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Fatigue Monitoring Tool for Airline Operators (FMT)

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Abstract **– A Fatigue Monitoring Tool (FMT) model was constructed for an operational airline in order to manage the fatigue levels of their crews in accordance with Fatigue Risk Management System (FRMS) practices. This article describes the implementation of the Fatigue Monitoring Tool model and the airline's aims to put the recent scientific findings on aviation fatigue into practical use. The model consists of proxy points allotted to various duties and rest periods.**

Keywords **– Fatigue Monitoring Tool (FMT), Fatigue Risk Management System (FRMS), fatigue.**

I. Introduction

Airlines are increasingly adopting a new method to ensure that their crews do not operate while being unduly fatigued. Aviation has had a tumultuous history with fatigue, from Lindbergh's first trans-Atlantic flight to more recent aviation disasters. While adhering to legal flight time limitations, airlines are now aware that more stringent methods of monitoring and controlling fatigue are required.

All airlines must work by the agreed rule sets of the International Civil Aviation Organization (ICAO) published in 19 annexes [1]. This is the framework by which all airlines operate and it is further enhanced by regional regulations (e.g. the European Aviation Safety Agency) and local authority requirements (e.g. the National Civil Aviation Agency). This framework sets limits on flight crew working hours, length of duties and other issues regarding work limitations. The current consensus within the industry is that these limits are not sufficient to combat fatigue as the simple prescribed rules do not fully address the complexities of various airline operators around the world. A pilot flying close to the legal limit for a prolonged period will become fatigued [2], which is not sufficiently addressed in the flight time limitations. It is hard to overstate how much of a safety risk fatigue poses to the aviation industry. Crew members suffering from fatigue exhibit a number of physical, mental and emotional symptoms, most or all of which are detrimental to the safety of the flight [3]. Table I represents a summary of most frequent physical, mental and emotional symptoms caused by fatigue [4].

In order to combat this risk to aviation, ICAO has prescribed that airlines and other aviation related operators implement and rely on Fatigue Risk Management. The EU addressed this issue with Regulation EU 83/2014, which introduces a new Flight Time Limitation regulations along with the requirements for aircraft operators to actively monitor fatigue and fatigue causing factors in their scheduling [5].

TABLE I

Physical, Mental and Emotional Symptoms of Fatigue [4]

Physical Symptoms	Mental Symptoms	Emotional Symptoms
Slowed reaction time	Concentration difficulty	Quiet and withdrawn
Lack of energy, weakness.	Attention lapses	Lack of motivation
Repeated yawning	Communication problems	Irritability
Heavy eyelids	Failure to anticipate events	Low morale

Physical Symptoms	Mental Symptoms	Emotional Symptoms
Eye rubbing	Making mistakes on routine tasks	Emotional sensitivity
Nodding off	Forgetfulness	
Microsleeps	Difficulty thinking clearly	
Headaches, nausea	Poor decision making	

A. *Fatigue Risk Management*

Airlines are now mandated to implement a thorough Fatigue Risk Management (FRMS) program in order to monitor and prevent the build up of fatigue in their crews. The guidelines for this program are mainly located in ICAO Annex 6 and document 9966, *Fatigue Risk Management for Regulators*, but state authorities may have additional requirements [6].

The FRMS is not meant to impose strict limitations of flight time, but rather to aid the air operator to schedule the crews in accordance with the best scientific practices and thus avoid fatigue [7]. The FRMS should highlight fatigue risks, predict what schedules are more demanding and suggest ways to alleviate cumulative fatigue. This can take the form of changing the schedule or distributing the duties to more crew members, thus allowing for more rest.

Furthermore, for European carriers, Regulation EU 83/2014 amended basic aviation Regulation EU 965/2012 and stipulated that aircraft operators willing to take full advantage of the Flight Time Limitations (e.g. long night flights) were required to implement the FRMS.

The FRMS is also focused on the role of the individual crew member – how they are responsible for their own rest and how they should ensure that they maximize their rest possibilities [8]. While the airline operator shall provide education on this matter to the crews, each member is responsible for their own rest and is required to inform the company if he/she is not well rested for the upcoming flight [8].

B. *How Can Sleep Hygiene Affect Fatigue?*

Sleep hygiene aims to address the responsibility of aviation scheduling. While the airline is committed not to overly schedule their crews, the crews must also try to maximize their rest potential while on rest periods or off days. No matter how good the FRMS is, it is rendered worthless if the crews do not similarly obtain rest when necessary. Sleep hygiene consists of certain recommendations listed in Tables II, III and IV [9]. This includes strategies to maximize the following:

- to optimize sleep opportunities;
- to adopt rotating shift schedules;
- to adjust for time zone changes.

TABLE II

OPTIMIZE SLEEP OPPORTUNITIES [9]

Wake up and go to bed at the same time every day if possible.
Use the sleep area for sleep – not for chores (hard for hotel dwellers).
Establish a bedtime routine, e.g. reading, shower, bed.
Exercise every day, but not within two hours of bedtime.
Keep the sleep area dark, quiet, comfortable and cool.
Put your phones on quiet and move out of sight (or face down in order to prevent screen lighting up in case of alarm or messages).
Avoid caffeine in the afternoon and evening.
Avoid using alcohol to promote sleep.
Avoid cigarettes, especially before bedtime. Nicotine is a powerful stimulant.
If you can’t sleep, leave the sleep area and do something relaxing. When sleepy, return to bed.

TABLE III

RECOMMENDATIONS FOR ROTATING SHIFT SCHEDULES [9]

When rotating onto night duty, avoid morning sunlight.
To promote daytime sleep, keep the sleep area dark and cool, use eye masks and earplugs.
Comply with "Optimize sleep opportunities" above.
Before night duty, take a short nap.
After waking from daytime sleep, expose yourself to at least two hours of sunlight or artificial bright light in the late afternoon or early evening.

TABLE IV

RECOMMENDATIONS FOR TIME ZONE ADJUSTMENTS [9]

Quickly switch to the new time zone schedule for sleep, meals and activities.
Maximize sunlight exposure during mornings.
Minimize sunlight exposure during afternoons.
Avoid heavy meals at night.
Comply with "Optimize sleep opportunities" above.
If possible, take a hot bath/shower before bed.

II. METHOD

A. FMT Model

A focus group was established to subjectively evaluate the weight of the fatigue causal factors based on professional experience. The focus group consisted of representatives of the airline's operational crew members: pilots, cabin crew members and station managers (representatives of an airline in outstation). The below contributory factors were established with the consensus of the fatigue focus group.

B. Fatigue Weights

Fatigue weights according to Flight Duty and Rest / Off Days including additional fatigue weights are represented in Tables V, VI and VII below.

TABLE V

FLIGHT DUTY DAYS

1	Flight Duty Day
2	2nd Consecutive Flight Duty Day
3	3rd Consecutive Flight Duty Day
4	4th Consecutive Flight Duty Day
5	5th Consecutive Flight Duty Day
6	6th Consecutive Flight Duty Day
7	7th Consecutive Flight Duty Day

TABLE VI

REST / OFF DAYS (DEFINED AS ANY 24 HOUR DAY WITHOUT ANY DUTY)

1	Off Day
2	2nd Consecutive Off Day
3	3rd Consecutive Off Day
4	4th Consecutive Off Day
5	5th Consecutive Off Day
6	6th Consecutive Off Day

TABLE VII

ADDITIONAL FATIGUE WEIGHTS

1	Long Duty (+10 h)	If FDP exceeds 10 hours
2	Reduced Rest (if accumulated points are more than 25)	Reduction of rest is considered detrimental to fatigue if crew is already in a tired state
3	Early to late transition	If crew has flown three consecutive (or more) early flights (between 5:00–12:00) and then has to take an afternoon flight on the fourth day
4	Reporting fatigue	Immediate removal from flight duty and points added
5	Late to early transition	If crew has flown three consecutive (or more) late flights and then has to take an early flight
6	Flight encroaches WOCL	If flight enters the Window of Circadian Low 0200 – 0559LT
7	Standby	Standby is considered somewhat restful if not called out for duty
8	Rest away from home base	Rest away from base is not considered to be as easy nor as restful as at home base where sleep schedule has been established
9	Time zone difference (±3 h) during rest	If rest is taken at a location with three hour (or more) difference from home base
10	Captain's discretion	If captain is required to extend the flight duty to above normal allowed levels, e.g. 13 h to 15 h FDP. Additional workload due to extended delays
11	Extra long duty (+12 h)	Flight duty that exceeds 12 hours FDP
12	Three landings or more	If crew has to perform three landings it is considered extra workload
13	Travel Duty	Travel duty, e.g. deadheading, is not overly tiring
14	Office Day (non-cumulative)	Office days are not considered as cumulative point days
15	SIM (non-cumulative)	Sim sessions are not considered as cumulative point days
16	Line Training	Line training is considered additionally taxing to a normal flight
17	Day rest	If rest period starts between 6:00 and 12:00
18	Early Start	A duty period starting in the period between 5:00 and 05:59 in the time zone to which a crew member is acclimatized
19	Late Finish	a duty period finishing in the period between 23:00 and 01:59 in the time zone to which a crew member is acclimatized
20	Early Start	a duty period starting in the period between 5:00 and 06:59 in the time zone to which a crew member is acclimatized
21	Late Finish	a duty period finishing in the period between 00:00 and 01:59 in the time zone to which a crew member is acclimatized

C. FMT Scoring

The basic scoring system was categorized as follows:

1) normal (green);
2) elevated fatigue (yellow);
3) high fatigue (amber);
4) excessive fatigue (red).

D. Implementation of FMT Model

The fatigue factor weights have been inserted and integrated into the Crew Management module of Aviolinx RAIDO (software system) along with the points allocated to each factor (that can be determined by each airline) which will then be capable of automatically calculating the daily fatigue scores and project possible fatigue load in future schedules. This would fulfil the legal requirements that demand that the model be predictive and reactive. The aim of the software would therefore be:

1) to calculate the projected fatigue scores for any given future schedule based on the numbers of crews allotted to the project;

to flag any individual crew member if fatigue score has reached an unacceptable level.

As presented to the crews and management, the model seems to have a good face value – the weights corresponded with the common agreement of fatigue inducing behaviour in flight operations. However, in order to validate the relationship between the model and actual fatigue, a study was conducted to elicit self-reported fatigue scores and correlate them with actual FMT scores.

The objective of this study was to determine if there are correlation relationships between FMT model score and self-reporting on Samn-Perrelli scale scores, which was designed for the use of monitoring air crew fatigue and is considered somewhat of an industry standard [10].

In order to obtain data, the crew members of an active Latvian airline were asked to self report fatigue in a monthly survey. 25 participants were randomly chosen every month and their scoring was registered on their company crew intranet. No distinction was made between positions (cabin crews or pilots), age or experience. The crew members were varied, operating on different bases worldwide and on similar projects in terms of frequency of flights and flight hours. According to aviation rules, all reports on fatigue are considered to be non-punitive, there can be no repercussions to the reporter. The participants were assured of this fact when answering. The survey simply asked the participants to state their fatigue at that current time on the 7 point Samn-Perelli scale.

All in all, the results were received from 155 participants out of 300 – a response rate of 51 %.

E. Results

Pearson correlation was used to measure the strength of the association between the FMT model and self-reported fatigue. There was a statistically significant correlation ($r = 0.651$; $p = 0.00 < \alpha = 0.001$; Table VIII). Therefore, the higher FMT score, the greater self-reported fatigue.

The correlation between self-reported fatigue and FMT scores is quite strong and significant. This will give crew planners confidence to accurately assess the probable fatigue level of crew members based on the accumulated FMT scores.

TABLE VIII

CORRELATION ANALYSIS OF FMT SCORE AND SELF-REPORT

		FMT self-report
FMT score	Pearson Correlation	0.651**
	Sig. (2-tailed)	0.000
	N	155

** Correlation is significant at the 0.01 level (2-tailed).

The scatter plot diagram of FMT score and crew member self-reported fatigue level illustrates a good relationship between the two variables.

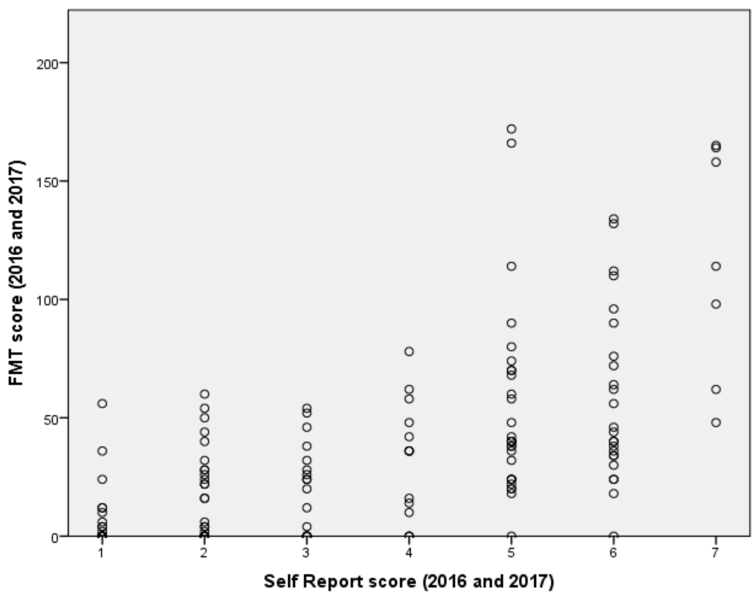

Fig. 1. FMT score and self-reported fatigue level.

III. Discussion

The correlation between self-reported fatigue and FMT scores is quite strong and significant. This will give crew planners confidence to accurately assess the probable fatigue level of crew members based on the accumulated FMT scores.

The model will continue to be improved with some additional factors to be taken into account.

The requested reports, which are automatically sent via a computerized system, seem to elicit a positive response – participants tend to downplay their fatigue when queried by email. This may be a teething problem as crew members are still not accustomed to be open about their actual level of fatigue and aviation culture has had a tendency for downplaying it.

The self-report scale may have to be re-evaluated as the Self Report score of 7 is automatically given to those who report unfit to fly due to fatigue. This may mask the relationship of accumulated fatigue and self-report scores as sometimes crew are fatigued due to other reasons, whether medical, social or other.

It bears considering the need to simplify the self-report scale and move away from the Samn-Perelli scale. It is possible that the 7 levels of granularity are too specific and may lead to misunderstanding amongst participants. A broader distinction between fatigue states may clarify the relationships.

Further study will be done via a regression analysis to assess the effects of fatigue on various subgroups – divided by age, sex and position.

Advantages of the Model

The following advantages of the model can be expected:

- provides integration with crew scheduling systems;
- provides rapid assessment of future schedules to identify and measure fatigue, and highlight problem areas for further investigation;
- interface can display fatigue points for a 31 day period and displays flags for any crew members whose fatigue points are excessive;
- designed for aviation applications, specifically for the aviation industry;
- applicable for use by flight crews and cabin crews, crew members can view their own fatigue projections, based on the model.

Limitations of the Model

The FMT is based on group data and it does not currently take into account individual differences (e.g. age, genetic disposition) or social factors (e.g. lifestyle, family responsibilities), however it should be taken into account that these may affect an employee's tolerance to the work hours that crew operations entail.

IV. Conclusion

As fatigue risk management gathers more weight within the aviation world, an automatic computerized system to evaluate possible fatigue will be essential to every airline. While such systems can only contain a model evaluation of actual fatigue, i.e. there are countless other fatigue related factors that are not work related, it gives an insight into the estimated fatigue caused by workload and lack of rest.

It is important to keep in mind that a crew member may still report fatigue even if the model has not projected high fatigue levels. This may be caused by personal reasons outside the scope of the model, e.g. insomnia, lack of sleep hygiene behaviour, situational factors, etc. Any reported fatigue must still be treated as actual fatigue, no matter what the system states.

It must also be kept in mind that all work is tiring to some extent. The goal of fatigue risk management is to manage the fatigue levels so that they do not pose a risk to operation rather than to establish zero fatigue.

The field of Fatigue Risk Management is a relatively young one within the aviation community and currently airlines are developing their own methods to comply with regulatory and safety requirements. This model can be a reliable and easy method to curtail fatigue within operational flight schedules. As a first step, it is a valuable one and the next steps will entail elaboration of the point system and further discussion on the contributory factors to fatigue.

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