BAM Prediction Power

A summary of Outputs and SPIs available in the Boeing Alertness Model

The Boeing Alertness Model (BAM) is the now leading bio-mathematical model for aviation in terms of features, performance and validation. This document is a summary of the different outputs available when integrating BAM with an application.

Sleep and Alertness.
The most fundamental output of BAM is obviously periods of sleep/wakefulness and the predicted level of alertness. BAM takes as input a chain of activities plus the properties for that chain. A chain here may be either a crew pairing or a crew roster containing a sequence of activities with start- and end-times etc. Overall chain properties are commute times, habitual sleep length and diurnal type etc that are common for the chain. In pairing construction, as the pairing is shared by many, still anonymous, crew, the company typically assumes properties to be used for their “average” crew member. In rostering however it is possible to pass the actual properties of the individual (for example expressing that “captain Smith has a 2h10m hour commute to work”).

The default output of BAM is alertness expressed on the Common Alertness Scale (CAS) that range from 0 to 10,000 where 0 is the least alert state and thereby the highest fatigue risk. The CAS scale is directly anchor-ed to the Karolinska Sleepiness Scale (KSS) in a way that CAS 0 = KSS 9 and CAS 10,000 = KSS 1. A transformation between CAS and KSS is therefore easily done using the formula below;

\[ KSS = 9 - \frac{CAS}{1250}. \]

BAM will, when being passed a chain of activities, return the predicted alertness at any point in time asked for. The default setting is asking BAM to provide the 50-percentile (median) prediction for top of descent (TOD) on all active flights. As BAM is aware of its own accuracy, it is possible with an argument to instead (for example) ask for the 90-percentile; the level above which 90% of the crew will be. Also the point in time representing a flight is easily configured; for example, a “cabin crew mode” is available using the average alertness throughout the flight instead of using TOD.

On each application call, BAM also responds with an array of the sleep periods predicted, making it easy to use this information for reading out the exact timings predicted for sleep on-set and wake up.

Light conditions.
Controlled by an additional argument in the call, BAM will return the local light conditions at location assuming a great-circle transition during flights. The output in this case is -1, 0 or 1 for night, dusk/dawn and day-time light conditions.

Mitigation strategies
BAM is also able, if initiated by yet another argument in the call, to produce proposed mitigation strategies for a given point in time. BAM will then optimise a sleep/wake pattern and a light-exposure strategy while gauging the effectiveness with the alertness prediction. In this way BAM is able to produce the “advise” as seen in CrewAlert in the mitigation strategy functionality. The output then includes an array of timings to “seek” or “avoid”aspects like sleep, light exposure, caffeine, exercise, communication, hydration, protein-rich meals and carbohydrate-rich meals.

Fatigue Model Components
BAM is capable of returning the activation level of the model sub components; meaning the contribution from the circadian rhythm, sleep homeostasis, sleep inertia etc. More information is available here.

Body Clock Time
BAM continuously predicts acclimatisation, gradually “pulling” a persons body-clock time into local time with a gravitational-like function. BAM can therefore answer back at any point in time with the crew members body-clock time - which is helpful when reasoning upon desynchronisation.

Safety Performance Indicators
The tables below (on the following page) lists the additional safety performance indicators that BAM is able to calculate for easy follow-up and build-up of statistics. These SPIs are both roster and model based and suitable for being tracked for example in the Jeppesen Concert product.
Safety Performance Indicators built into BAM.

The Boeing Alertness Model is able to calculate a large number of different metrics as a function of a chain (pairing or roster) with work/rest activities. The table below summarises the metrics and definitions available. These metrics are all calculated for a user-specifed reference time. The picture directly below illustrates how this reference time (T) and the lead-in period (t) will capture and count various aspects such as block time, working time etc.

<table>
<thead>
<tr>
<th>General Predictive SPIs</th>
<th>Description</th>
<th>Unit</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, KSS, LC</td>
<td>Alertness/KSS/Light Conditions</td>
<td>CAS/KSS/LS</td>
<td>A &gt; 0.61/KSS &gt; 0.63/LS &gt; 1</td>
</tr>
<tr>
<td>EBCT</td>
<td>Estimated Body Clock Time</td>
<td>Time</td>
<td>EBCT = 16:20</td>
</tr>
<tr>
<td>AFR</td>
<td>Absolute Fatigue Risk</td>
<td>AFR</td>
<td>AFR (26:00) = 773</td>
</tr>
<tr>
<td>NFR</td>
<td>Normalized Fatigue Risk</td>
<td>NFR</td>
<td>NFR (26:00) = 34</td>
</tr>
</tbody>
</table>

**SPI in time period breakdowns**

<table>
<thead>
<tr>
<th>SPI</th>
<th>Description</th>
<th>Unit</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>WTI</td>
<td>Working Time</td>
<td>Retime</td>
<td>WTI(16:00) = 71:20</td>
</tr>
<tr>
<td>BTI</td>
<td>Block Time</td>
<td>Retime</td>
<td>BTI(16:00) = 31:20</td>
</tr>
<tr>
<td>IST</td>
<td>Inflight Sleep Time</td>
<td>Retime</td>
<td>IST(16:00) = 6:00</td>
</tr>
<tr>
<td>SOT</td>
<td>Sleep Opportunity Time</td>
<td>Retime</td>
<td>SOT(16:00) = 71:20</td>
</tr>
<tr>
<td>PST</td>
<td>Predicted Sleep Time</td>
<td>Retime</td>
<td>PST(16:00) = 43:10</td>
</tr>
</tbody>
</table>

**Miscellaneous SPIs**

<table>
<thead>
<tr>
<th>SPI</th>
<th>Description</th>
<th>Unit</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIN</td>
<td>Minimum alertness</td>
<td>CAS</td>
<td>MIN(46:00) = 1132</td>
</tr>
<tr>
<td>PFA</td>
<td>Predicted Forced Awakenings</td>
<td>Int</td>
<td>PFA(16:00) = 3</td>
</tr>
<tr>
<td>MSQ</td>
<td>Minimum Sleep Quality</td>
<td>Retime</td>
<td>MSQ(16:00) = 2.45</td>
</tr>
<tr>
<td>TZN</td>
<td>Time Zone Span</td>
<td>Retime</td>
<td>TDZ(16:00) = 2.00</td>
</tr>
<tr>
<td>ASQ</td>
<td>Acclimatization Span</td>
<td>Retime</td>
<td>ASZ(16:00) = 3.16</td>
</tr>
<tr>
<td>SOTF</td>
<td>Sleep Opportunity Time In Darkness</td>
<td>Retime</td>
<td>SOTF(72:00) = 19:20</td>
</tr>
</tbody>
</table>

**Block Time SPIs**

<table>
<thead>
<tr>
<th>SPI</th>
<th>Description</th>
<th>Unit</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTBL</td>
<td>Block Time Below Limit</td>
<td>Retime</td>
<td>BTBL(200:00,168:00) = 3:10</td>
</tr>
<tr>
<td>BTO</td>
<td>Block Time in Darkness</td>
<td>Retime</td>
<td>BTO(168:00) = 21:20</td>
</tr>
<tr>
<td>BTA</td>
<td>Block Time during WOL</td>
<td>Retime</td>
<td>BTA(72:00) = 3:13</td>
</tr>
</tbody>
</table>

**Landing SPIs**

<table>
<thead>
<tr>
<th>SPI</th>
<th>Description</th>
<th>Unit</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>LF</td>
<td>Landings</td>
<td>Int</td>
<td>LF(168:00) = 5</td>
</tr>
<tr>
<td>LBL</td>
<td>Landings Below Limit</td>
<td>Int</td>
<td>LBL(200,168:00) = 2</td>
</tr>
<tr>
<td>LD</td>
<td>Landings in Darkness</td>
<td>Int</td>
<td>LD(168:00) = 3</td>
</tr>
<tr>
<td>LWL</td>
<td>Landings in WOL</td>
<td>Int</td>
<td>LWL(168:00) = 3</td>
</tr>
</tbody>
</table>

**Take-off SPIs**

<table>
<thead>
<tr>
<th>SPI</th>
<th>Description</th>
<th>Unit</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>TF</td>
<td>Take-offs</td>
<td>Int</td>
<td>TF(168:00) = 5</td>
</tr>
<tr>
<td>TBL</td>
<td>Take-offs Below Limit</td>
<td>Int</td>
<td>TBL(200,168:00) = 2</td>
</tr>
<tr>
<td>TD</td>
<td>Take-offs in Darkness</td>
<td>Int</td>
<td>TD(168:00) = 3</td>
</tr>
<tr>
<td>TWL</td>
<td>Take-offs in WOL</td>
<td>Int</td>
<td>TWL(168:00) = 3</td>
</tr>
</tbody>
</table>

**Time beyond limit SPIs**

<table>
<thead>
<tr>
<th>SPI</th>
<th>Description</th>
<th>Unit</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>WTL</td>
<td>Working Time above Limit</td>
<td>Retime</td>
<td>WTL(10:00,168:00) = 2:30</td>
</tr>
<tr>
<td>BTL</td>
<td>Block Time above Limit</td>
<td>Retime</td>
<td>BTL(10:00,168:00) = 4:30</td>
</tr>
<tr>
<td>SOTL</td>
<td>Sleep Opportunity Time below Limit</td>
<td>Retime</td>
<td>SOTL(12:00,168:00) = 3:30</td>
</tr>
<tr>
<td>PTA</td>
<td>Predicted Time Awake Above Limit</td>
<td>Retime</td>
<td>PTA(16:00,168:00) = 11:20</td>
</tr>
<tr>
<td>PSTL</td>
<td>Predicted Sleep Time below Limit</td>
<td>Retime</td>
<td>PSTL(8:00,168:00) = 4:30</td>
</tr>
</tbody>
</table>

For more details on these SPIs, please contact us through frm@jeppesen.com

Learn more about what we offer: www.jeppesen.com/frm