InterDynamics

Navigating complexity. Delivering clarity.

What you need to know about FAID® Quantum

enquire@interdynamics.com

www.interdynamics.com

Contents

1. FAID Quantum Fatigue Assessment Software

InterDynamics' FAID software and biomathematical model (BMM) has been an industry standard for fatigue exposure prediction and fatigue management since its introduction in the late 1990s. In 2016, InterDynamics set a new standard with FAID Quantum, which offers a whole new level of scientifically-verified alertness prediction with a new BMM. FAID Quantum software can be customised according to the users' needs to include:

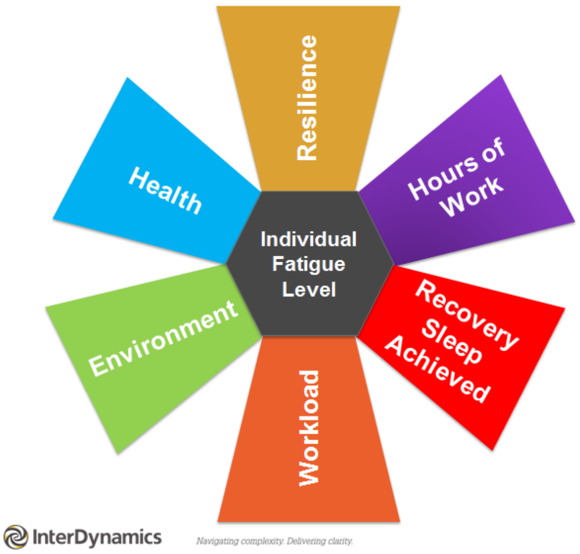
- FAID Score - using the FAID original BMM
- Optional Sleep Prediction and KSS Score - using the FAID Quantum BMM
- Optional time zone adaption (for adjustments when travelling over multiple time zones)
- Optional crew augmentation (for resting pilots on long flights)

The following document includes details of the two biomathematical models and all the software options. Please disregard information that does not apply to your needs and software options.

A user of a BMM is responsible for understanding how it works and its suitability for the purpose it is being used for. Please read BMM Warning for further details.

1.1. Introduction to FAID Quantum and Fatigue Risk Management

Fatigue levels for individuals can be the result of a number of factors including recovery sleep achieved (quality and quantity), hours of work impacts, workload, environment, health issues, and individual susceptibility/resilience to fatigue. Both work and non-work related fatigue factors contribute to safety risks at work, and as a result require proactive management by individuals and the organisation to ensure the risks associated with fatigue are controlled to a tolerable level.



FAID Quantum is a powerful analytical tool based on scientific knowledge which can support the management of hours of work within an organisation's fatigue risk management guidelines. Managing hours of work taking into account fatigue is one of the major elements of a proactive and effective Fatigue Risk Management System (FRMS). Please refer to InterDynamics' website for a discussion on other key elements of an FRMS.

1.2. What you need to know about FAID Quantum

FAID Quantum has been developed using scientific research and knowledge gained over several decades on circadian factors, the effects of shift lengths, timing of shifts and the importance of previous work periods on fatigue and performance. The FAID Quantum software contains two biomathematical models of human alertness response to work and rest patterns associated with trans-meridian travel.

Many regulators and industry bodies recognise that within an FRMS, adequate management of fatigue-related risks associated with working hours involves more than simply limiting working hours. Circadian influences and biological limits to recovery are also important. Consideration of these factors and possible adaptation to time zone changes can most effectively and efficiently be supported by the strategic use of biomathematical models such as those in FAID Quantum.

FAID Quantum has been designed to be a powerful decision support tool based on what can be known with confidence: working hours or duty periods. FAID Quantum uses work hours (in UTC and local time for time zone version) as its inputs to predict the effect on fatigue and performance of different duty periods or work schedules, taking into account rest time and the number of time zones crossed. It models human biology and is best used as a statistically significant indicator of general human response, but not as a predictor of an individual's condition. This is true of all models given that variations in sleep requirements and tolerances do exist within the human population.

FAID Quantum considers the influence of work periods (time of day, length, how recent and time zones travelled) and human biological limits associated with sleep and recovery to determine work-related fatigue scores. FAID Quantum does not consider other personal factors that contribute to an individual's fatigue (i.e. sleep disorders, health, sleeping conditions etc.). However, there is an option to review the fatigue exposure taking into account less than full quality sleep during in-flight rest periods ("augmentation"). Like any biomathematical model, which (by definition) uses general population level data to provide a view of relative fatigue exposures, neither FAID Quantum nor any other model in the market can provide an accurate prediction of an individual's level of fatigue. To try to do so with FAID Quantum or any other fatigue model would be inappropriate. Individuals will always need to be considered and managed as individuals, within any fatigue risk management regime.

FAID Quantum does provide the option for actual sleep obtained to be considered in its calculations, if such data is available. While this enables FAID Quantum to reflect more closely the experience of an individual, the results are still based upon a statistical model representing the general population response to that sleep pattern and not a prediction of the individual's level of fatigue.

1.3. The FAID Quantum Biomathematical Models

No biomathematical model (BMM) can predict work-related fatigue completely, however the likelihood of fatigue impairment associated with different work hours can be reviewed using FAID Quantum Software which includes two discrete BMMs.

Each of these BMMs has its own characteristics, sensitivities and strengths which are described in detail in the following sections.

1.3.1. **FAID Standard BMM**

The FAID Standard BMM was first released by InterDynamics in 1999 and has been a reliable contributor to assessing and managing fatigue risk since then.

A FAID Score is provided, indicating different levels of fatigue exposure for different work hours. The higher the FAID Score the higher the fatigue exposure.

Using formulae and factors developed and validated by Dr Adam Fletcher and Professor Drew Dawson at the Centre for Sleep Research, University of South Australia, the FAID Standard BMM provides a representative score of the hours of work related fatigue exposure of a worker, based on the following biological determinants of fatigue:

a. Time of day of work and breaks
b. Duration of work and breaks
c. Work history in the preceding seven days
d. Biological limits on recovery sleep

This model is structured upon a probabilistic scoring method with weighting scores for each hour of a day for both work and rest. This model is most sensitive to the cumulative effects of consecutive work periods, particularly those at night.

1.3.1.1. Validation and assumptions

The formula and factors used by the FAID Standard BMM have been validated within simulated work environments and field-based situations by the Centre for Sleep Research, University of South Australia.

Provided below are the major assumptions used to develop the FAID Standard BMM.

1. **Recovery** from work-related fatigue by sleeping can be obtained at any time an individual is not working. The amount of recovery sleep assumed at any point in time is a subset of the opportunity available, dictated by time of day and competition from factors such as social pressures (Dean, Fletcher, Hursh, & Klerman, 2007). FAID is a statistical model and considers the changing likelihood and quality of recovery sleep at different times of the day.
2. The FAID Standard BMM takes into account a rolling **7-day history** in its analysis, giving consideration to the accumulating impact of fatigue over the past 7 days. There is no weighting given to time further back than 7 days or 168 hours.
3. Individuals can only recover from fatigue that has been accumulated and cannot store recovery to offset against potential future fatigue (Dawson & Fletcher, 2001).

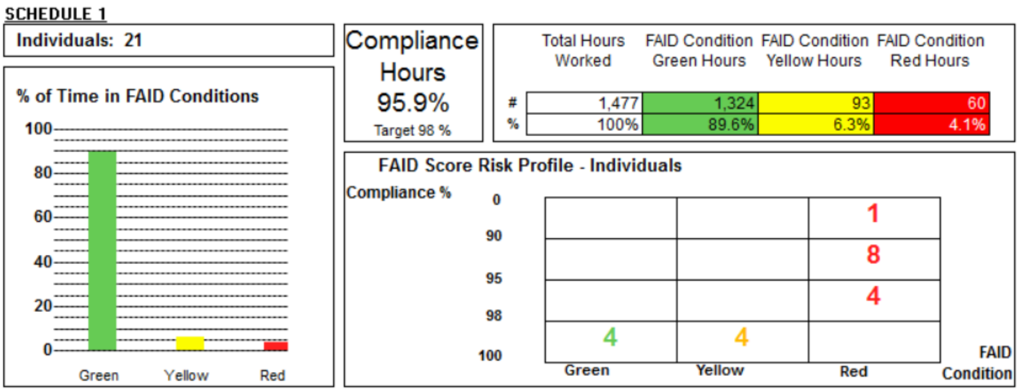
The development and validation of the FAID Standard BMM is well substantiated and has been published in numerous international peer-reviewed journals and books.

1.3.1.2. FAID Score

A standard work week of 40 hours, Monday to Friday, 9 a.m. to 5 p.m., when analysed, results in a peak FAID Score of 41. By comparison, a 40-hour week of 11 p.m. to 7 a.m. night shifts results in a peak FAID Score of 97. A study by Dawson and Reid indicates that scores between 80 and 100 (high fatigue likelihood) are comparable to the level of fatigue-related impairment after 21-24 hours of continuous sleep deprivation (Dawson & Reid, 1997). This result was observed when the sleep deprivation started at 8 a.m. on a Monday, following a standard working week and weekend break. Multiple studies have shown that performance impairment at such a level of sleep deprivation is comparable to that experienced at blood alcohol concentrations of over 0.05% (Fletcher, Lamond, van den Heuvel & Dawson, 2003).

A FAID Score can provide an indication of the likelihood of performance impairment associated with fatigue. Validation studies suggest that work-related FAID Scores correlate very highly with sleep-onset latency, neurobehavioural impairment and subjective sleepiness (Fletcher, 1999).

This score is used by the FAID Standard BMM.



Risk Profile displaying how many individuals peaked in Green, Yellow or Red FAID Score Condition

1.3.2. FAID Quantum BMM

The FAID Quantum BMM was introduced in 2016 and incorporates sleep prediction together with results in the more familiar Karolinska Sleepiness Scale (KSS).

The FAID Quantum BMM sleep prediction is based upon formulae developed by Dr David Darwent in conjunction with Professor Drew Dawson and Dr Greg Roach of the Appleton Institute, Central Queensland University. These algorithms are the best sleep-wake predictors that have yet been published (at the time of writing) in international peer-reviewed literature (Darwent, Dawson & Roach, 2012).

The FAID Quantum BMM is able to determine a predicted KSS Score from predicted sleep periods utilising an implementation of the Three Process Model of Alertness (Akerstedt & Folkard, 1995). The implementation in FAID Quantum BMM does not include the sleep inertia component of that model.

Most importantly, the FAID Quantum BMM allows organisations to see each of the steps in predicting fatigue. That is, the work-rest schedule, the estimated sleep-wake schedule and the resultant fatigue expressed as a KSS Score.

By making the predicted sleep/wake schedule explicit, it is possible to review the degree with which the model is reflecting the real world experience of workers. This creates a direct measurable feedback mechanism for verifying FAID Quantum based on unique organisational data. This is a critical element of audit and compliance of a BMM as required under many regulatory environments.

FAID Quantum also provides the option for actual sleep obtained to be considered in its calculations. See Section 1.7.4 *Actual Sleep*.

The FAID Quantum BMM focusses on the sleep periods consequential to the work periods and is particularly sensitive to sleep pattern disruptions and day-time sleep.

1.3.2.1. Validation

The formula and factors used by the FAID Quantum BMM have been validated by what may be the largest database of quality sleep-wake data in the world, incorporating nearly 15,000 days and nights of data collected by the Appleton Institute, Central Queensland University from various industries (including long-haul aviation) to underpin predictions.

The development and validation of the FAID Quantum BMM is well substantiated and has been published in numerous international peer-reviewed journals and books.

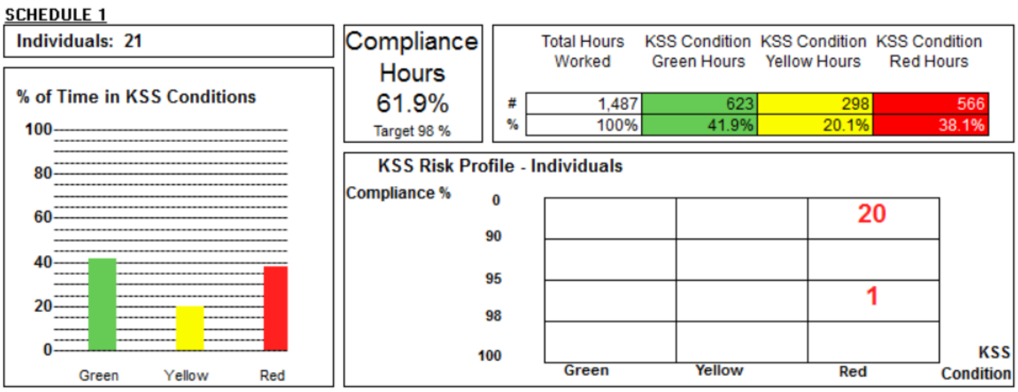
1.3.2.2. Karolinska Sleepiness Scale (KSS)

The KSS is a 9 point Likert scale often used when conducting studies involving self-reported, subjective assessment of an individual's level of drowsiness at the time.

The KSS Scores are defined as follows:

9. Extremely sleepy, fighting sleep
8. Sleepy, some effort to keep alert
7. Sleepy, but no difficulty remaining awake
6. Some signs of sleepiness
5. Neither alert nor sleepy
4. Rather alert
3. Alert
2. Very alert
1. Extremely alert

The KSS has an extensive body of literature linking KSS Scores to actual workplace performance and objective measures of fatigue. The FAID Quantum BMM incorporates the Karolinska Sleepiness Scale, providing predicted KSS Scores, enabling the user to better understand the numeric output aided by the descriptions associated with each score value.



Risk Profile displaying how many individuals peaked in Green, Yellow or Red KSS Condition

1.4. Setting Tolerance Levels

Biomathematical models do not make decisions on which work schedules are most appropriate in specific workplaces. What the models do, however, is provide information that can be useful when decisions about fatigue management need to be made. Tracking KSS & FAID Score results in relation to incident frequency, absenteeism levels, employee sick days or other organisationally meaningful data would allow a clearer illustration of the relationship between hours of work and its related costs.

Hours of work-related fatigue exposure can be limited by allocating work hours within a tolerance level or benchmark score.

As FAID Quantum produces both KSS and FAID Scores it provides the facility for the user to set a **KTL** (**KSS Tolerance Level**) and a **FTL** (**FAID Score Tolerance Level**). Desirable compliance percentages can also be set. FAID Quantum provides reports specific to these settings.

Different Tolerance Levels may be set for specific tasks or roles. A lower Tolerance Level may be set for a higher risk task or role, and a higher Tolerance Level may be set for a lower risk task or role. For a specific task or role, one Tolerance Level may be used for planned hours of work, with the option of reviewing actual hours against a higher Tolerance Level, acknowledging that variances to the plan may occur on day of operations.

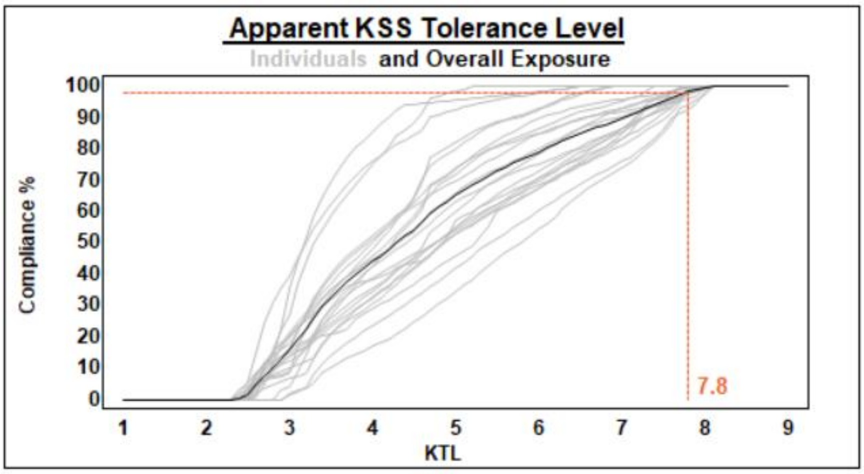
The list below represents an example of a combination of hours of work rules that could fit within an organisation's FRMS guidelines, utilising FAID Quantum software as a key component in the development and audit of fatigue risks associated with hours of work:

- A Tolerance Level of ***x*** (or multiple Tolerance Levels for tasks of various risks)
- Monthly, or roster cycle period compliance to Tolerance Level of all shifts for each individual to be no less than ***y***%
- Individual shifts should not exceed ***z*** points above the Tolerance Level
- Varying levels of actions/controls to be applied as exposures approach/exceed Tolerance Level
- Potential for differing values of ***x***, ***y***, and ***z*** for planned and actual hours.

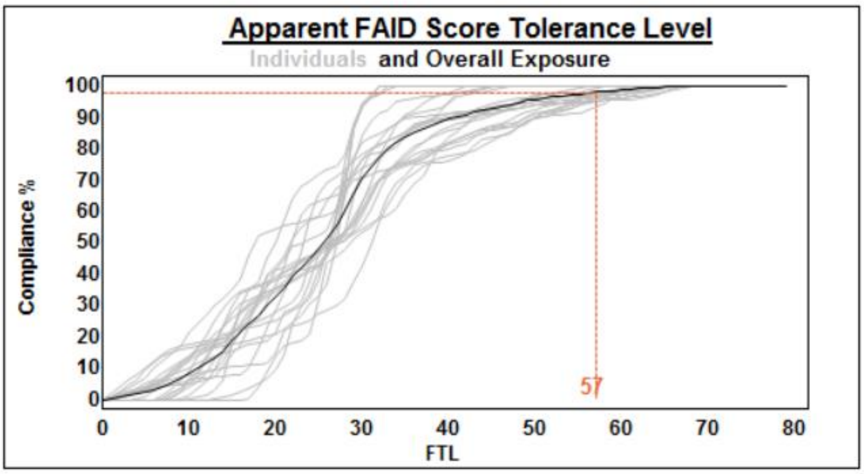
Tolerance Levels and target compliance percentages are usually determined by an organisation after carrying out a Fatigue Hazard Analysis (**FHA**) risk assessment for a specific role[1]. That is, a risk assessment which reviews the hazards of a role when fatigue is present. The risk assessment would take into account (among other things) the current hours of work fatigue exposure analysed using FAID Quantum, including, importantly, the Apparent Tolerance Levels (the overall hours of work fatigue exposure currently being tolerated by the organisation).

For more information on Tolerance Levels, please see Establishing Fatigue Tolerance Levels.

[1] *InterDynamics' risk assessment methodology founded on Zurich's Hazard Analysis methodology aligned with AS/NZS ISO 31000:2009.*



Apparent Tolerance Level - KSS



Apparent Tolerance Level - FAID Score

Understanding and managing an organisation's risk profile with relation to fatigue is an important process within a FRMS that involves looking at multiple areas of exposure. For example, a view of the organisation's fatigue risk profile can be gained by determining the:

- Fatigue risk profile of the workforce through an employee Managing Fatigue Survey;
- Hours of Work risk profile through a FAID Quantum Hours of Work Diagnostic of planned and actual hours worked;
- Workplace hazards in the context of fatigue, associated with specific roles and environmental factors through a Fatigue Hazard Analysis risk assessment;
- Drawing it all together with a fatigue risk grading will provide contextual data on the specific, system level fatigue-related risks for the organisation, and how to manage them effectively within a true risk-management framework.

As can be seen, the use of FAID Quantum in determining the Hours of Work risk profile is one component of many.

1.5. Research into circadian disruptions from changing time zones

The biggest challenge posed by multiple time-zone movement is the time required for the body to adjust to the new time-zone.

Research is not 100% conclusive regarding how adaptation to time zones occurs. There are, however, some principles that are generally agreed.

A number of researchers have proposed that the period of adjustment appears to depend on the direction of travel. Adjustment appears to be faster after westbound flights than eastbound flights (Klein & Wegmann, 1980).

More recent research (Waterhouse, Reilly, Atkinson & Edwards, 2007) has found that adaptation to an eastwards shift of more than 3 time zones takes, on average, two thirds as many days as the number of time zones crossed. That is, a 9E shift takes 6 days; a 6E takes 4 days, etc.

Additional research (Waterhouse, Edwards, Nevill, Atkinson, Reilly, Davies & Godfrey, 2000) found that adaptation to a westward shift of more than 3 time zones takes, on average, one half as many days as the number of time zones crossed. That is, an 8W takes 4 days; a 6W takes 3 days, etc.

Two other key papers (Auger & Morganthaler, 2009 and Eastman, Gazda, Burgess, Crowley, & Fogg, 2005) concluded that the maximum shift eastwards in any 24-hour period is 1.5 hours and in a westward direction is 2 hours.

It is now generally considered reasonable to make predictions of up to 9 hours East and 12 hours West. Between these there is a ‘grey zone’ in which shifts can occur in the opposite direction to the physical direction of travel; for example, a 10 hour Easterly trip by the body can be associated with the circadian sleep/wake rhythm adjusting 14 hour Westward.

Some researchers (Klein & Wegmann, 1980) propose that resynchronisation is best expressed as 50% of the remaining difference between body clock and local time every 48 hours.

It is important to note that not all international travel warrants individuals to try to move their circadian sleep/wake rhythm. For example, the adaptation will be zero or negligible in fast turnaround situations where individuals stay at their destination less than 24 hours before returning to the home time zone. If individuals stay longer than 48 hours at their destination, then adaptation will start to occur. There is a ‘grey zone’ in research knowledge between 24 hours and 48 hours. It is also generally considered that when operations occur within three time zones or less of the home time zone, there is no significant impact due to circadian adaptation.

1.6. How FAID Quantum accounts for circadian disruption caused by trans-meridian changes

The method used for calculating the hours of work fatigue score when time zone changes apply is to calculate the individual hours of work fatigue score for each hour of duty based on the individual's current ‘body clock’.

An individual's initial 'body clock' is based on their starting time zone from the first duty in the work schedule, which is established using the difference between UTC and local time where the first duty commenced. Adjustments to the 'body clock' are then made taking into account the rest time and number of time zones crossed.

1.6.1. FAID Standard BMM

In the FAID Standard BMM the researchers chose to implement rates that differ by direction of travel.

Adjustment begins at the end of the duty, and the magnitude of adjustments is as follows:

- 1.5 time zones per day when traveling in an Easterly direction
- 2 time zones per day when traveling in a Westerly direction

There are additional rules and exceptions for adjustments being made:

1. There is no adjustment to an individual's 'body clock' when the second of two consecutive duties involves a return to the starting time zone of the first duty in the work schedule and either:
   a. the rest period between the two duties is less than 36 hours[2], or
   b. the time zone difference is three hours or less, and the rest period between the duties is less than 48 hours[3].
2. Any duty performed at the rest period location will not prevent rule one (above) being applied. The quickest adjustment to the target time zone will be selected beyond 10 time zone changes (which is not always the direction of travel).

When analysing a work schedule, a work history of 15 days is recommended to best correct an individual's current body clock before the start of the Analysis Period.

When displaying analysis results, if there is a difference of more than three hours between the starting time zone of a duty and the previous duty's ending time zone, then no FAID Score Outputs will be displayed for 15 days after the end time of the previous duty. This action is to provide time for the **circadian sleep/wake rhythm adaptation** to the new time zone, in response to the absent time zone movement information.

1.6.2. FAID Quantum BMM

In the FAID Quantum BMM the researchers chose to implement resynchronisation expressed as 50% of the remaining difference between 'body clock' and local time adjusts every 48 hours.

When analysing a work schedule, a work history of 15 days is recommended to best correct an individual's current body clock before the start of the Analysis Period.

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2 A mid-point of 36 hours has been used within FAID Standard BMM to reflect the length of time when circadian disruption begins to occur when the second of two consecutive duties returns to the starting time zone of the first duty, to accommodate the 'grey zone' in research knowledge between 24 hours and 48 hours.

3 Recognising that circadian adaptation is less likely to occur when the time zone difference is three hours or less.

1.6.3. Comment on differences

While these two methods seem quite different in most cases they lead to differences in assumed ‘body clock’ position, at any given time, of less than 3 hours. This would typically be well within the variations seen between individuals and does not lead to significant differences in the calculated model scores.

1.7. FAID Quantum Assumptions and Features

1.7.1. Assumptions

FAID Quantum uses duty period start and finish times (in UTC and local time for time zone version) as inputs, in determining the work and non-work period to be analysed. In performing its analysis of the work period and non-work periods, FAID Quantum does not take into account the following considerations:

- A reduction in opportunity for sleep when **commute times are greater than 45 minutes between home and work**. Hence, FAID Quantum will overestimate the recovery value of non-work periods in these circumstances. An organisation may wish to extend the shift start and finish time by the amount travelled longer than an hour to account for the longer commute scenario, or extend the sleep buffer in settings.
- **Short breaks within a duty period as non-work periods**. For breaks within a duty period to be included as non-work time they need to be at least 4 hours and/or greater in duration, and quality sleeping facilities must be available (Dean, Fletcher, Hursh, & Klerman, 2007). This means that breaks, such as for meals, are not included as non-work time, as short breaks are unlikely to be long enough for recovery sleep to be obtained. However, see Section 1.7.3 on *Augmentation* below.
- What an individual has actually achieved with regards to **recovery sleep during a non-work period**. FAID Quantum formula and factors provide an estimate of the fatigue exposure typical of the average person based upon statistics gathered from a large sample group. It is not a pure measure of fatigue, and cannot by itself give an indication of whether an individual is fit for work. In the instance where individuals do not use a non-work period to obtain the recovery sleep predicted by FAID Quantum then the fatigue exposure indicated by FAID Quantum might be quite different from that actually experienced by the individual. However, see Section 1.7.4 on *Actual Sleep* below.

1.7.2. Prior History or Initial State of an Individual

At the point of time at which the input data starts there is no information about the prior activity of the individual. The individual may have worked many hours or none, they also may have transited many time zones or none.

While the software can commence to calculate scores from the time of the first work period this is only valid if there was no work performed in the previous seven days and the person’s ‘body clock’ is synchronised with the start location.

If the person may have performed work in the week prior to the start of the data, it is prudent to consider as valid only the results beyond seven days after the start of the data. This is to rule out any influence the undocumented work periods might have on the scores in the first week.

If the person may have changed time zones in the fifteen days prior to the start of the data, it is prudent to consider as valid only the results beyond fifteen days after the start of the data. This is to rule out any influence the undocumented time zone changes might have on the scores in the first fifteen days.

By default, the FAID Quantum software will determine the time of the first work period and set an analysis start date seven days later (fifteen days for time zone version). This may be changed by the user if prior conditions are known and as appropriate recognising the fifteen and seven day periods described above.

1.7.3. **Augmentation**

When using the flight crew augmentation option within FAID Quantum, breaks during a flying duty period can be recognised as a non-work period with the quality of sleep set to ‘Partial’ to indicate the less than full quality sleep during in-flight rest periods compared to the higher quality of sleep achieved with quality sleeping accommodation on the ground. ’Partial’ is by default defined as 50% of normal sleep quality and would normally apply to sleep achieved during in-flight rest. Such a selection would require Class 1 Quality Rest facilities to be available on the aircraft. 50% has only been populated for demonstration purposes.

The percentage of sleep quality represented by the ’Partial’ setting needs to be determined by the operator and can then be adjusted within the software. It should be noted that good quality in-flight rest facilities are essential for “any” quality of sleep to be obtained. An appropriate sleep quality setting can be determined through a scientific sleep study and risk assessment process.

1.7.4. **Actual Sleep**

FAID Quantum also provides the option for actual sleep obtained to be considered in its calculations, if such data is available. While this enables FAID Quantum to reflect more closely the experience of an individual, the results are still based upon a statistical model representing the general population response to that sleep pattern and not a prediction of an individual’s level of fatigue. This also provides a mechanism for comparing calculated KSS Scores for both the predicted sleep/wake and the actual sleep/wake data to permit determination of the significance of any sleep differences.

1.8. Appropriate Use

FAID Quantum is an easy product to use when appropriate training is undertaken. The above points need to be considered when using FAID Quantum, to ensure its most effective and appropriate use in the organisation’s operational context. Please contact us (faid@interdynamics.com) if you would like **training in the context of use and functionality of FAID Quantum**.

We hope that this information assists you as you become familiar with the use of FAID Quantum as one element of a Risk-Based Approach to managing fatigue in your workplace.

The InterDynamics FRMS team.

2. Further Recommended Reading

Below are some documents available from InterDynamics for further reference:

- BMM Warning
- Establishing Fatigue Tolerance Levels

Further articles regarding Biomathematical Models and Fatigue Risk Management can also be found on our website's resources page.

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3.1. FAID Standard BMM References

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