	

CHECKLIST AXIS 1: FATIGUE SUSCEPTIBILITY

Topic	Guidance	Suggested questions
Organizational and management aspects	Check for the existence of organizational and management factors that may contribute to fatigue susceptibility.	1. What were the last times you took a night flight before the event? 2. During this period, did you run consecutive schedules on alternate shifts without adequate recovery periods? 3. Did you have early-starts, typically between 6:00 am and 8:00 am? 4. Were there multiple flight sectors of operation? 5. Were you subject to successive schedules with a counter-clockwise pattern (check-in times systematically anticipated in relation to the previous day)? 6. Have you had significant changes between your published and executed flight schedule, without due predictability to provide adequate rest? 7. Did the roster comply with the regulations (Law 13.475/17, RBAC 117, or specific operation, as applicable)?
	If possible, check the work schedules (planned and executed); time spent from hotel to airport and vice-versa; the check-in and check-out times of the duty period; whether the resting facility at the hotel or in flight was adequate to perform the schedule; and the policies and procedures adopted by the company/organization related to Fatigue Risk Management.	
	If possible, check whether union or association representatives have received fatigue reports or complaints from the individual or other individuals on similar schedules.	
	Check if there is evidence that the current regulation may not have been sufficient to mitigate the fatigue risk.	

CHECKLIST AXIS 2: PERFORMANCE

Topic	Guidance	Suggested questions
Performance of the individual	Assess whether the individual's performance was consistent with the effects of fatigue.	1.Was there evidences that the individual forgot or ignored tasks or parts of tasks? 2.Did the individual's focus on a task exclude other important information? 3. Was there evidence of delayed responses to stimuli or apathy? 4.Was there evidence of impaired decision-making or an inability to adapt the behaviour to new information? 5.Was there evidence of altered speech or any kind of misunderstanding in the communication between the pilots and the ATC?
	Use available evidence to determine whether the individual's performance was deteriorating prior to the aeronautical event.	
	Whenever possible, request a technical evaluation of the recorded speech data, in order to identify if there were variations compatible with signs of fatigue or sleepiness.	
Behaviour and physiognomy of the individual	Analyze whether the individual's physiognomy or behavior before the aeronautical event was suggestive of sleepiness or fatigue.	
	Use: (1) individual report on perception of fatigue; (2) testimonials from other crewmembers, co-workers or observers; (3) audio files [aspects of pilots' communication with ATC and audios stored in the Cockpit Voice Recorder (CVR) for performance evaluation] and, (4) videos (crew room, boarding, ramp, etc.)	