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Assessing risks from operator fatigue

Guidance document for the oil and gas industry

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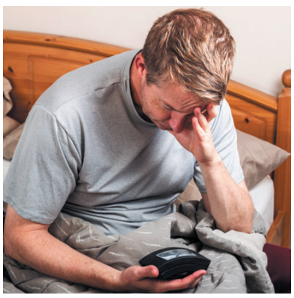

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Assessing risks from operator fatigue

Guidance document for the oil and gas industry

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Executive summary

This document provides guidance on assessing risks from operator fatigue in the oil and gas industry. Designed to support operating companies, contractors and service companies, it complements two existing OGP-IPIECA publications on fatigue risk management: *Managing fatigue in the workplace: A guide for oil and gas industry supervisors and occupational health practitioners* (2007) and *Performance indicators for fatigue risk management systems: Guidance document for the oil and gas industry* (2012).

Assessing risks from operator fatigue: Guidance document for the oil and gas industry describes a structured approach to implementing a fatigue risk assessment (FRA). Recognizing that the impacts of fatigue vary in different situations, this document provides guidance on factors for determining the applicability and acceptability of assessed levels of fatigue. The guide offers a standardized method (with suggested support tools) for documenting and reporting an assessed level of fatigue risk. The approach described could potentially support cross-industry benchmarking.

The *Introduction* describes the scope and structure of the document, and defines fatigue and fatigue risk assessment.

The following section on *Approaches to fatigue risk assessment* identifies three recognizably different situations when an FRA may be required, and discusses the importance of barriers when deciding what level of fatigue might be considered tolerable.

The third section, entitled *A process for performing a fatigue risk assessment,* describes a two-stage approach to preparing for, implementing and interpreting an FRA. Stage 1 is an initial screening, which will help to determine whether a detailed risk assessment, Stage 2, is required.

The section on *Quality assurance* makes recommendations to help deliver consistency and quality in fatigue risk assessments and reporting.

Three Appendices are included. Appendix A provides a model process for assessing whether activities are likely to be at risk from fatigue. Appendix B offers a version of a public-domain tool, the 'Prior Sleep Calculator'. Modified to better suit oil and gas operations, this tool can be used to support decisions to define, at any time, an individual's likely fatigue level and to determine whether action may be needed to reduce the risks associated with that individual's work. Appendix C contains suggestions for data reporting of fatigue risk assessments.

Introduction

This document provides guidance to operating companies, contractors and service companies on assessing risks from operator[1] fatigue in the oil and gas industry[2].

The document complements two other OGP/IPIECA publications on the topic of fatigue risk management:

- *Managing fatigue in the workplace: A guide for oil and gas industry supervisors and occupational health practitioners* (OGP report number 392, 2007) explains the health and safety risks posed by fatigue, provides background information on sleep and the body clock, describes the main causes of fatigue and provides strategies for managing the causes.
- *Performance indicators for fatigue risk management systems: Guidance document for the oil and gas industry* (OGP report number 488, 2012), proposes indicators that can be used to monitor the effectiveness of a fatigue risk management system (FRMS).

The 'Performance indicators' report states that, '*While data-driven decision making is clearly a desirable aspiration, the reality for many companies is that hard data on fatigue are difficult to come by. In most cases, where data are not available, decisions are risk based. An FRMS therefore needs to be properly grounded in assessment of the risks facing the operation or organization*'. The report also indicates that the existence an FRA can in itself be a leading indicator of controls against

1 Throughout the document, the term 'operator' refers to 'employees' as opposed to 'operating company'.

2 The scope and level of detail contained in this document is based on the recommendations from a workshop organized by IPIECA and held in Rio de Janeiro in November 2013.

fatigue. It also proposes measures that can be used to assess the effectiveness of a fatigue risk assessment programme.

This document supports the two reports mentioned above in the following four ways:

- It sets out and illustrates a structured approach to performing a fatigue risk assessment.
- It provides guidance on considerations that should be taken into account in determining whether the assessed level of fatigue can be considered acceptable in different situations.
- It proposes a standardized method of documenting and reporting an assessed level of fatigue risk that could potentially be used to support cross-industry benchmarking.
- It provides some suggested tools that can be used to support the proposed approach.

Definition

Fatigue (mental fatigue) is a progressive decline in alertness and performance caused by insufficient quality or quantity of sleep, excessive wakefulness, or the body's daily circadian rhythm.

A fatigue risk assessment is a structured, evidence-based assessment of the likelihood that fatigue could reduce the ability of an individual who is otherwise fit to work to maintain the levels of attention and cognitive performance necessary to perform an assigned activity to the expected standard during a defined period of time.

Approaches to fatigue risk assessment

The approach to performing a fatigue risk assessment will depend on why the assessment is being performed, and on the scope and complexity of the operations involved. An assessment may be needed to assess the risk of an individual working extended overtime on a particular day. Alternatively, it could be required to assess the risk of operator fatigue in terms of the potential for major accidents at an entire worksite or asset. The situations in these two examples are very different, and although similar factors will need to be taken into account, different approaches to the assessment, involving different levels of detail, will be required for each case. An FRA may be performed by individuals with different backgrounds, experience and knowledge. In the first example, the assessment may be carried out by a local supervisor or a operations manager having considerable operational experience but little in-depth knowledge of the science behind human fatigue. The second example is likely to require a fatigue specialist (see *Competence to perform a fatigue risk assessment* on page 22).

In general, there are three identifiable situations that will require different approaches to conducting a fatigue risk assessment.

1. **Individual:** Assessing the risk that a particular individual may become unfit to work safely over a specific period of time due to fatigue.
2. **Job or activity:** Assessing the risks of fatigue associated with a specific activity or operation being carried out by a defined group of people under the same work arrangements. For example assessing the risk of fatigue associated with a specific job, or planning for an unusually complex or hazardous activity to be performed by a team over a few days or weeks.
3. **Population:** Assessing the fatigue risk that could exist at a whole site covering a range of activities and a diverse workforce.

Defences and tolerability

Assessing whether a given level of fatigue can be considered tolerable requires consideration of other barriers or defences that may be expected to intervene if an operator's performance is impaired by fatigue. A higher fatigue exposure may be considered tolerable if there are adequate additional defences in place.

For example, if a driver who is alone in a car experiences a microsleep there are limited barriers or defences that will intervene to prevent an accident. By contrast, if a control room operator or field operator falls asleep, or if the operator's level of attention is reduced due to fatigue, a number of defences should be available—from alarms to the presence of other people as well as automatic shut-down systems—that may reduce the potential for a serious outcome. An organization may therefore decide to tolerate a higher level of fatigue in control room or field operators than they would for a lone driver.

It should be noted, however, that this argument should *not* be applied if the operator's tasks are explicitly relied on as process safety barriers[3].

[3] Process safety barriers are measures or controls that an organization relies on to mitigate the risk of events occurring involving loss of containment of hydrocarbons or other highly hazardous materials, or of such a loss escalating and leading to significant loss of life, or damage to assets or reputation. Process safety barriers can be mechanical, electrical, human or organizational in nature.

A process for performing fatigue risk assessments

A fatigue risk assessment can be performed efficiently in two stages[4], as described below.

Stage 1: a high-level screening comprising the following three objectives:

1. Define the target workforce and the scope and timescale of operations to be assessed (i.e. the 'assessment unit(s)').
2. Identify whether any of the critical operator activities within each assessment unit are likely to be sensitive to impairment by fatigue.
3. Identify the potential consequences of fatigue leading to significantly impaired performance in any of the activities.

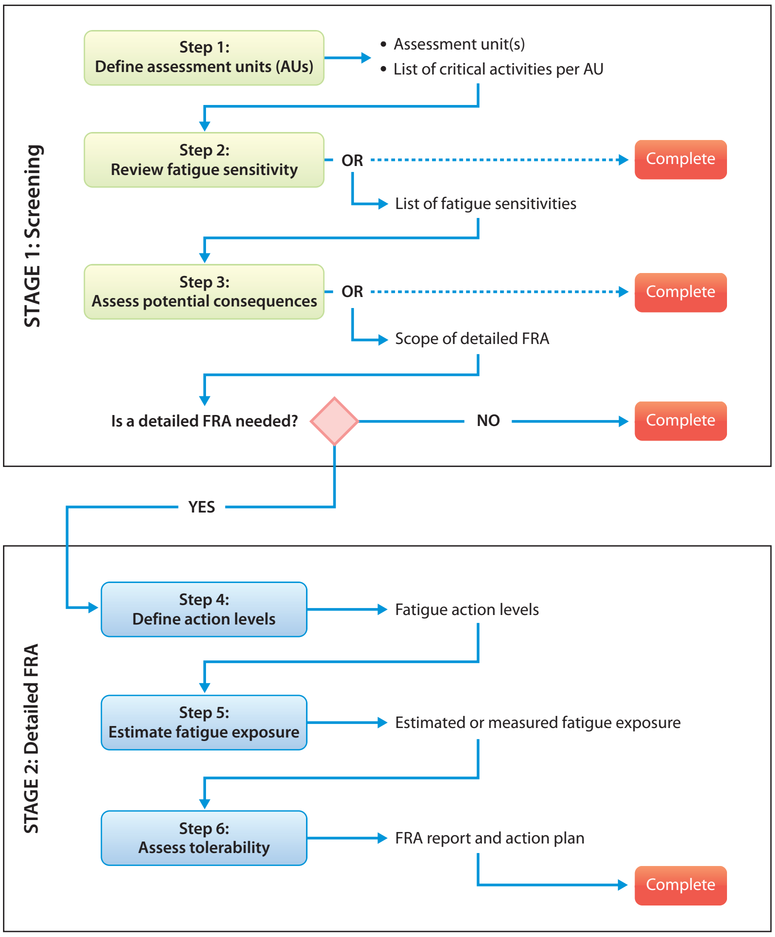
Stage 1 leads to a decision on whether a detailed FRA is needed (Stage 2).

Stage 2: A detailed risk assessment comprising a further three objectives:

4. Define the maximum level of fatigue exposure that would be considered tolerable for the critical activities performed by the assessment units.
5. Estimate the expected level of fatigue exposure.
6. If the anticipated level of fatigue is greater than the level considered tolerable, determine what action can be taken to reduce the fatigue exposure, or what additional controls should be implemented to reduce the risk to an acceptable level.

The two stages are summarized in Figure 1 and explained below.

Figure 1 *Recommended process for performing a fatigue risk assessment*



Most organizations should be able to complete Stage 1 using the guidance provided in this document, drawing on appropriate operational and safety management experience. For relatively simple situations, a competent health or safety professional should be able to perform the more detailed analysis involved in Stage 2, again using the guidance in this document. More complex situations will require greater competence in fatigue risk management.

The six steps involved in Stages 1 and 2 can be completed in different ways dependent on the scope of the assessment, the skill and experience of the assessors, the nature of the tasks and operations being assessed, and the regulatory and legal context of the assessment.

[4] For clarity and simplicity these two stages are set out sequentially. However, where a fatigue risk assessment forms part of a broader human reliability assessment, or if it is led by a specialist in human reliability analysis, the two stages could be conducted in either order.

Furthermore, the scientific knowledge base underpinning understanding and prediction of risks from fatigue is developing rapidly.

For these reasons, this section only describes and illustrates the six steps. It does not try to define precisely how each step should be completed; that is left to the discretion and judgment of the organization responsible for the assessment, suitably informed by this guidance, and by competent people. The appendices on pages 24–32 provide examples of tools that may be useful in completing some of the steps.

Stage 1: Screening

The purpose of the screening stage is to clarify the scope of the assessment and to decide whether there is a need to perform a more detailed analysis. The screening considers the nature of the operations involved, the potential consequences if workers become impaired by fatigue, and the existence of other defences that may be relied on to mitigate the effects of fatigue. Appendix A contains a procedure that may be helpful in completing Stage 1.

Stage 1 may not be necessary if the scope of the assessment is clear, or if the organization believes that the people involved in the activities are at risk from fatigue, and that the consequences of fatigue could be significant. However, Stage 1 should be completed if the organization believes, with no reasonable evidence, either that critical activities will not be at risk from fatigue, or that any fatigue-induced impairment would corrected by other defences

Figure 2 summarizes Stage 1, showing the decisions and outputs from each of the three steps. Note that the figure shows that it is possible for the process to finish at the end of steps 2 or 3, depending on the results and conclusions from those steps.

Stage 1 therefore provides clarity on the potential risk from fatigue that may exist in each assessment unit, and leads to a decision on whether or not a more detailed analysis is required. If a more detailed analysis is considered necessary, Stage 1 should define the scope of that analysis.

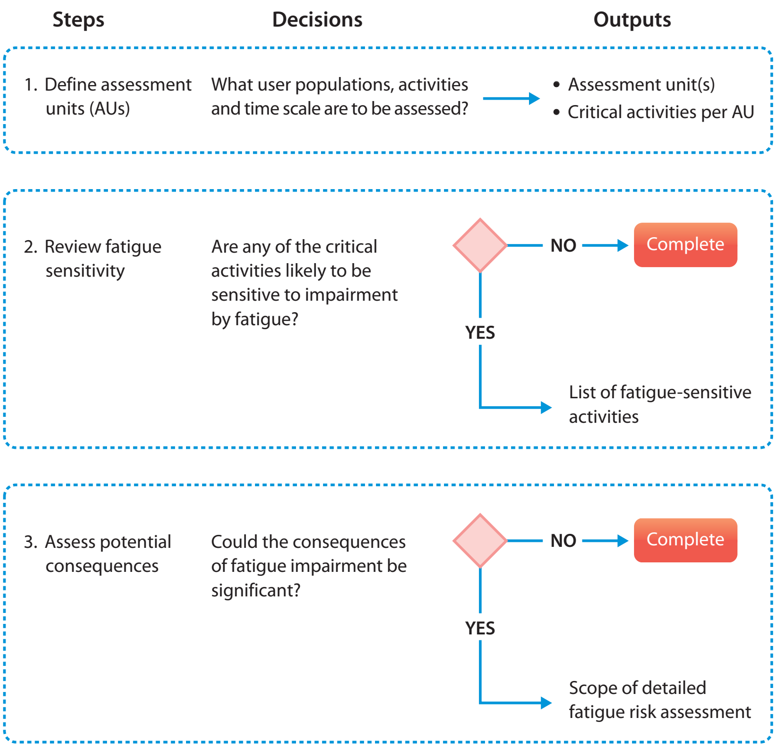
Step 1: Define the assessment unit(s)

The first step is to set the boundaries of the FRA by defining the people or roles to be assessed, and the activities and timescale to be covered. In common with the guidance for performing health risk assessments (OGP-IPIECA, 2006), these are referred to as 'assessment units'.

The basis for grouping roles and operations into assessment units is a matter of judgment, taking account of factors such as:

- the nature of the operations, processes and technologies involved;
- inherent risks;

Figure 2 *Summary of Stage 1 (Steps 1, 2 and 3 of the overall FRA process)*



- work schedules (in terms of daily hours of work in a shift) and rotations (sequences of consecutive work shifts over a period of time);
- working and living arrangements of the workforce (i.e. workers living at home and travelling to work each day may need to be treated differently from those who live in camp or at the asset while on a rotation); and
- geographical location.

At a simple level, the assessment unit could be a particular individual doing a few hours overtime to finish a critical job. The assessment unit in this case would be the named individual, doing the specified work, over the defined time.

Alternatively, the assessment unit could be a small group of people doing a limited range of activities, e.g. driving, monitoring computer displays or doing equipment rounds, over a period of a few weeks when there is expected to be higher than usual workload.

On a larger scale, an assessment unit could include everyone working on, or supporting, an entire worksite or facility over an entire year. In this case the population may need to be organized into a number of discrete assessment units.

For each assessment unit, a summary of the activities that are considered most critical for the purpose of the analysis should be prepared. The degree of 'criticality' in this sense will depend on the purpose of the analysis: this may be process safety, personal safety, environmental control, security, production, reputation or even competitive position in a market[5].

Being clear about the timescale of the operations to be covered is especially important in defining the assessment unit(s). The issues to be taken into account in assessing the inherent fatigue risk over the course of a year can be very different from assessing the risk of someone continuing to work for a few hours. There may also be regional or geographical differences: in operations at high latitudes for example, where there is very little daylight during the winter months, and very little darkness in summer, there can be significant variations over the year in the extent to which the circadian rhythms of shift workers are able to adapt to working at night, with consequences for sleep and fatigue.

Step 2: Assess activity fatigue sensitivity

The purpose of Step 2 is to determine whether any of the critical operator activities within each assessment unit are likely to be sensitive to significant impairment by fatigue. This will be referred to throughout this document as the 'activity fatigue sensitivity'. At this stage it is only necessary to make a high-level judgement: if it is concluded that none of the activities are likely to be sensitive to fatigue, it may not be necessary to take the analysis further.

This decision needs to consider both potential impairment to specific tasks, as well as a generally reduced capability to work, independent of specific tasks.

Task-independent fatigue sensitivity

Many of the effects of fatigue are the consequence of the negative impact of fatigue on an individual's level of energy and/or motivation: this may include a reduction in an individual's ability to pay attention, to attend to detail, to check, question or find out if there is uncertainty, to notice or react to information. This general decline in energy can have an impact on nearly every human activity. Potentially, there is a risk that a seriously fatigued person will perform all activities less well than an alert and motivated individual.

5 A fatigue risk assessment cannot meaningfully be applied at the level of a whole business, unless the business only has a single type of operation that is organized in exactly the same way within a limited geographical region.

Box 1 *Examples of task characteristics that can be especially sensitive to fatigue*

- Monitoring or paying attention to information or events over a sustained period of time
- Reasoning, performing mental calculations, making sensitive judgements or decisions involving complex information, especially where there is uncertainty
- Attending to, or using, detailed information or procedures especially where there is a high reliance on memory or knowledge
- Detecting, acknowledging and/or correctly interpreting alarms, especially when there are multiple similar alarms and understanding the meaning relies on correctly interpreting details (e.g. tag numbers), or where there is a high alarm rate with many false or nuisance alarms
- Being aware of changes in the operational situation or risk exposure
- Assessing or prioritizing risk in a complex multi-risk environment
- Communicating or understanding detailed information in communications

Task-specific fatigue sensitivity

Some types of cognitive and psychomotor tasks are particularly sensitive to impairment from fatigue. The general characteristics of these tasks are summarized in Box 1.

To take driving as an example, task-specific fatigue sensitive activities would include the cognitive demands associated with:

- continuous attention and concentration over an extended period to control the vehicle's speed and position on the road;
- detecting and responding to variations in the road conditions; and
- predicting, detecting and responding to the behaviour of other road users.

Professional drivers also perform many other activities, including journey planning, checking loads, securing the vehicle, refuelling, etc. However, most of these will be less prone to impairment by fatigue than the core driving task.

The critical activities within the scope of each assessment unit should be reviewed to decide whether any of them are likely to rely on any of the characteristics shown in Table 1, or whether there may be other reasons for concern with regard to their potential impairment by fatigue. In some situations[6], this could require a task analysis to be performed. In many cases, however, it will be clear from an understanding of the operation whether there is likely to be a high reliance on fatigue-sensitive task characteristics: driving a car or a crane, monitoring computer displays in a control room or overseeing operations on a drill floor all clearly rely on the ability to monitor or pay attention to information and events over a sustained period of time.

Appendix A includes a possible approach to estimating the activity fatigue sensitivity of different types of activities.

Step 2 therefore involves reviewing each assessment unit, and considering the following three issues:

- Do any of the critical activities rely on characteristics known to be particularly sensitive to fatigue?
- Even if none of the tasks involved are specifically sensitive to fatigue, could there still be significant risk from errors due to reduced motivation as a result of fatigue?

[6] For example complex and infrequently performed start-up/shutdown activities, extensive maintenance on pressurized or H_2S systems, or simultaneous operations (SIMOPS).

- If the answer to both of these questions is 'no', then there will be little justification for continuing the analysis for that unit.

Step 3 should be followed for each assessment unit where the answer to either question is 'yes'.

Step 3: Potential consequences of fatigue impairment

The third objective of Stage 1 is to identify the potential consequences that may result if fatigue leads to significantly impaired performance of any of the critical activities.

Exposure to fatigue in itself, or impaired task performance due to fatigue, is not necessarily a risk. The potential consequence of any given fatigue level depends on a number of considerations, including:

- the hazards associated with the operation (such as the presence of hydrocarbons, high pressure, or sources of energy);
- the activity fatigue sensitivity of the activities involved (i.e. the potential that an activity may not be performed to the expected standard as a consequence of fatigue); and
- the existence of other barriers or defences that could either prevent fatigue leading to task impairment or prevent a fatigue-induced mistake or omission from contributing to an incident.

It is assumed that the organization undertaking the risk assessment will understand the hazards associated with the target workforce and operations. Usually, hazards are assessed using some form of risk assessment matrix (RAM) (Dawson *et al.*, 2011) that provides a standardized rating of the relative risks associated with an operation. Organizations should use whichever RAM process they are familiar with to assess the potential consequence of fatigue-impaired performance. The potential activity fatigue sensitivity should have been assessed in Step 2.

Step 3 involves judging whether, in the event of fatigue impairing the performance of a critical activity, other barriers or defences could be expected to be relied on to intervene and prevent the undesired consequences (see Box 2). Appendix A provides a possible means of assessing the likely strength of other barriers to prevent fatigue impairment from contributing to an incident (termed the 'fatigue barrier factor').

To make this judgement with any confidence, an organization will need to be able to draw on a deep knowledge of local operational procedures and practices.

Box 2 *Assessing the likelihood that interventions may be relied upon to prevent undesirable consequences*

Knowing whether or not barriers or defences exist which could be expected to intervene to prevent undesirable consequences requires a thorough knowledge of the specific operational procedures. For example:

- If a control room operator falls asleep at a console, how likely is it that neither the operator nor anyone else would detect a high level alarm on the console?
- If a field operator who is seriously fatigued mishears a radio instruction and, as a result, attempts to perform an action on the wrong piece of equipment, how likely is it that the error would be noticed and an intervention made before the action was taken?

In both of these examples, the answer will depend on many factors. In the case of the alarm, other defences might include the presence of other people in the control room, whether there is an audible as well as a visual alarm, the location of the alarm panel relative to the operator, and the level of background acoustic noise. For the field operator, the answer may depend on whether they are working alone, and what procedures are in force at the site for confirming actions on equipment before and after they are taken.

Output from Stage 1

The output from the screening conducted in Stage 1 is a decision about whether there is a need to proceed to Stage 2 and carry out a detailed FRA.

Appendix A provides a possible means of combining the likely activity fatigue sensitivity with the fatigue barrier factor to assess the likely level of risk that may be associated with fatigue for the critical tasks involved in the assessment unit.

If there is a case for a detailed FRA, Stage 1 should define the scope of the analysis in terms of at least the following:

- The assessment units to be covered (operations, operator roles and geographical location).
- The work schedules, rotations and living arrangements of the workforce involved.
- The timescale and duration of the activities to be covered by the assessment.

Stage 2: Detailed analysis

The second stage of the recommended approach addresses the remaining three steps in the fatigue risk assessment process:

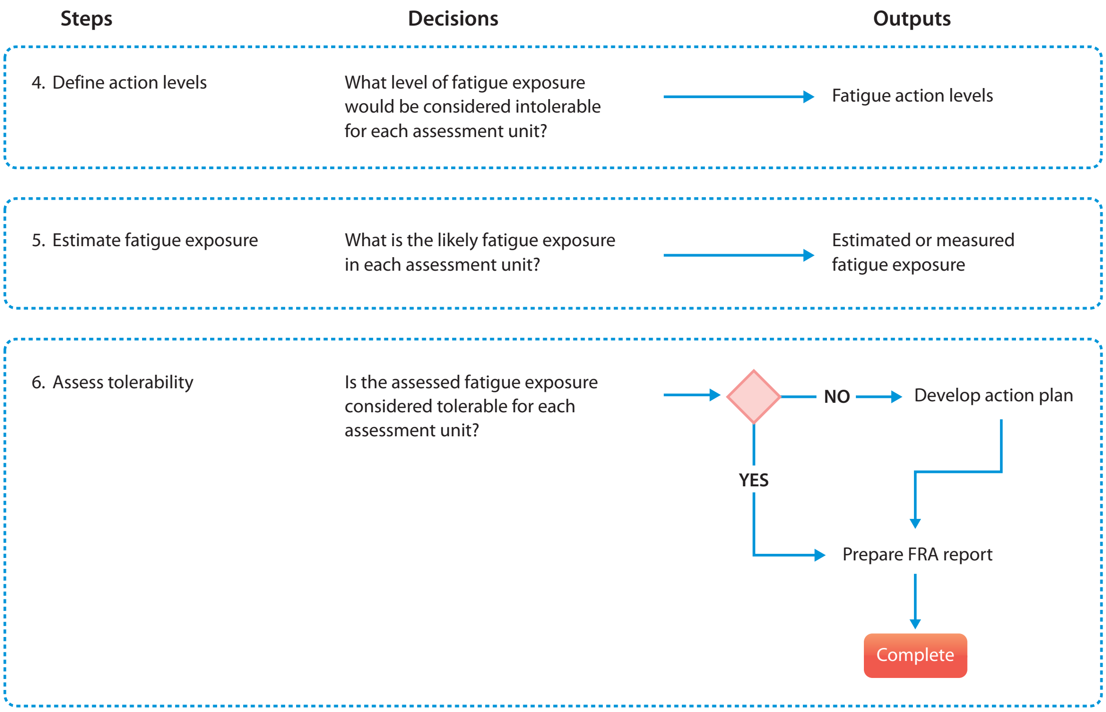
Step 4: Define the maximum level of fatigue exposure that would be considered tolerable for the critical activities performed at the assessment unit(s).

Step 5: Estimate the expected fatigue exposure.

Step 6: If the anticipated level of fatigue exposure is greater than the level considered tolerable, determine what action can be taken to reduce the fatigue exposure, or what additional controls should be implemented to reduce the risk to an acceptable level.

Stage 2 should only be applied to those assessment units and critical activities identified in Stage 1 as justifying a detailed FRA. Figure 3 summarizes Stage 2, showing the decisions and outputs from each of the three steps.

Figure 3 *Summary of Stage 2 (Steps 4, 5 and 6 of the overall FRA process)*



Step 4: Define action levels

The purpose of Step 4 is to determine what level of fatigue can be considered tolerable for the target workforce performing the activities of interest. This can be among the most difficult decisions to make, although it is probably the most important.

There are currently no regulations or other standards that define a level of fatigue that would be acceptable for any operation: existing regulations and standards generally focus on work and rest time, and some require implementation of fatigue risk management systems in certain situations. While these require compliance, and can limit exposure to fatigue risk, none define the level of fatigue considered tolerable for any activity. Each organization must therefore make its own judgement about the level of fatigue risk that it considers tolerable. As far as possible, such judgements should be evidence based, and consistent both with scientific knowledge and industry good practice.

The following considerations should be taken into account when attempting to determine a tolerable level of fatigue:

- It should be set in advance of the assessment of fatigue exposure. Determining tolerance levels after fatigue exposure in a workforce has been estimated has the potential to be unduly influenced, or biased, by operational considerations.
- The tolerance level should, as far as possible, be based on an objective and evidence-based assessment of the potential consequences of a fatigued individual not being able to perform the activity to the standard expected.
- A tolerance level is a maximum level that can be considered acceptable for an activity without additional controls being in place. It does not mean that an individual experiencing the estimated level of fatigue cannot perform the work safely; but it does mean that if the tolerance level is exceeded, additional controls need to be put in place to ensure that the operation is not exposed to an unacceptable level of risk.
- Tolerance levels need to reflect the inherent fatigue sensitivity of the activities being assessed (i.e. the combination of the likelihood that fatigue may impair performance of an activity, and the potential consequence if performance is actually impaired by fatigue). If activities within the scope of an assessment are considered to have different inherent fatigue sensitivities, it may be therefore necessary to adopt different tolerance thresholds.
- Tolerance levels must recognize individual differences in the way people may be affected by a given fatigue level, i.e. they should recognize variability between individuals as well as variability in the same individuals over time. It may not be operationally realistic to base a tolerance level on the worst case (i.e. individuals whose performance may be significantly impaired at relatively low fatigue exposures). It would, however, be risky to adopt a tolerance level that reflects the expected impairment of the population average: this could mean accepting a level of risk while anticipating that up to 50% of the activities may be exposed to a greater level of impairment than is considered to be tolerable.

The way tolerance limits are expressed needs to be consistent with the way fatigue exposure is estimated. If, for example, an assessment of likely fatigue exposure is made using a biomathematical model, the tolerance thresholds should similarly be expressed in the scores produced by the model.

Step 5: Estimate the fatigue exposure

Risk assessment is about predicting the level of risk that is likely to be experienced in a population at some time in the future. There are two general approaches to predicting the level of fatigue that individuals or a population are, or are likely to be, exposed to. These are:

- measuring the level of fatigue that currently exists in an equivalent population, and extrapolating forward to the future population in similar circumstances; and
- predicting the level of fatigue that is likely to be experienced based on knowledge of the factors and mechanisms that cause fatigue, the relevant characteristics of the target population and estimates of their expected exposure to those causal factors.

Fatigue continues to be the topic of a significant body of high quality scientific research, both applied and theoretical. Research is continually revealing better ways of both measuring and predicting fatigue.

Measuring fatigue

Approaches to measuring fatigue range from subjective measures, usually using a validated rating scale (such as the Karolinska Sleepiness Scale) through more objective performance-based measures (such as the Psychomotor Vigilance Task), to electrical and chemical measures of brain activity and biomarkers taken from urine or blood samples. However, currently there is insufficient evidence for the rigour of biomarker use in operational environments.

Technologies are also available that are designed to be worn or attached to the body while people continue to work. Examples include actigraphy[7] which can give an indication of the amount of sleep obtained over a period of time, as well as a range of devices developed to monitor an individual's state of alertness and detect drowsiness, most commonly among drivers.

Measurement of mental fatigue and sleep can provide a good basis for estimating the level of fatigue likely to be experienced in the future (assuming, of course, that no significant change occurs in the meantime). However, gathering the data, interpreting it and extrapolating to the future are specialist activities. Where technically and logistically practical, measures of actual fatigue should be used as the basis for predicting future fatigue. Undertaking these measures is beyond the scope of this recommended practice. Organizations wishing to base an assessment of future fatigue risks on measures of actual fatigue, should use specialists with the skills, knowledge and experience to make valid measurements, and who know how to interpret and extrapolate them.

Predicting fatigue

The science base has generated a good understanding of the causes, mechanisms and effects of fatigue on human performance. Based on that understanding, a variety of biomathematical models are now available that can predict the levels of fatigue likely to be experienced based on factors such as an individuals recent sleep history and the time of day[8]. Table 1 (page 13) summarizes some of the more widely used models for predicting fatigue or estimating an individual's likely state of alertness. In each case, the table gives examples of what the developers of the models claim the scores produced mean. Some regulators (ITSR, 2010) have published comments and expressed views on the interpretation of the fatigue scores produced by some of these biomathematical models.

The scores shown in Table 1 should not, on their own, be treated as thresholds. As discussed in Step 4, deciding what level of fatigue might be considered tolerable depends on many factors, not least the inherent activity fatigue sensitivity, and, as mentioned in Step 3, what barriers are in place to manage the risks of fatigue-impaired task performance.

7 Actigraphs are devices worn on the wrist, which passively collect activity data and use this to give an indication of sleep obtained over a period of time.

8 See Dawson *et al.* (2011) for a review of biomathematical approaches to modelling fatigue.

Table 1 *Examples of fatigue models, predicted fatigue output scores and their interpretation*

Model	Scores	Interpretation
Prior Sleep Calculator (PSC)	PSC Score	Score ranges from 1 to more than 11. See Appendix B for details.
UK HSE Fatigue and Risk Index (HSE, 2006)	Fatigue Index (FI)	An FI of 20.1 equates to the levels of fatigue experienced by an individual working a two-day, two-night, four-off schedule, involving 12-hour shifts starting at 08:00 and 20:00 (DDNNRRRR[9] — i.e. 2 day shifts, followed by 2 night shifts, followed by 4 rest days).
	Risk Index (RI)	An RI of 1 reflects the relative likelihood of an incident or accident for an individual working a two-day, two-night, four-off schedule, involving 12-hour shifts starting at 08:00 and 20:00 (DDNNRRRR).
FAID® (Fatigue Assessment Tool by InterDynamics) (FAID®, 2014)	FAID Score	A FAID score of 40 is equivalent to the maximum fatigue, which would be experienced during a 09:00 to 17:00, Monday to Friday workweek. A FAID score of 80 is approximately 200% of the maximum fatigue that would be experienced during a 09:00 to 17:00, Monday to Friday workweek. A score of 80 has been found to be similar to 21–22 hours of continuous sleep deprivation (when the sleep deprivation begins at 08:00). FAID scores of 80 have been equated to an equivalent level of performance impairment in some psychomotor tasks as has been observed in laboratory subjects with a blood alcohol concentration (BAC) of 0.05% for 17 hours of continuous sleep deprivation (when the sleep deprivation begins at 08:00). A score of 100 has been equated to a BAC of 0.08%, which has been found to be similar to 21–22 hours of continuous sleep deprivation.
FAST (Fatigue Avoidance Scheduling Tool) (FAST, 2014)	Effectiveness	Risk of human factors accidents elevated at effectiveness scores below 90 and increases progressively with reduced effectiveness. Human factors accidents when average effectiveness is less than 77 is considered 2½ times more costly than similar accidents when effectiveness is greater than 90.

9 D = day N = night R = rest day

Biomathematical models that predict the level of fatigue likely to be experienced in a population should, as a minimum, take into account:

- the amount and quality of sleep that individuals working in an operation are likely to get in each 24-hour period;
- how long they are likely to have been awake at the time of work; and
- the effect the body's circadian rhythm is likely to have on alertness levels at the time work is performed.

Some models also take into account variables such as the characteristics and demands of the work being performed, opportunities for rest while awake, as well as the value of short sleep periods ('naps') during the working day. The most sophisticated models claim the capability to make allowance for factors such as circadian adaptation (the way in which the timing of an individual's daily sleep cycle adapts to a change in time zone, or a change in the timing of sleep, for example when working night shift), as well as individual differences.

The ability to measure or estimate the parameters required by any biomathematical model depends on how specific the assessment is to a particular population and work situation. The more specific the assessment is in terms of the individuals involved, the timing of the work, travel and other issues that can impact on the obtained sleep and the time since the last sleep, the more accurate will be the assessed exposure to risk from fatigue.

An especially important limitation of biomathematical models is that they only produce population averages, i.e. they represent a 'typical' or 'average' person. Currently, no models are available commercially, nor are there any under development, that are capable of predicting the fatigue that a specific individual in a specific situation will experience. This can be a significant limitation; while some people will experience less fatigue than is predicted, others will experience more.

This limitation of biomathematical models has been recognized, and is a concern to regulators. For example, in 2010, building on work of the US Department of Transportation Federal Railroad Administration, Australia's Transport Safety Regulator published a Transport Safety Alert concerning the use of biomathematical models of fatigue (ITSR, 2010). Among other recommendations, this stated that:

"*… models that are based on group average data should not be used as the sole basis for decisions on fatigue impacts on individual workers. Individual factors and the risk context should also be examined in each case*". It concluded that: "*When setting criteria for safety risk decision making, rail transport operators should take into consideration the risk context and the basis of any recommended limits that may be associated with particular models.*"

However, if biomathematical models are used appropriately, and if the results are interpreted intelligently, taking account of the assumptions and limitations associated with each, they can provide an effective means of estimating the typical fatigue likely to be experienced in operational settings.

Biomathematical models can be used, where appropriate, to support fatigue risk assessments for oil and gas operations. However, they must be used with caution, recognizing the assumptions and limitations inherent to each model, and there must be recognition that the maximum fatigue exposure in the workforce being assessed may be significantly higher than that predicted by any model.

It is important to note that currently available models vary greatly in their degree of sophistication, their scientific validity, and their suitability for use by non-professionals. In most cases, the mathematical algorithms they are based on continue to be the subject of ongoing research and validation. None of them are perfect, and none are capable of being applied 'off-the-shelf' to the full range of situations experienced in the global oil and gas industry. None of them have been validated for fly-in fly-out operations that are common in the oil and gas industry. They all need to be used with caution.

This document does not recommend any one particular biomathematical model. That decision is left to organizations wishing to adopt a model-based approach.

The Prior Sleep Calculator

The Prior Sleep Calculator (PSC) is a simple means of estimating an individual's likely state of alertness either at a given time or in the near future (assuming they remain awake)[10]. It can be used to support a situational fatigue risk assessment, for example if a situation arises where there is a need for someone who is already at work to continue to work for a few hours beyond his or her rostered hours.

The calculator is based on scientific research that has demonstrated a strong relationship between three factors: how long an individual has been awake, how much sleep they have had in the previous 24 and 48 hours, and their ability to remain alert and to think clearly and quickly. The PSC uses the actual sleep obtained by the individual in the previous 24 and 48 hours, as well as the actual length of time they have been awake. Based on these three parameters, it indicates the individual's likely state of alertness at the time. By allowing for additional waking hours beyond the current time, it is also able to suggest an individual's likely state of alertness in the near future.

Appendix B presents a variant of the Prior Sleep Calculator that may be appropriate for application in the oil and gas industry. (The version contained in Appendix B differs from other versions available in the public domain in the meaning and recommendations that are associated with each level of the scale).

The calculator can help in deciding whether someone is likely to be able to work safely now or at some time in the coming hours. The estimates are useful for most people, most of the

time, but the recommendations must be treated with caution; the calculator is not an exact science and the calculated scores can be no more than a guide to the likelihood of a 'typical' individual being in a fatigued state. Organizations considering using the PSC should take care to ensure that it is used appropriately and for specific situations, and that the advice and recommendations that it provides are consistent with the organization's experience and are appropriate for the activities involved.

Using the calculator does not remove an organization's responsibilities to comply with the law, their own company's health and safety management systems, or other relevant requirements for the safe management of work, including workforce agreements.

Table 2 illustrates how different approaches might be needed in conducting a fatigue risk assessment in a number of different situations.

[10] Note: the PSC can be readily implemented as a simple 'app' or online tool in which the user simply enters the data and the tool provides a recommendation.

Table 2 *The different approaches to performing fatigue risk assessments in different situations*

Situation/decision required	Population to be assessed	Time period	No. of different roles/ activities	Critical or hazardous work?	No. of work schedules	Travel and domestic arrangements	Travel across multiple time zones	Multiple geographical regions	Comments
A drilling supervisor needs to decide whether to allow a worker who has already worked an additional 2 hours overtime at the end of a 12-hour shift to carry on working on a safety-critical task for another 2 hours.	1	next 2 hours	1	yes	1	n/a	no	n/a	Assessment can be made using the Prior Sleep Calculator.
A driver about to start a journey needs to assess the risk that he/she will be excessively fatigued before reaching the intended destination.	1	next 8 hours	1	yes	1	single	no	no	Assessment can be made using the Prior Sleep Calculator.
The manager of a small terminal with a workforce, comprising field operators, technicians, security personnel and control room operators, wants to demonstrate that the risk of operator fatigue in terms of its potential for major accidents is being managed to levels which are as low as reasonably practicable (ALARP).	20	long-term	3 or 4	yes	2	Workforce all live at home and travel for less than 1 hour to work daily.	no	no no	Analysis needs to consider both work schedules separately—i.e. to treat each as a separate assessment unit. Analysis can be conducted using a biomathematical model.
The offshore installation manager of a large production platform wants to demonstrate that the risk of operator fatigue in terms of the potential for major accidents is being managed in accordance with the ALARP principle.	200	long-term	many	yes	1	All the workforce live and work on the platform.	Some key personnel travel long distances to get to the platform.		Analysis can be conducted using a biomathematical model. Roles should be grouped into assessment units according to criticality and inherent task sensitivity of the work involved, with appropriate fatigue tolerance levels.

continued …

Table 2 *The different approaches to performing fatigue risk assessments in different situations (continued)*

Situation/decision required	Population to be assessed	Time period	No. of different roles/ activities	Critical or hazardous work?	No. of work schedules	Travel and domestic arrangements	Travel across multiple time zones	Multiple geographical regions	Comments
An exploration company carrying out essentially the same operation in different locations around the world wants to perform a single fatigue risk assessment that can be applied to all field operations worldwide.	1,000	long-term	many	yes	few	All the workforce live on the platform or in camp while on rotation.	some	yes	One comprehensive analysis should be appropriate for most of the field workforce, although variants may need to be assessed where there are significant differences. A separate analysis will be needed for those individuals who travel across time zones. Assumptions about sleep quality and circadian adaptation should be checked locally in different geographical regions. Roles should be grouped according to criticality and inherent task sensitivity of the work involved, with appropriate fatigue tolerance levels set for different groups.
An operating company carrying out a range of exploration and production operations in different locations around the world wants to perform a single fatigue risk assessment that can be applied to all operations worldwide.	many '000s	long-term	many	yes	many	varied	yes	yes	It is not possible to conduct a single FRA for the whole company. The business should be organized into a number of assessment units that are similar in terms of the key factors and individual analyses performed for each. Generic business-wide fatigue risk tolerance levels should be defined, based on role and activity types, and applied consistently across the different operations.

continued …

Table 2 *The different approaches to performing fatigue risk assessments in different situations (continued)*

Situation/decision required	Population to be assessed	Time period	No. of different roles/ activities	Critical or hazardous work?	No. of work schedules	Travel and domestic arrangements	Travel across multiple time zones	Multiple geographical regions	Comments
A specialist contractor who supplies a rapid response service involving flying technical specialists from Northern Europe to worldwide locations at short notice is considering a change to work practices and wants to assess the risk that the specialists will experience significantly more fatigue at the worksite compared with current arrangements.	<100	long-term	few	yes	Few—all unpredictable, short-notice	All workforce is office-based, live at home and travel to the worksite as needed. Living arrangement at site is highly variable.	yes	yes	Because of the unpredictability, the short notice and the variability in multiple time zone travel requirements, the analysis could best be performed using a number of scenarios representing typical and demanding situations.
The manager of a road transport operation wants to assess the fatigue risk if changes are made to the shift schedules for a small team of tanker drivers working from the same urban location; the proposed changes would result in the drivers starting work 2 hours earlier than they do at present.	<20	long-term	1	yes	1	All drivers live at home and have <1 hr travel to/from the depot.	no	no	Drivers can be treated as a single assessment unit. The assessment could be carried out using a biomathematical model. The tolerance level should be appropriate for driving tasks.

Step 6: Define action plan

The final step in Stage 2 is to document the analysis and to determine whether action is needed to ensure that the risk from fatigue is managed to a level that can be considered to be tolerable for the operations assessed. This involves using the data gathered in Steps 4 and 5 to answer two questions:

1. Does action need to be taken to reduce the fatigue exposure for this target workforce to a level that can be considered tolerable?
2. What additional controls should be implemented to reduce the risk to a level that can be considered tolerable?

Table 3 *Recommended contents of a fatigue risk analysis report*

Section	Subsection	Documents
Introduction		The purpose of the analysis and the reasons why it was performed. Decisions to be supported by the analysis.
Assessment units	Assessment units	Assessment units and critical activities.
	Fatigue sensitivity	Critical activities considered potentially sensitive to fatigue for each assessment unit. Potential consequences if fatigue should lead to significantly impaired performance. Barriers considered likely to mitigate the effects of fatigue.
Work and sleep	Work schedules	Work schedules, rotations, rest days, overtime, etc. for each assessment unit. Details in the Appendix.
	Work intensity	Details and assumptions about work intensity and rest opportunities (including napping) during work shifts.
	Living arrangements	Daily travel, living and sleeping arrangements. Travel before and after extended rotations as well as assumptions about sleep obtained during travel.
Fatigue exposure	Method	How fatigue exposure was estimated.
	Assumptions	Assumptions made in preparing the estimated fatigue exposure. Known limitations in the assessment method.
	Tolerance levels	Fatigue tolerance level(s) adopted. By critical activity and assessment unit (if necessary).
	Results	Estimated fatigue exposure for each assessment unit.
Conclusions	Interpretation	Comparison of estimated fatigue exposure against defined fatigue tolerance level(s) for each critical activity.
	Recommendations	Action plan to reduce fatigue exposure or provide additional controls to allow increased fatigue tolerance level(s).
Appendix	Work schedules	Details of work schedules, rotations, etc. used in estimating fatigue exposure. (See Appendix C of this Good Practice Guide for recommended details to be recorded.)

The assessment of tolerability should be made in the context of the total risk profile, i.e. there are situations where the safest, lowest risk option might be to accept a higher threshold for acceptable fatigue, recognizing that the overall risk profile for an operation will be reduced. An example would be a decision to carry out maintenance on a producing asset overnight, recognizing that there will be fewer people working, and the risk of interference or distraction from events associated with simultaneous operations is reduced.

The output from Step 6 is a documented fatigue risk assessment report including, if appropriate, a recommended action plan. To encourage consistency of reporting, and to provide the potential for future benchmarking, FRA reports should follow a structure consistent with the list of contents outlined in Table 3 and supported by Appendix C in this guidance document.

Quality assurance

Oil and gas operations are highly diverse, and can be extremely challenging to both people and technology. They can be located in very different locations and geography. Their workforce and support personnel may be drawn from highly diverse cultures. They may also involve wide ranging working, living and travelling conditions. For these reasons, conducting a valid assessment of the potential risks from fatigue can be complex and technically demanding. It is neither realistic nor practical to try to provide simple guidance to non-specialists in an effort to overcome these and other difficulties.

Experience shows that there are many reasons why an FRA may be of limited technical or scientific validity. Examples include:

- A lack of clarity within the initiating organization about the exact nature of their concerns, i.e. what is really meant by the term 'fatigue' and, therefore, what is to be assessed. Most commonly, a lack of clarity arises when fatigue due to insufficient sleep is confused with either physical or mental tiredness or exhaustion caused by the intensity or duration of work, or by stress or other psychological responses to work, social or personal pressures.

- Not taking adequate account of the wide range of factors that can contribute to exposure to fatigue, for example, only taking account of time when operators are actually actively working, and not allowing for the total time awake or time required for travel to and from a worksite.
- Using biomathematical models without an adequate awareness of the many assumptions that can limit the application of the algorithms to operational situations, or without a proper understanding of the meaning of the results produced.
- Treating estimated population averages produced by biomathematical models as representing the full range of experienced fatigue and potential performance impact, i.e. not taking account of individual differences, either between different people, or in the same person on different occasions.
- Extrapolating knowledge or data that has been found to be valid in one operational context or for a particular population (who may have special characteristics in important ways, such as pilots or the military) to very different situations or populations. For example extrapolating research evidence about adaptation to night working generated from an operation at a very high latitude in winter months to a different type of operation at a temperate location in summer months. (The importance of the difference in latitude being the impact of exposure to natural daylight on circadian adaptation).
- Making unrealistic assumptions, often with no evidence, about the value of other defences in limiting fatigue exposure, or mitigating the likelihood of a fatigue-induced error actually leading to an event. An example would be an asset where the workforce has a lengthy bus ride to and from the site each day. Because it is known that many people regularly sleep on the bus, the analysis assumes, incorrectly, that all workers sleep on the bus every day and that the sleep obtained has recuperative value equivalent to sleep obtained in bed.

While every attempt should be made to ensure that an analysis is grounded in scientific evidence and best practice, it is often necessary for analysts to make assumptions that go beyond what is accepted as established knowledge by the scientific community. The single most important safeguard to assuring the quality and validity of an FRA therefore lies in assurance of the competence of those individuals tasked with performing and interpreting an analysis.

Competence to perform a fatigue risk assessment

Currently, no professional body provides any assurance of the technical or professional competence of individuals offering to conduct fatigue risk assessments. Further, biomathematical models are easy to acquire and the simplicity of the interfaces makes it relatively easy to enter data and generate fatigue predictions. This raises the risk that individuals tasked with performing an assessment may lack the background necessary to understand the range of factors that need to be considered, what the data produced by a model means, or the limitations and assumptions inherent in those data.

A large, global community of researchers, academics and practitioners are actively involved in various aspects of sleep, sleep medicine and fatigue. Their interests are represented by a range of professional bodies and high-quality scientific journals that support professional development and the sharing of knowledge. A range of post-graduate and other professional training courses are available which cover different aspects of sleep science and fatigue. In most cases, these courses are of high scientific quality, concentrating on aspects of sleep science and/or sleep medicine. A small number of professional courses concentrate on the operational aspects of the effects of fatigue on human performance, and on the management of fatigue in the workplace.

Considerable knowledge and experience is needed to perform a valid FRA. Despite the community of sleep scientists and practitioners and the professional organizations and communities that support them, there is as yet no simple means for OGP-IPIECA member companies to be confident that a particular individual will possess the experience, skills and competence to perform a valid FRA for their operations. If the necessary expertise is not available in-house, external resources should be identified to provide support with the appropriate background, either from academia or consultancies. For an oil and gas operation, anyone engaged to facilitate Stage 2 of the approach set out in this document should have capabilities/qualifications that meet the following criteria:

- a degree or higher level qualification in a relevant Human Science (such as Psychology; Human Biology; Occupational or Sleep Medicine, etc.);
  AND
- experience in operational aspects of fatigue risk management (probably more than three years);
  AND
- sufficient relevant industry experience (this may be replaced if the analysts are closely supported by individuals with significant industry experience);
  AND
- either;
  - experience leading fatigue risk assessments for a variety of different types of operation;

  or
  - experience in supporting or performing fatigue risk assessments under supervision;

  AND
- membership of a recognized professional body specializing in fatigue, sleep science or sleep medicine.

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Appendix A: Estimating potential task sensitivity to fatigue impairment

This appendix sets out a three-step procedure that may, if no better approach is available, be used to support an assessment of the possible fatigue sensitivity of critical tasks within the scope of a fatigue risk assessment.

Step 1: Rate the possible activity fatigue sensitivity of the critical activities identified in each assessment unit.

Step 2: Estimate the potential strength of other controls or defences that may prevent a fatigue-impaired task performance from leading to an undesirable consequence.

Step 3: Combine the results of Steps 1 and 2 to produce an assessment of the risk that significantly fatigued-impaired operators could lead to undesirable consequences.

Four hypothetical examples of different types of activities are presented below to illustrate how the procedure may be applied. These are purely illustrative and are not meant to be representative of actual assessments performed by OGP-IPIECA member companies.

Example 1: Fork lift truck operator

The first example is an assessment of the risk of fatigue affecting the ability of a fork lift truck driver to work safely.

Driving a fork lift truck safely requires the operator to maintain a high level of awareness of people and elements in the world around the routes driven. It can also require close monitoring and control of loads at height above the drivers' head. However, journeys are generally short and the driver is not usually expected to maintain continuous attention at any time for more than a few minutes between stops.

Example 2: Field operator tasked with closing a manually operated valve

The second example is an assessment of the risk of fatigue impairing the safety of field operator activities. The specific concern is that fatigue may cause an operator to misunderstand an instruction and take action using the wrong piece of equipment. The task of correctly understanding a radio instruction requesting the operator to use a specific piece of equipment is used as the basis for this example.

A field operator receives a radio communication from the control room asking the operator to close a manually operated valve. There are three identical units in the operator's area, and each unit has six manual valves. Valve tag numbers are similar, comprising a string of nine alphanumeric characters, with different units identified by alphanumeric codes, and valves identified by the least significant digit in the tag number (e.g. note the difference between pumps numbered P124321 and P124322). Labelling of the units does not correspond to the layout of the units along the walkway (i.e. units are labelled A, C, B in sequence). The numbering of valves is consistent across the three units, but does not follow the sequence in which they are physically encountered when walking round the units. (i.e. if the operator walked clockwise round the unit, the valves would be encountered in the sequence 1, 4, 3, 6, 5, 2).

Example 3: Control room operator—modern, highly automated system with large control team

Control room operators need to maintain a high level of situational awareness across the whole of their span of control for the full duration of their shift. The third example is an assessment of the effects of fatigue on a control room operator in a modern, well-designed control room with a relatively high manning level.

The task demands placed on control room operators depends on the nature of the operation and the level of automation involved, as well as on factors such as the quality of the control room design, and manning levels. However, operators are usually expected to be aware of trends in operational parameters over time, to detect, understand and often respond to high numbers of alarms, and to know when and how to intervene in the event of unexpected situations. They are expected to know and to be able to quickly recognize a large number of scenarios requiring them to implement predefined operating procedures quickly and accurately.

A key part of their role involves both making and responding to voice communications, both face-to-face and via radio or phone. These communications include requests for detailed technical information, as well as task instructions.

In this example, the control room operator is part of a team of operators. Two operators man each workstation. There are two levels of supervision, and at least one of them is present in the control room all of the time. The control system is modern and sophisticated, with advanced graphics designed to support high levels of situation awareness, and with a well designed visual and audible alarm system having a low alarm rate and very few false alarms. The control room is well designed with all critical information within a comfortable viewing arc. All displays are well positioned and the operators rarely have to turn their back on key information sources. The occurrence of new alarms at any console is made visible from across the control room by the use of alarm lights on extended vertical poles.

Example 4: Control room operator—one-man control room with less automated system

The fourth example concerns an asset with a single-person control room, with very low manning and dated technology. There is a high alarm rate, including many false alarms. There are numerous display screens spread across the control room, some behind the operators back, and there are many audible alarms. Operators often disable the audible alarms due to the high false alarm rates. The control room is rarely visited by anyone else; the operator works alone most of the time.

There are frequent radio communications both locally as well as from remote sites. Because of the layout of the control room, the operator spends a lot of time working on a work surface that does not give a good view of the main screens.

The example in this case assumes the operator is on the third consecutive night shift. The concern is whether the operator would fail to detect, interpret and respond correctly to a series of critical alarms following an unexpected process upset.

Step 1: Estimating the activity fatigue sensitivity

For each example, the rating scale in Table A1 could be used to estimate the activity fatigue sensitivity of the critical tasks involved based on the extent to which they rely on different perceptual/cognitive characteristics.

Step 1 involves selecting a value from Table A1 that reflects the greatest extent to which any of the critical activities within each assessment unit are thought to rely on any of the task characteristics shown. Only a single score should be selected—i.e. if multiple task characteristics are involved, it is the highest score that should be selected. The activity fatigue sensitivity rating for the assessment unit will be the highest score for any of the critical activities identified for that unit.

Table A1 *Inherent task fatigue sensitivity (ITFS)*

		Relative extent to which task characteristic is relied on for incident free performance				
Task characteristics		Not at all	Low	Moderate	High	Very high
A	Continuously monitor or pay attention to information or events over a sustained period of time.	0	0.25	0.5	0.75	1
B	Reasoning, mental calculation, judgment, risk assessment or decision making involving multiple variables.	0	0.25	0.5	0.75	1
C	Attending to or using detailed information or procedures, especially where there is a high reliance on memory or knowledge.	0	0.25	0.5	0.75	1
D	Detecting, acknowledging and/or correctly interpreting alarms, especially when there are multiple similar alarms and where understanding the meaning relies on correctly interpreting details (e.g. tag numbers), and there is a high alarm rate with many false or nuisance alarms.	0	0.25	0.5	0.75	1
E	Maintaining awareness of change in the operational situation or risk exposure.	0	0.25	0.5	0.75	1
F	Assessment or prioritization of risk in a complex multi-risk environment.	0	0.25	0.5	0.75	1
G	Communicating or understanding detailed information in communications.	0	0.25	0.5	0.75	1

Example 1: Fork lift truck operator

The task is identified as relying on task characteristic A, to a moderate or high level, and is therefore assessed as having an overall activity fatigue sensitivity of 0.75.

Example 2: Field operator tasked with closing a manually operated valve

This task is identified as relying on task characteristics C and G, both to a very high level. The activity is therefore assessed as having an overall activity fatigue sensitivity of 1.

Example 3: Control room operator—control team

The control room operator's job is assessed as relying on all seven task characteristics identified in Table A1. However, consideration of the high level of automation and a well-designed alarm system, means that only task characteristics B and G are assessed as having a fatigue sensitivity of 1, while characteristics A and E are assessed as being high, and C and D are considered moderate. The overall activity fatigue sensitivity of this operator role is therefore considered to be 1.

Example 4: Control room operator—single operator

As with Example 3, the panel operator's job is assessed as relying on all seven task characteristics identified in Table A1. Because of the more dated technology, the high alarm rate and high false alarm rate however, all of the characteristics are assessed as having an activity fatigue sensitivity of 1.

Step 2: Fatigue barrier factor

Step 2 involves assessing the strength of other controls or defences that may either prevent a fatigue-induced error being made on a critical activity, or would detect and correct it before an undesirable event could occur.

For each of the activities identified in Step 1 as having activity fatigue sensitivities greater than 0, a relative rating value should be selected from Table A2 that best reflects the estimated strength of the other defences.

Table A2 *Fatigue barrier factor (FBF)*

Level	Defences against fatigue-induced impairment	Value
0	No other defences. If the individual does not act or makes an error and does not self-correct, there is nothing else that will prevent an incident.	1
1	One other defence or opportunity to intervene, relies on the performance of other people.	0.75
2	More than one other defence or opportunity to intervene, all reliant on performance of other people.	0.5
3	At least one automatic defence that does not rely on human performance.	0.25
4	At least two other automatic defences that do not rely on human performance.	0

Example 1: Fork lift truck operator

The fork lift truck driver works as part of a small team, with a team leader always present at the worksite, although effectively working alone when the truck is in motion. There are no collision avoidance alarms or instruments to indicate the stability of loads at height; control and safety relies to a very large extent on the driver's attention and vision. Audible alarms can alert others to the presence of the truck, but do not alert the driver to obstacles or people in their path.

If the driver's behaviour indicated the likelihood of high levels of fatigue, this would be recognized by the supervisor or the driver's colleagues. Barrier strength is therefore assessed as Level 1, and is given a value of 0.75.

Example 2: Field operator tasked with closing a manually operated valve

The field operator works as part of a shift team, although each operator works alone in their respective area. There are no radio protocols requiring operators to use controlled language to deliver critical information, or to speak-back instructions to confirm that they have been correctly understood. There is no procedure requiring the operator to confirm with the control room what action they are about to take, or what equipment they are about to use to take action.

The tag numbers are inherently confusing: there is nothing to prevent the operator misreading a tag number.

If the operator attempted to close a manually operated valve on a unit that was in operation and under pressure, the valve would probably be stiff due to the pressure in the system. However, a fatigued operator may not recognize the stiffness as an indication that they are acting on the wrong equipment. Furthermore, valves that are not maintained well are frequently stiff. It cannot therefore be assumed that the operators would themselves identify that they were attempting to close the wrong valve.

The panel operator is able to see from the control system's human-machine interface when a valve has been manually moved. This relies on them watching the correct screen and graphic object; the three units each have a separate graphics page and they cannot be viewed simultaneously.

In the event that the operator did close the wrong valve on an operating unit, the change in pressure would cause the valve to automatically trip (reset) with an alarm being raised in the control room, to protect the unit from damage or more serious consequences.

In terms of process safety, the trip is considered an automatic defence although a response to the alarm relies on human performance. The defences are therefore assessed as Level 3, and given a score of 0.25.

Example 3: Control room operator—control team

In the third example, there are a variety of defences that could reasonably be assumed to intervene in the event that an operator was sufficiently fatigued that his or her performance was affected. It is considered to be highly likely that the other people in the control room—especially the second operator at the panel, and the two levels of supervision—would detect indications of fatigue in an operator. A well designed human-computer interface and alarm system—including new visual alarms which are clearly visible from anywhere in the control room—should reduce the potential for critical changes being missed. Having other people around should also help to diagnose events and ensure that sound decisions are taken before interventions are made.

However, all of these defences rely on other people. They are therefore assessed as being Level 2, and given a score of 0.5.

Example 4: Control room operator—single operator

In the case of the single operator control room, there are no other defences that could be relied on to ensure that a fatigued operator will either notice or correctly interpret and act on the unexpected alarms. Barrier effectiveness is therefore assessed as Level 0, and given a score of 1.

Step 3: Fatigue task sensitivity

The third step simply involves multiplying together the ratings from Steps 1 and 2 to determine the *fatigue sensitivity* of the activities being considered. The following matrix can be used to rate the likelihood that each of the critical activities covered by the fatigue risk assessment will be sensitive to significant impairment by fatigue:

ITFS x FBF	Fatigue sensitivity
< 0.2	Low
0.2–0.49	Moderate
0.5–0.74	High
0.75>	Very high

Table A3 illustrates the results of applying this step for the four hypothetical examples.

Table A3 *Calculation of fatigue sensitivity for the hypothetical examples*

Example	Step 1 Inherent task sensitivity (ITS)	Step 2 Fatigue barrier factor (FBF)	Step 3 Product	Step 3 Fatigue sensitivity
Fork lift truck driver	0.75	0.75	0.56	High
Field operator (safety)	1	0	0	Low
Field operator (reliability)	1	0.75	0.75	Very High
Control room operator—control team	1	0.5	0.5	High
Control room operator—single operator	1	1	1	Very high

Appendix B: The Prior Sleep Calculator

The Prior Sleep Calculator (PSC) referred to earlier in this document can be used where there is a need to estimate the likely state of fatigue of a particular individual at a specific point in time.

The recommendations given by the calculator must be treated with caution: the calculator is not an exact science and the calculated scores can be no more than a guide to the likelihood of a 'typical' individual being in a fatigued state. Using the calculator does not take away an organization's responsibilities to comply with the law or with their own company's health and safety management systems, and other relevant requirements for the safe management of work, including workforce agreements.

The calculation is performed in two steps:

Step 1: Calculate the individuals recent sleep history as follows:

x = number of hours sleep in the past 24 hours;
y = number of hours sleep in the past 48 hours;
z = number of hours since the last sleep.

Step 2: Calculate the fatigue likelihood score:

- For every hour that **x** is less than 5, add 4 points to the PSC score.
- For every hour that **y** is less than 12, add 2 points to the PSC score.
- For every hour that **z** exceeds **y**, add 1 point to the PSC score.

The total PSC score is the sum of the three values generated by applying these three rules. Refer to Table B1 to interpret what the PSC score may mean and to find a recommendation.

Table B1 *Meaning and recommendations associated with PSC scores*

Score	What it may mean	Recommendation
0	Unlikely to show signs of fatigue.	No action is needed. Should be fit to continue working as normal.
1 or 2	Thinking is likely to be a bit slower. May show minor indications of fatigue and minor mood changes.	Take simple actions to maintain alertness: drink coffee, have a break, go for a walk. Be aware of signs of fatigue.
3 or 4	May experience difficulty concentrating on complex tasks.	Avoid tasks that require sustained concentration. Do not start a long drive.
5 or 6	Difficulty concentrating for long periods. Lapses of attention likely. May show poor judgement on complex tasks.	Positive action is needed to reduce fatigue risks.
7 or 8	Performance and/or behaviour likely to be impaired. Difficulty sustaining attention even on simple tasks.	Apply measures to reduce the likelihood of a fatigue-induced error actually leading to an incident. Do not drive or work alone. Do not make critical decisions alone.
9 or 10	Serious lack of energy and motivation. Ability to perform tasks and to maintain situational awareness is likely to be seriously impaired.	Implement additional controls to prevent the potential for incident in the event that fatigue does impair performance. Do not drive or work alone. Do not make critical decisions alone.
11 or more	Difficulty staying awake at times. Will struggle to stay focused on any task. Short, involuntary sleep episodes (microsleeps) are likely.	Probably not fit to continue working on safety-critical tasks.

Example 1

6 hours sleep in the past 24 hours;
13 hours sleep in the past 48 hours;
woke up at 06:00 and been awake for 16 hours.

Calculation		*Fatigue points*
x = 6	0 hours below the 24-hour threshold	0
y = 13	0 hours below the 48-hour threshold	0
Awake for 3 hours more than the 48-hour sleep (**y**), so **z** = 3		3
Score		**3**

What the score may mean:
May experience difficulty concentrating on complex tasks.

Recommendation:
Avoid tasks that require sustained concentration. Do not start a long drive.

Example 2

4 hours sleep in the past 24 hours;
9 hours sleep in past 48 hours;
woke up at 0600 and been awake for 11 hours.

Calculation		*Fatigue points*
x = 4	1 hour below the 24-hour threshold	4
y = 9	3 hours below the 48-hour threshold	6
Awake for 2 hours more than the 48 hour sleep (**y**), so **z** = 2		2
Score		**12**

What the score may mean:
Difficulty staying awake at times. Will struggle to stay focused on any task.
Microsleeps are likely.

Recommendation:
Probably not fit to continue working on safety-critical tasks.

Appendix C: Fatigue data recording

Consistency in data reporting offers the potential to facilitate learning and awareness of the levels of fatigue that may exist as well as benchmarking of the levels that are considered tolerable for different types of operations. Table C1 defines a set of data that IPIECA member companies could consider, including in any fatigue risk assessment reports.

Table C1 *Fatigue risk data reporting form*

Parameter	Meaning	Format
Assessment unit	*Free-text for description of the assessment unit*	
Ro Rotation	Planned number of consecutive work days.	Days
RP Pattern	Shift pattern within a rotation	(See footnote 11)
RD Rest days	Planned number of consecutive rest days	Days
Notes on rotation	*Free-text for description of the rotation*	
Shift structure		
WH Work hours	Planned shift duration	Hours
Hp Handover	Planned shift start time	HH:MM
Ha Handover (actual)	Assumed time before the start and after the end of shift needed for shift handover	Minutes
Notes on shift structure	*Free-text for further details of the shift structure*	
Overtime and call-outs		
OTs Shift overtime	Maximum overtime in any shift	Hours
OTr Rotation overtime	Maximum overtime in any rotation	Hours
Con Number of call-outs[12]	Maximum times called-out during any period of rest days	Integer
COl Length of call-outs	Maximum length of each call-out	Hours
Notes on overtime and call-outs	*Free-text for further details of overtime and call-outs*	

continued …

[11] D = Day; N = Night; R = Rest; E = Early; M = Mid

[12] A call-out is defined as any occasion when an individual who is planned to be on a rest day is required by their employer to attend work, whether for operational duties, training or other reasons.

Table C1 *Fatigue risk data reporting form (continued)*

Parameter	Meaning	Format
Travel		
TZ Time zone	Does the work involve travel across multiple time zones?	Yes/No
Time zone details	*If TZ is 'Yes', provide a description of the cross-time zone travel involved, including frequency, number of zones crossed and direction of travel.*	
ST Shift travel	Travel time immediately prior to starting shift each day	
RT Rotation travel	Travel time immediately prior to arrival at start of rotation	
Notes on travel	*Free-text for further details of assumptions made about travel*	
Interrupted sleep		
IF Interruption frequency	Frequency of interrupted sleep for individuals on-call	Per rotation
ID Interruption duration	Length of each period of interrupted sleep while on-call	Hours
Notes on interrupted sleep	*Free-text for further details of assumptions made about interrupted sleep*	
Circadian adaptation		
Is adaptation assumed?	Did the analysis assume that Circadian adaption to night working, or long distance travel would occur?	Yes/No
Description	*Describe what adaptation was assumed*	
Implementation	*Describe how the assumed adaptation was accounted for in the fatigue estimation stage*	
Estimated fatigue exposure and tolerance levels		
Measurement or prediction?	*Was actual fatigue experienced measured (e.g. by actigraphy or sleep diaries) or predicted, e.g. by PSC or biomathematical modelling)?*	
Assessment method	*Brief description of how fatigue was measured or predicted*	
Metrics	*Metric used as estimates of fatigue*	
Critical activities within scope of the assessment unit		Tolerance level
Estimated fatigue	*Description of the estimated fatigue exposure*	

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OGP represents the upstream oil and gas industry before international organizations including the International Maritime Organization, the United Nations Environment Programme (UNEP) Regional Seas Conventions and other groups under the UN umbrella. At the regional level, OGP is the industry representative to the European Commission and Parliament and the OSPAR Commission for the North East Atlantic. Equally important is OGP's role in promulgating best practices, particularly in the areas of health, safety, the environment and social responsibility.

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