Fatigue Risk Management Tools and Techniques
An overview

28th September 2015

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Fatigue Risk Management Science Limited

Managing Occupational Alertness Makes Good Business Sense

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Agenda

- Where Hazards Hide
- Measuring Fatigue
- Managing Fatigue
WHERE THE HAZARDS HIDE
Causes of fatigue

Increased levels of fatigue and decreased alertness are due to:

- Disturbed sleep or loss of sleep
- Circadian rhythm disruption (time of day etc)
- Task-related factors such as increased workload, noise and vibration
- Physical activity

- Usually Fatigue is caused by a combination of these factors.
- Fatigue is often not the primary cause but a contributing factor in incidents. When fatigued, decision making and the ability to react to avoid an incident are impaired.
Effects of fatigue

Fatigue is an inevitable consequence of disrupted sleep schedules and circadian rhythm disruption. For pilots it can mean:

- Inaccurate flying and Missed radio calls
- System warnings missed or slow to pick up
- Routine tasks performed inaccurately or forgotten
- Loss of situational awareness
- Micro sleeps and Task fixation
- Poor communication between crewmembers

But fatigue is not exclusive to pilots........any member of the team can be affected - cabin crew, managers, maintenance staff, ATCs

Estimated that fatigue contributes to approx. 15-20% of commercial aviation accidents.
Factors Leading to Disturbed Sleep in Air Operations

There are many factors associated with design of duty rosters and a flight time limitation (FTL) scheme that can lead to disturbed sleep and contribute to the development of fatigue. For example:

- Extended duty hours
- Reduced rest between duties
- Long commuting times
- Split duties
- Standby duties
- Unpredictable work schedules
- Irregular duty start and end times
- Time zone crossing
The combined effect of the components of fatigue leads to an approximately flat level of alertness throughout the working day and a steady decline in alertness during normal period of sleep; flattening at the time where the circadian rhythm begins to rise in the early morning.
Some characteristics of short haul duties are drivers of fatigue. These include:

- multiple sectors
- early starts
- late finishes
- overnight duty
- consecutive duties
- sleep (before and after duty)
Sleep before early starts

The amount of sleep possible before duty shortens with early starts

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Long-haul and Ultra-Long Haul operations

Concern is principally with:

• sleep disturbance (e.g. on layover and on recovery)
• circadian adaptation
• the recuperation provided by in-flight rest including sleep inertia
• Crew composition
ULR Phase III: observed v predicted

Singapore Airlines ULR study 2002 using SAFE version 3.5

- Relief crew - outward flight
- Main crew - outward flight
- Relief crew - return flight
- Main crew - return flight

Predicted fatigue vs. Observed fatigue over time into flight (h).
Recovery after a 10-hour eastward transition

- Pattern of adaptation varies considerably
  - some individuals took more than a week to adapt
- Even the direction of adaptation varied
- The amplitude of the rhythms was much reduced compared with westward travel
The Haj Studies
Concerning the effect of time of day and use of bunks

- A method of operating was introduced which was cost-effective and avoided excessive fatigue
- Crew rotation was implemented on all augmented flights
- Bunks were installed on all the critical flights
- Unique dataset that allowed the impact of flights of a similar duration to be assessed at two-hourly intervals throughout the 24-hour period
Consecutive nights in cargo operations

- Data from cargo operations suggest that the first night is the most fatiguing.
- The trend is reversed after the fourth night.

![Fatigue and Sleepiness Graphs](image)

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Cabin Crew, ATC and Maintenance Engineers

Differences between pilots and cabin crew
- Workload
- Rest period timing
- Rest accommodation

Maintenance engineers
- Mainly overnight work with 12 hour shifts
- No time zone crossings
- Similarities with Air Traffic Controllers
TOOLS FOR MEASURING AND ASSESSING FATIGUE
Fatigue Measurement Scale

**Samn Perelli Subjective Fatigue Scale**

1. Fully Alert, wide awake
2. Very lively, responsive, but not at peak
3. OK somewhat fresh
4. A little tired, less than fresh
5. Moderately tired, let down
6. Extremely tired, very difficult to concentrate
7. Completely exhausted, unable to function

**Other Scales**
- Karolinska sleepiness scale
- Karolinska Probability
- Missed responses
- Vigilance degradation
- Complex vigilance degradation test
- 100 point alertness scale
- Etc.
Tools to measure fatigue

- Interviews, investigations and model analysis after incidents and accidents
- Surveys & Reviews
- Rectal temperature probes
- Sleepiness detection devices
- Fatigue reports
- PVT and other objective performance measures
- Actigraph and EEG
- Diaries
- Melatonin measurements
- Predictive models
- Fatigue Studies

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Fatigue reports

<table>
<thead>
<tr>
<th>Fatigue prior to duty?</th>
<th>Yes / No</th>
<th>How long had you been awake when the event happened? (hrs mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hotel</td>
<td>Yes / No</td>
<td>How much sleep did you have in the 24 hrs before the event? (hrs mins)</td>
</tr>
<tr>
<td>Home</td>
<td>Yes / No</td>
<td>How much sleep you did have in the 72 hrs before the event? (hrs mins)</td>
</tr>
<tr>
<td>Duty itself</td>
<td>Yes / No</td>
<td>Flight deck nap? (Yes / No) If yes, when start end</td>
</tr>
<tr>
<td>In-flight rest</td>
<td>Yes / No</td>
<td></td>
</tr>
<tr>
<td>Disrupt</td>
<td>Yes / No</td>
<td></td>
</tr>
<tr>
<td>Personal</td>
<td>Yes / No</td>
<td></td>
</tr>
<tr>
<td>Other comments</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Actions taken to manage or reduce fatigue (for example, flight deck nap)
Fatigue reports

<table>
<thead>
<tr>
<th>If confidentiality required tick here</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
</tr>
<tr>
<td>WHEN DID IT HAPPEN?</td>
</tr>
<tr>
<td>Duty description (trip pattern)</td>
</tr>
<tr>
<td>Sector on which fatigue occurred</td>
</tr>
<tr>
<td>Hours from report time to when fatigue occurred</td>
</tr>
<tr>
<td>Aircraft type</td>
</tr>
</tbody>
</table>

**WHAT HAPPENED?**

Describe how you felt (or what you observed)

Please circle how you felt

1. Fully alert, wide awake
2. Very lively, somewhat responsive, but not at peak
3. OK, somewhat fresh
4. A little tired, less than fresh
5. Moderately let down, tired
6. Extremely tired, very difficult to concentrate
7. Completely exhausted

Please mark the line below with an ‘X’ at the point that indicates how you felt

alert

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## Fatigue reports

### Why Did It Happen?

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes / No</th>
<th>Additional Information</th>
</tr>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

### What Did You Do?

Actions taken to manage or reduce fatigue (for example, flight deck nap)

### What Could Be Done?

Suggested corrective actions
### Example analysis

<table>
<thead>
<tr>
<th>Analysis</th>
<th>No of instances of reports</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No reference made to roster design</td>
</tr>
<tr>
<td>On Board</td>
<td></td>
</tr>
<tr>
<td>Equipment malfunction</td>
<td>19</td>
</tr>
<tr>
<td>Passenger noise Adults</td>
<td>3</td>
</tr>
<tr>
<td>Children</td>
<td>27</td>
</tr>
<tr>
<td>Airline Management</td>
<td></td>
</tr>
<tr>
<td>Staff Education</td>
<td>2</td>
</tr>
<tr>
<td>Rest policies</td>
<td></td>
</tr>
<tr>
<td>Sick day policy</td>
<td></td>
</tr>
<tr>
<td>Roster design</td>
<td></td>
</tr>
<tr>
<td>Hotel</td>
<td></td>
</tr>
<tr>
<td>Climate</td>
<td>22</td>
</tr>
<tr>
<td>Management</td>
<td>2</td>
</tr>
<tr>
<td>Food</td>
<td></td>
</tr>
<tr>
<td>Personal</td>
<td></td>
</tr>
<tr>
<td>Sleep disorder</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>75</td>
</tr>
<tr>
<td>Grand total</td>
<td>153</td>
</tr>
</tbody>
</table>
PVT for IPad

Pschomotor Vigilance Test

Tap the screen as quickly as you can when the numbers appear inside the rectangle.

Proceed

Practice
Actiwatch
Movement

• An actiwatch or actigraph measures movement using a three axis accelerometer
• Little movement during sleep
Electroencephalograph (EEG)

- Intrusive as involves sticking on electrodes
- Is the ‘gold standard’ for sleep recording
- Since 2001, probably impractical in aviation, unless technology improves
Diaries for Subjective Data Collection
Sleep, Fatigue and Activity

Subjective data gathering iPad app
Circadian rhythm measurements

- Core body temperature measurement by rectal probe was a method that provided useful information on circadian adaptation in the past but now impractical in studies of aircrew adaptation due to metal detectors and increased security.

- Melatonin levels in urine samples can detect circadian shifts but urine collection and storage can be impractical.
Fatigue studies

• Studies useful for
  – validating models
  – Studies of new schedules
  – schedules associated with fatigue reports
  – schedules associated high predicted fatigue from Model output

• Tools used
  – Diaries,
  – Actigraphs
  – EEG (if possible)
  – PVT performance tests (if required)
  – Rectal probes/urine collection
  – Aircrew surveys
Using models

Very quick and productive way to
• Identify hazards
• Measure fatigue levels
• Model strategies to reduce fatigue

BUT
• Models can only do so much!
• Intra and Inter-individual variability
  – response to time-zone transitions
  – ability to sleep during the day
  – ability to remain alert overnight
  – morningness / eveningness
  – age
• Inter-operation variability
  – models could be customised for specific operations
MANAGING FATIGUE
Managing fatigue

• Gain management commitment
• Educate
  – Understand the nature, causes, mechanism and countermeasures to fatigue.
• Measure
  – Use a model to plan rosters and to assess actual rosters
  – encourage use of fatigue reports
  – Use fatigue studies to measure actual fatigue where required

• Analyse: identify and assess risk
• Take action as required
• Measure effects of change
• Assure quality

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Update due 4th to 6th April 2016
ICAO Montreal
An outline of FRMS

Fatigue Risk Management Processes

- Fatigue Hazard Identification
- Risk Assessment
- Manage

FRMS Safety Assurance Processes

- Compliance Investigations
- Evidence-based controls
- Performance Indicators
- Analysis and System Evaluation
- Manage

Effective Reporting

Just Culture

Policy and Documentation

FRMS Promotion Processes

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A Nobel sleepiness detection device

- Alfred Nobel suffered the loss of his brother and several workers at his armaments factory due to a Nitro-glycerine explosion.

- The nitration of glycerine was a risky exothermal process which had to be carefully controlled at 72 deg F.

- If the charge reached 86 deg F it must be dumped into a pool of very cold water to avoid it reaching the temperature at which detonation occurred.

- Process control was by means of a human controller who must never fall asleep on the job.

- Nobel came up with a 19th century solution to his sleepy operators problem.
One legged stool used in nitro-glycerine production
Thank you for listening

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