



Practical and contextual use of  
biomathematical models

## Contents

<b>1. Context and use of models .....</b>	<b>3</b>
<b>2. Practical use of bio-mathematical models.....</b>	<b>4</b>
2.1. Introduction.....	4
2.2. What a model will do.....	4
2.3. Bio-mathematical modelling of human fatigue.....	4
2.4. Fulfilling the purpose of the model .....	5
2.5. Conclusion.....	5
<b>3. Understanding bio-mathematical models.....</b>	<b>6</b>

# 1. Context and use of models

*by Tu Mushenko, Senior Fatigue Risk Consultant, InterDynamics Pty Ltd*

In light of the probabilistic nature of models, and the understanding that the fatigue measures provided by any model do not (and cannot) give an absolute measure of fatigue, models cannot be used to detect individual fatigue. Consequently, models cannot therefore be used as a means of testing individual fitness for work.

The correct and most effective application of any bio-mathematical model of fatigue and performance is as an analytical tool, used strategically, within an FRMS. The FRMS should give consideration to the likelihood and consequence of a fatigue-triggered event, and determine adequate controls to manage fatigue-related risks outside of the organisation's risk tolerance level.

An organisation's FRMS can be summarised into four key areas of influence as part of addressing fatigue-related risks:

1. Promoting and fostering a safety culture that recognises fatigue as a safety concern. This can be stimulated by adequate fatigue education and training that focuses on the fatigue-related risks at work as well as for the individual. Appropriate staff engagement and consultation is required to truly foster a cohesive and effective FRMS. Adequate protections and treatments can only be developed through an approach that draws on the experience and feedback of personnel. This approach should therefore be applied to the remaining 3 areas of influence.
2. Implementing protective measures within the working environment from the likelihood and consequence of unacceptable fatigue-triggered events. These are determined as outcomes of a Fatigue Hazard Analysis risk assessment process.
3. Lowering the fatigue exposure provided by the hours its personnel are allocated to work. This can be supported by the use of a bio-mathematical model such as FAID.
4. Proactively investigating fatigue as a contributing factor, as part of incident, accident and near-miss review and corrective action activities.

## 2. Practical use of bio-mathematical models.

*by Peter Page, Managing Director, InterDynamics Pty Ltd*

### 2.1. Introduction

For the past twenty years InterDynamics has built and supplied software simulation models and decision support tools to assist managers, analysts and operators understand and manage their business operations. Over this time we have learned much about the practical implementation of models as decision support tools. This experience has also exposed us to common misunderstandings, and at times inappropriate use of models.

### 2.2. What a model will do

We often find ourselves explaining to clients what a model is for and what they can do with a model. Models will give you a sense of what the futures might look like; but they are "futures", with statistical likelihoods and distributions around the numbers. The validity of a model depends upon the simplifications, and the data upon which the model is built.

Furthermore in creating a model one must be cognisant of the decisions to be supported and the appropriate level of simplification for the intended purpose. These simplifications may make it unsuitable for other purposes.

### 2.3. Bio-mathematical modelling of human fatigue

In creating a bio-mathematical model of human fatigue due to work hours, for the purpose of an employer managing the risk of fatigue related incidents, one must consider the following:

- There is no unit or absolute measure of fatigue.
- The sleep needs and responses to sleep deprivation vary significantly between people.
- An individual's alertness, or conversely fatigue, is better predicted if actual hours of sleep are known.
- For a practical decision support tool to function it must be driven from available data, and in the work environment, actual sleep data is usually not available for past events and not available for future events.
- The model must be good enough to predict the relative fatigue of the average person to a pattern of work hours such that likely higher risk patterns of work may be identified, enabling appropriate risk management assessment and responses.

FAID<sup>®</sup> is a bio-mathematical model that uses available data as an input, i.e. actual or planned work hours. FAID is based upon the biology of the circadian rhythm and sleep. FAID is calibrated against a large data set of work hours and measures of alertness. FAID scores are expressed on an arbitrary scale where a higher score indicates that the average person is likely to be more fatigued and inversely less alert.

## 2.4. Fulfilling the purpose of the model

The purpose of FAID is to be a model that is good enough to predict the relative fatigue of the average person to a pattern of work hours such that likely higher risk patterns of work may be identified, enabling appropriate risk management assessment and responses. The simplifications and functionality of FAID are appropriate to this purpose.

From a pure modelling point of view, I do not believe that FAID needs to be "better" than it is in terms of accuracy of predicting human behaviour and response to sleep and work. The variations between people are likely to be greater than any change in FAID scores achieved through further refinement of the model.

FAID allows users to quickly review roster patterns and broad working arrangements, and determine which particular patterns of work generate higher FAID scores. These higher FAID scores identify where work arrangements may require modification.

FAID's strength is in providing an organisation the ability to perform a diagnostic on over a year's worth of data, encompassing all shifts and work patterns. The results highlight the high points that need to be managed, and possibly eliminated from the system. This capability goes a long way to helping any organisation manage fatigue-related risk.

## 2.5. Conclusion

FAID and other bio-mathematical models should be used as support tools within a Fatigue Risk Management System (FRMS). An FRMS should address systemic risks and consider controls for the general work environment that the average working person is operating within. This is an appropriate use of such models.

While scientists in controlled laboratory conditions may continue to refine fatigue modelling of individuals. There is no viable bio-mathematical model that can predict fatigue in a specific individual in a work place environment. To try to do so with FAID or any other fatigue model would be inappropriate.

It remains highly unlikely that a viable individual model will ever be available to an employer. This is so because the personal data required to calibrate such a model for each individual employee is never likely to be available to employers. Furthermore the use of such a model would likely raise issues of discrimination that the employer would do well to avoid.

NB: In recent years InterDynamics has supplied both logistics and human factors simulation models for multiple projects to such significant clients as BHPBilliton, Alcoa, Rio Tinto, QRNational, Pacific National, Union Pacific Railroad, Norfolk Southern, Hitachi, Orica and EDI. InterDynamics also supplied the logistics planning and simulation software for delivery vehicle scheduling at the Sydney 2000 Olympic Games and the construction on the World Trade Centre site.

## 3. Understanding bio-mathematical models

*Adam Fletcher PhD and Richard Yates FRAeS*

When it comes to managing fatigue-related risk, regulators and businesses have been (and are increasingly) using bio-mathematical models to assist them in predicting fatigue levels. These predictions are often used in conjunction with other factors to make assessments of fatigue-related risk. Such models, including FAID®, have generally been developed after extensive scientific research, validation and industry testing. However, some models have not undergone any sort of rigorous process.

There are several things about bio-mathematical models that should always be borne in mind. Firstly, it should be remembered that all bio-mathematical models have their limitations and it is crucially important that these limitations are understood by everyone who uses them. Secondly, it is important that practitioners understand how any research upon which a particular bio-mathematical model that they use is based relates to their particular operation/context. In this respect, it helps if an operator has an idea of such factors as the demographic details of the research subjects (for comparison with a group of workers), any workload or tasks undertaken by research subjects and the research environment etc.

Thirdly, operators need to understand that, in the fatigue management context, bio-mathematical models generally estimate average fatigue levels using research data gathered from a group of individuals. This means that the results of analysis using general bio-mathematical models in terms of estimated fatigue levels should never be interpreted as applying to any one individual. For this reason such bio-mathematical models should not be the sole input used as a tactical decision-making tool with respect to an individual on (or close to) the day of operations. Particular caution should be exercised in utilising bio-mathematical models for day of operations decisions in organisations with less mature fatigue risk management systems. Within more mature systems, models may give a 'first-cut' view of potential exposures, but individual circumstances and conditions should always be assessed when making go/no-go decisions. It is however entirely appropriate that bio-mathematical models should be used strategically, that is to say when planning or designing rosters or as part of periodic reviews of actual hours, but it is always important that a model's limitations are fully understood by its users.

In light of the above, it is important to be able to answer the following questions satisfactorily. If you can do so it is likely that you and your colleagues will have an adequate understanding of the capabilities and appropriate use of the bio-mathematical model(s) that you use.

If you use bio-mathematical models as part of your fatigue risk management arrangements, what is the scientific basis of the model(s) that you use?

Has the model been validated in an operational context or is it simply marketed as having application in industrial settings?

If the model has been validated, how this was done?

How does the nature of your operation compare with the research parameters and environment upon which the model(s) you use is based?

What are the limitations of the bio-mathematical model(s) that you use?

Are these limitations widely understood in your operation and if so, how do you know?

How do you verify the validity of the data fed into the bio-mathematical model(s) that you use and how reliable are the results? For example, if a model relies on individuals' self-estimates of their own daily sleep, how can you accurately verify their estimates are correct and meaningful in the case of an audit or incident investigation?

On the other hand, if satisfactory answers to these questions cannot be found, then determining the answers (and sharing that knowledge with other model users) should assist in raising the level of understanding of the capabilities, limitations and appropriate use of bio-mathematical models.