Electricity Engineers' Association

DRAFT FOR CONSULTATION

MAY 2024

Fatigue Guide - Electricity Supply Industry

FIRST PUBLISHED: **MAY 2024 - DRAFT FOR CONSULTATION**

HEALTH + SAFETY
——
ASSET MANAGEMENT
——
PROF DEVELOPMENT
——
NCLW + LIVE WORK

DRAFT FOR CONSULTATION

Fatigue Guide – Electricity Supply Industry

Issued and published by the Electricity Engineers' Association of New Zealand (Inc.) (EEA).

First published: **JULY 2024 – DRAFT FOR CONSULTATION**

ISBN (PDF): 978-1-0670105-4-6

Copyright

Disclaimer

This guide is recommended as good practice by electricity supply industry representatives, but it is not a substitute for legislative or other regulatory requirements. If there is uncertainty on what guidelines or legislative requirements should apply in any particular situation, specialist advice, including legal advice, should be sought.

The Electricity Engineers' Association of New Zealand (Inc.) (EEA) and the electricity supply industry representatives involved in preparing this guide, accept no liability or responsibility for an error or omission contained in this guide, or any injury, loss, damage (including indirect or consequential loss or damage), or any other claim from any reliance on, or failure to rely on, the contents of this guide.

This guide has been prepared by representatives of the electricity supply industry to provide guidance on safety practices for use by the industry.

This guide has been prepared on the basis that the user will be appropriately trained, qualified, authorised and competent.

Status of Examples and Case Studies

Examples including sample processes, or case studies in this guide are included to assist with consideration of health and safety issues. The examples or case studies are not a comprehensive statement of matters to be considered, nor steps to be taken, to comply with any Statutory Obligations pertaining to the subject matter of this guide.

Preface

The content of this guide will be monitored and revised periodically.

Suggestions for changes should be sent to admin@eea.co.nz or Electricity Engineers' Association, P O Box 5324, Wellington, 6145. www.eea.co.nz.

Purpose

This guide provides information on and aims to support good practice in policy development for the evaluation and mitigation of fatigue risk management in the Electricity Supply Industry (ESI) in NZ.

The guide has been prepared with the aim of improving the understanding of, and the ability to manage fatigue for everyone within the wider electrical industry.

Scope

This guide

- Provides a basic definition and description of fatigue.
- Introduces a systematic approach to the identification, evaluation and management strategies that can be adopted by the reader in the management of fatigue and its existence within a business.
- Identifies the necessity for fatigue to be managed in a "defences in depth" Fatigue Risk Management System (FRMS) framework.
- Explains that effective management of fatigue related risk requires the use of fatigue proofing as a complementary approach to fatigue reduction.
- An approach integrating both fatigue reduction and fatigue proofing strategies is recommended to balance the societal pressure exercised through the Commerce Commission that electricity is a lifeline utility which modern society has a twenty-four-seven reliance on (Sadgrove, 2023). While this is true it has been said by one of the world's leading researchers on fatigue that a fatigued person is better than no one at all. Irrespective of this polarising viewpoint, which is true for many professions, balance is required utilising scientific methods that take the subjectivity out of deciding the likelihood in a risk assessment. This then leads to much clearer actions deemed necessary to mitigate risk and therefore reduce harm potential in the hazardous work within the electrical supply industry.

Acknowledgements

The creation of this guide is primarily due to the revealing research completed in November 2022 by EEA member Matthew Sadgrove and his dedication to see his research evolve into an operationally functional guide for the industry. As the author of that research and the primary author of this guide Matthew wishes to acknowledge and thank Professor Drew Dawson, Dr Kirsty McCulloch, and the many others whose research in the field of fatigue has contributed to the progressive nature of this guide.

The EEA is indebted to Matthew, Drew, and Kirsty, for their contribution and additionally wishes to thank Lian Pasmore, Craig Stewart and Dave Houston whose involvement on later drafts has brought this guide to its current state and lastly those members of the SSPG who helped approve this work.

Contents

DRAFT FOR CONSULTATION

FIGURES

TABLES

1. Introduction

Working in a fatigued state decreases the "ability to process and react to new information and respond to hazards" *(Techera, Hallowell, Stambaugh, & Littlejohn, 2016).* Fatigue is associated with slower reaction times, poor judgement, increased error rates, and ultimately has a negative impact on worker safety and the safety of others as well *(Wagstaff & Lie, 2011).* Fatigue therefore has a direct relationship with the achievement of safe outcomes, fatigue affects task control, planning, and preparation ability *(Lorist, Boksem, & Ridderinkof, 2000).*

'The Prospect', a London based *Trade Union* blog, identifies fatigue as "a problem haunting the electricity industry", references a survey where nearly a third of respondents' recall feeling too fatigued to work safely at some point in their working lives *(Ferns, 2021).* Workers in the electricity industry internationally have been identified as experiencing fatigue because of the necessity for shift work; it is reasonable to assume that workers in the NZ electrical distribution industry would be no different.

Most mature New Zealand businesses have identified fatigue as a workplace hazard and therefore understand the obligations for persons conducting a business or undertaking (PCBUs) and workers to manage fatigue at work. Section 30 "Management of risks" Health and Safety at Work Act 2015 is clear that any duty under the Act requires a person with that duty to eliminate risk to health and safety so far as reasonably practicable or minimise it. . Under section 36, "Primary duty of care", a PCBU must ensure (among other things) so far as reasonably practicable, the health and safety of workers and others. Section 45, "Duties of Workers", includes provisions which mean (among other things) a Worker must present to work in a fit state free from impairment in order to take reasonable care for their own health and safety and the health and safety of other persons.

Traditionally, there are two approaches which can be utilised to reduce fatigue related risk: Reducing the likelihood of a fatigued worker working or, reducing the likelihood of a fatigued worker's error evolving into an incident which results in damage to plant and equipment or harm to a person *(Berastegui, Jaspar, Ghuysen, & Nyssen, 2018)*. Recent progress and indeed risk treatment for fatigue has been predominantly focused on fatigue reduction by reducing working hours, adjusting shift rosters, or enforcing working limits. We know there is room for improvement and this guide aims to set out how.

2. Definitions and Acronyms

Fatigue Fatigue is the physical and/or mental exhaustion that can be triggered by stress, medication, overwork or mental and physical illness or disease *(Ford-Martin, 2011)*.

In the broadest of senses, Fatigue, especially at work, has been connected to an imbalance between the intensity, length, and timing of work, with recovery time.

This imbalance is frequently related to working for prolonged periods and the subsequent inability to sustain the required level of performance on a task *(Dinges, 1995).*

ESI	Electricity Supply Industry
FRMS	Risk Management System
FRS	Fatigue Reduction Strategies
FPS	Fatigue Proofing Strategies
KSS	Karolinska Sleepiness Scale
HSMS	Health and Safety Management System
ICAM	Incident Cause Analysis Method
PCBU	Person conducting a business or undertaking
SSPG	Safety Standards and Procedures Group

3. Background

In 2023, a New Zealand electrical industry specific, fatigue and night shift focused research paper concluded that "the safety risks associated with nightshift in the New Zealand electrical distribution industry are not well managed" *(Sadgrove, 2023).* This research was shared broadly across the industry and the representative body the SSPG held a meeting with the researcher and decided an industry guide was required to address the issue. "Fatigue is a complex and dynamic phenomenon" *(Phillips, 2014)* yet it is widely agreed that fatigue impacts decision making *(Chan, 2011).*

Predominately fatigue is not caused by something but more accurately a lack of it, good quality sleep. Anytime sleep is affected, either in the duration or the timing (for example during the day) this can lead to fatigue. Long shifts like during a storm response, shift rotations, double shifts and evening or night work all pose both short- and long-term safety risks to workers, their work mates, and the public. There are other factors which may contribute to fatigue such as depression, anxiety, medication side effects, illness, mentally or physically demanding work as well as personal factors like financial worries, relationship concerns and diet. Often it is a combination of many factors, both inside and outside of work, that cause fatigue as is shown in the below diagram often called the bucket model which suggests that stress and fatigue may occur when a person's reservoir (bucket) of personal resilience is drained faster than it can be replenished.

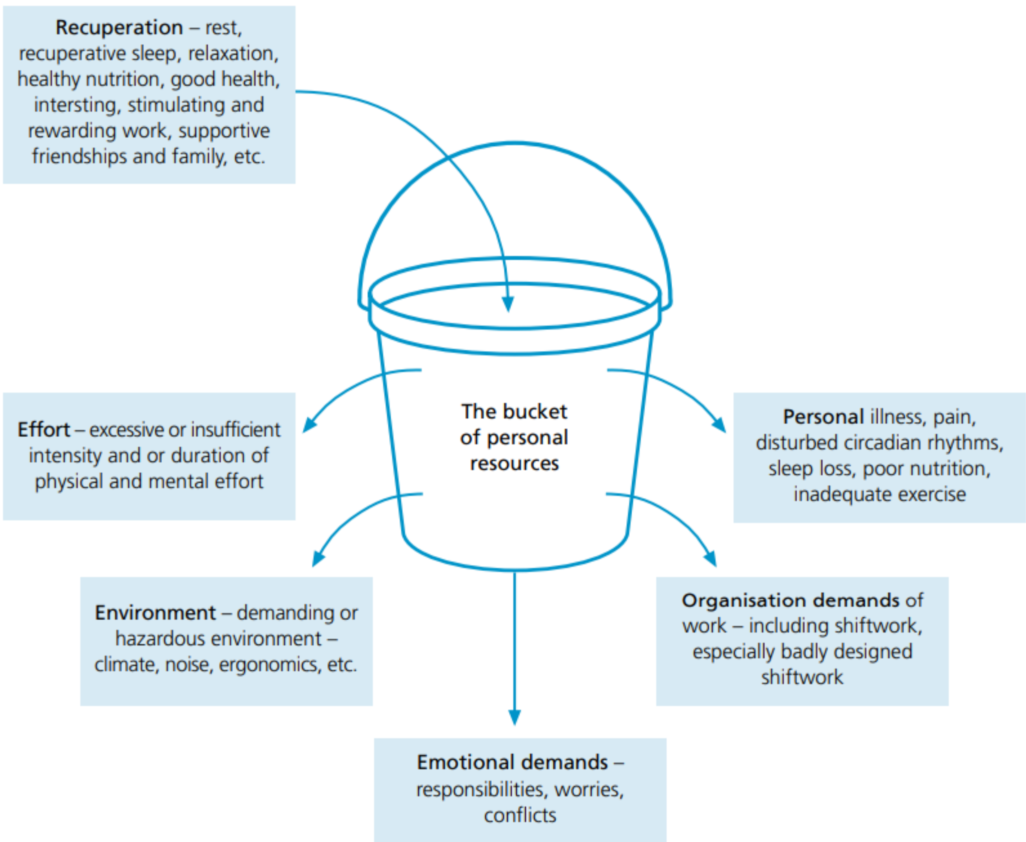

Figure: 1 - The bucket of personal resources.

The prefrontal cortex of the brain is shown in studies to be severely affected by sleep deprivation *(Muzur, Pace-Schott, & Hobson, 2002).* Meaning tasks that require higher cognitive function like verbal fluency, response inhibition, innovative thinking, and emotional control are significantly impaired in an individual who is functioning while sleep deprived.

Decreased alertness and brain function.		This can make it difficult to concentrate, process information and make decisions, leading to an increase in risk, error, and incidents
Decreased productivity		During the nighttime workers will take longer to complete tasks and will require more rest and breaks
Increased error rates		Through impaired judgement when tasks require attention to detail
Poor quality of work		Night shift /fatigued workers are not able to perform at their best due to decreased alertness, cognitive function, and productivity. For example, switching instructions written between 3:00am and 5:00am contain a larger number of errors which could have catastrophic consequences.

In most emergency management models and essential service provider activities, a fatigued worker is better than no worker at all. While this may be controversial especially when thinking about patient outcomes in a hospital environment, this is more about having a system which allows for accurate and consistent triaging or prioritising of work while being aware of the risks. Fatigue is a safety issue and long hours (one potential cause) of work are still an entrenched work practice in many industries. The traditional approach to remedy this being to reduce hours and therefore the opportunity for a person to turn up to work fatigued *(Dawson & McCulloch, 2005).* This doesn't however factor in 'out of work' causes, shift rosters negatively affecting circadian rhythm and the presence of illness or disease. So, when the FRMS is built with only reduction strategies, compliance doesn't mean safe.

4. Fatigue Reduction Strategies

A good Fatigue Reduction Strategies (FRMS) allows people to adapt to the work environment understanding that this environment is not perfect and, in some instances, not safe. This adaptation often takes the shape of fatigue proofing strategies, focused on improving the resilience of the system so any fatigue related error is detected before it translates into an unwanted event, either harm or damage. Which at their core are both rework in nature and unnecessary costs on the business. Traditionally, fatigue reduction strategies have been used in isolation and are about reducing the likelihood an individual will be working when fatigued *(Dawson & McCulloch, 2005).* Both are needed as part of a defences in depth approach and a business needs to be in a mature enough state to recognize fatigue proofing which is often informal and formalise it for the benefit of customer outcomes.

A defence in depth approach is critical when designing a FRMS because of the variability in the three main points below.

- Flexible working times can be unpredictable and hard to manage.
- Non-work causes of fatigue are difficult to identify and manage.
- Prescription can be paradoxical as one size does not fit all.

Control is often exercised in stable environments where constants are easily identified or established however in this case because people are similar but unique at the same time, multiple layers are needed to ensure safe outcomes or indeed a safe to fail environment.

Because of its complexity to effectively manage fatigue your FRMS must start with a standard/policy/procedure which includes a 'shared responsibility' that is present throughout all levels of defence in your FRMS. For example.

- Management is responsible for ensuring working arrangements provide a sleep opportunity sufficient to recommence 'fit for work' and, is also responsible for providing clear guidelines on how to manage an employee who is not 'fit for work.'
- Workers are responsible for ensuring a sleep opportunity to obtain sufficient sleep-in order to be fit for work. Workers must notify line management when this does not occur.

DRAFT FOR CONSULTATION

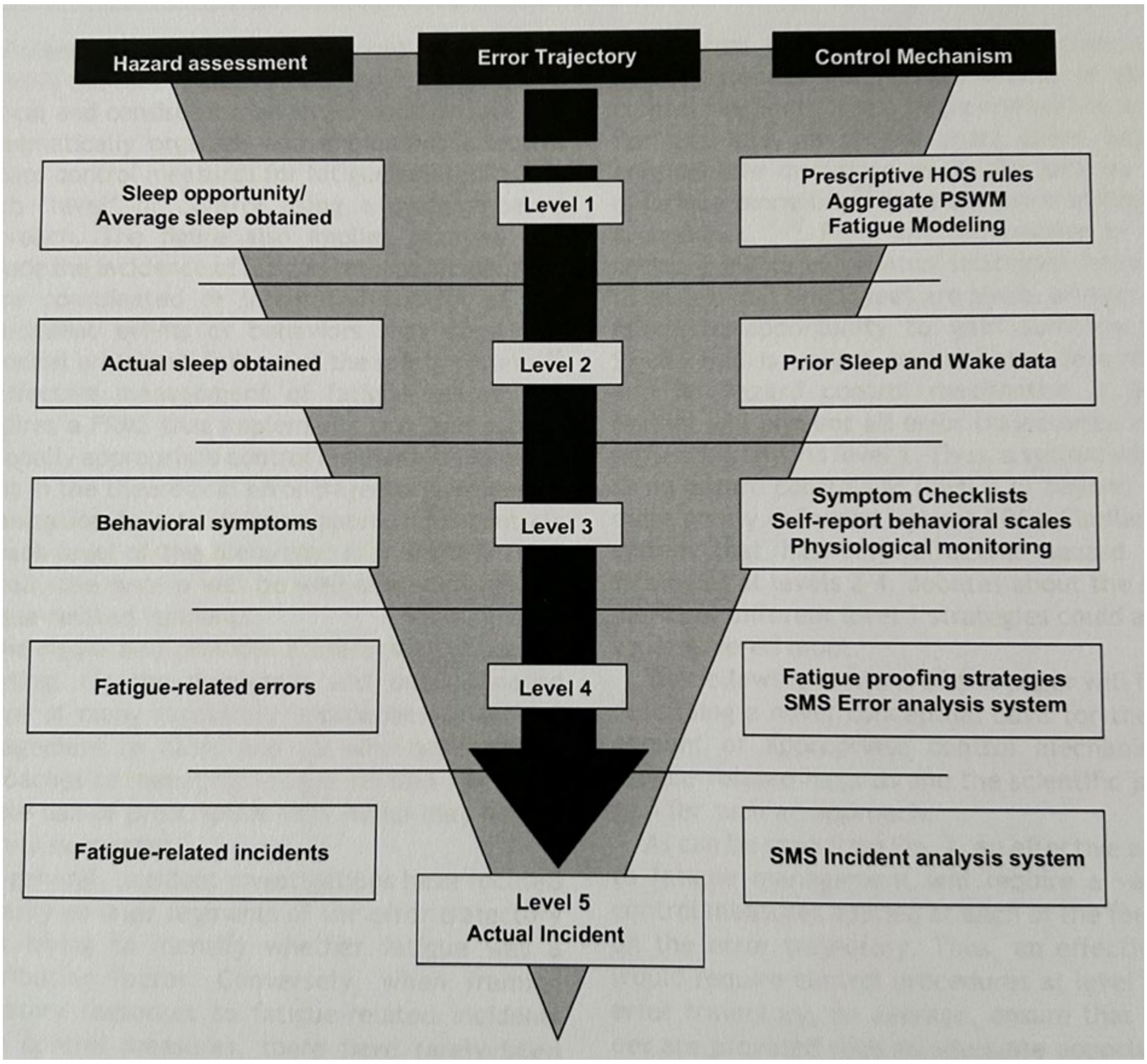

Figure: 2 - Example of a defence in depth approach (Dawson & McCulloch, 2005)

Utilising these five levels of defence we can then translate scores using a key in the first three levels to correspond with the likelihood side of the risk matrix in *ISO31000* (below). Thus, reducing the subjectivity often associated with risk assessment, achieved in this instance with the use of scientifically proven methodology to appropriately flag situations where fatigue happens, and risk mitigation is required to ensure a safe outcome *(Dawson & McCulloch, 2005)*.

The below table shows the first three levels of control roster assessment, personal fatigue likelihood score and *Karolinska Sleepiness Scale* values that transpose to the five likelihood levels in *ISO31000* risk assessment. The 4th and 5th levels of defence should already be in place in most organisations in the shape of error capture and assessment and then incident investigation.

Table: 1 first three levels of control roster assessment

Likelihood (ISO31000)	Level 1 Five dimensions	Level 2 PFLS	Level 3 KSS
1	0-5	0	1-2
2	6-11	1-3	3-4
3	12-20	4-8	5-6
4	21-25	9-12	7-8
5	25+	12+	9

5. Level 1 Controls

Five Dimensions Assessment

Risk assessment of roster/shift structure and likelihood of fatigue. Looking at weekly hours (maximum hours per 7 days), shift duration, break duration, night work hours (maximum hours of night work per 7 days), reset breaks (days between resets).

Assessing fatigue likelihood of Five Dimensions

Table: 2 Risk assessment of roster/shift

Roster Dimension Scoring	0	1	2	4	8
Max Hours per 7 days	≤36h	36-43h	44-47h	48-54h	55+
Shift Duration	≤8h	8-10h	10-12h	12-14h	≥14h
Short break duration	≥16h	16-13h	12-10h	10-8h	≤8h
Max hours of night shift work per 7 days	0h	1-8h	8-16h	16-24h	≥24h
Days between Resets	<6d	6d	7-10d	11-12d	12+d

6. Level 2 Controls

Calculate Personal Fatigue Likelihood score (PFLS).

This looks like $(6 - X) \times 4 + (12 - Y) \times 2 + (Z - Y)$ where $X<6$, $Y<12$.

X score For every hour of sleep less than 6 hours in 24 hours add 4 points.

Y score For every hour less than 12 hours in 48 hours add 2 points.

Z score Time since last sleep longer than 2 hours.

The PFLS calibration looks like the following:

Table: 3 PFLS calibration

PFLS	Descriptor
12 +	Struggling to stay focused on tasks, difficulty concentrating, micro-sleeps likely.
10	Clear loss of motivation. Significant loss of situational awareness. Task performance impaired.
8	Clear evidence of behavioral impairment. Difficulty sustaining attention on simple tasks.
6	Difficulty concentrating. Occasional lapses of attention. Poor judgement on complex tasks.
4	Difficulty maintaining extended concentration for complex tasks.
2	Slowed cognition. Occasional minor fatigue behaviours. Minor mood changes observable.
0	Not fully alert but able to perform tasks safely. Few external signs of fatigue.

Knowing this is an assessment at a specific time, we can project out the completion time of work even if estimated and see what the fatigue levels will be of our workers at the start, part way through and by the end of their working day (allowing for travel time/journey management).

7. Level 3 Controls

The scientifically proven *Karolinska Sleepiness Scale* is an evaluation of subjective sleepiness. It has been validated in many scientific journals and has been measured against *EEG* (measures electrical activity in the brain). It is a self-assessment tool that gives context to cognitive performance.

Table: 4 self-assessment tool

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

To be included as a part of level 3 control is the potential of physiological monitoring devices/wearables and how these will evolve and improve over time.

Current models available offer features like:

– HRV status

– Pulse oxygen

– Body battery

– Sleep score and advanced sleep monitoring

– VO2 Max

– Recovery time

– Etc…

Understanding the sensitivity of private information might be a hurdle to jump but this technology will improve as people seek to decrease morbidity and improve vitality.

8. Level 4 Controls

This deep we get into fatigue error mitigation. This looks like creating a resilient system to work that fails safely and harvests any current fatigue proofing strategies. This, however, requires the ability to build it and find it in the first place. Once found formalisation can take place as previously discussed. The ability for your FRMS or for that matter the larger HSMS to capture accurate data for analysis is critical.

9. Level 5 Controls

An example of a level 5 control is an incident investigation and analysis model, much like our tool the *Incident Cause Analysis Method* (ICAM) . Trying to break down an event in a focused effort to avoid another.

Additionally given the collection of information from the previous layers of defence which should remove part of the subjectivity of a risk assessment we can then utilise the table below to determine risk and therefore the level of response which is most appropriate *(Dawson & McCulloch, 2005).*

Table: 5 Determine risk

RISK	ACTION
Low	Do nothing unless indicated otherwise by higher level of control
Moderate	Minor increase in likelihood of fatigue. Notify co-workers and supervisors. Self-management controls are usually sufficient. Typical controls, self-monitoring, caffeine, task rotation, self-paced workload.
High	Moderate increase in likelihood of fatigue. Notify co-workers and supervisors. Team and process management controls usually sufficient increase supervision, consider task re assignment.
Extreme	Significant increase in likelihood of fatigue. Notify co-workers and supervisors. Document a near miss report and do not continue in any safety critical task without 1 up approval based on pre-existing risk assessment. Controls unlikely to be sufficient. Typically, only used where the risk of stopping outweighs the risk of continuing. This would be in exceptional circumstances.

10. Working Examples

Here are three typical examples of workers and work types within the electricity sector. They are used to show you how to utilise the assessment. Remembering the defences in depth approach is primarily a shift work assessment tool.

Note: The levels 1-3 are predominantly designed to assess shift work and more so night shift than day shift and more so full shifts than variable shifts. The following examples show you how to use the tool outside of that primary purpose gives you more function and capacity to assess fatigue in your business.

John's working example

John is a Network Control Supervisor who works 12hr day shifts from 0600hrs to 1800hrs, on a 4-on, 4-off rotation. Due to the handovers required however, these shifts often extend to 12.5 or 13 hours. As John lives 30 minutes from work and is a diligent worker who likes to be at least 15 minutes early to ensure the handover is not rushed, he is often away from home from 0500hrs to 1900hrs on his rostered days on. On his fourth day of the shift pattern, one of his controllers called in sick and John must fill in.

Will he and his work quality be affected by fatigue? And what controls could be adopted to support john in completing the shift safely?

First, we must look at the five-dimension assessment of the roster (Max hours per 7 days, shift duration, short break duration, max hours night shift per 7 days and days between resets).

John works a on off roster which would mean in any given week he could work 4 days. As he often has a handover (up to 1 hour, from pre- and post-shift) and is 15min early to it on top of 30min travel time. His actual max hours is 4 × 14.25hrs = 57 so a score of 8

Shift duration as highlighted above is 12hrs + 1hr handover = 13 which is a score of 4.

Short break duration is about opportunity to sleep. So, 12hr shift + 1 hour handover + 15min early + 1 hour travel = 24 – 14.25 hours so a 9.75-hour sleep opportunity so a score of 4.

John works a day shift and night shift work can be defined as working at least 3 hours between midnight and 0500hrs (Stevens, et al., 2011). So, using this definition the score is 0.

John's days between resets is often called long break frequency. In this instance it is greater than 1/7days (3/7days) which is a score of 0.

Table: 6 John's roster assessment

Roster Dimension Scoring	0	1	2	4	8
Max Hours per 7 days	≤36h	36-43h	44-47h	48-54h	55+
Shift Duration	≤8h	8-10h	10-12h	12-14h	≥14h
Short break duration	≥16h	16-13h	12-10h	10-8h	≤8h
Max hours of night shift work per 7 days	0h	1-8h	8-16h	16-24h	≥24h
Days between Resets	<6d	6d	7-10d	11-12d	12+d

John's roster assessment is shown in the above table in the white boxes. $8 + 4 + 4 + 0 + 0 = 16$, so using the table below, a 16 in the 5 dimensions assessment is the 12-20 box (in white) and correlates to a 3 on the likelihood side of the ISO31000 risk matrix which equals a possible. You would then require understanding of John's work to work to figure out the consequence and be able to establish the risk to be low, moderate, high, or extreme, now knowing the risk, take the appropriate action required.

Table: 7 Likelihood (ISO31000)

Likelihood (ISO31000)	Level 1 Five dimensions	Level 2 PFLS	Level 3 KSS
1	0-5	0	1-2
2	6-11	1-3	3-4
3	12-20	4-8	5-6
4	21-25	9-12	7-8
5	25+	12+	9

We would absolutely want more context as a recognition that roster assessments do not factor in out of work factors for fatigue. So, you would then complete a *Personal Fatigue Likelihood Score* (PFLS). PFLS is not about opportunity like the roster assessment, it is about how much you did get. The equation for PFLS is $(6 - X) \times 4 + (12 - Y) \times 2 + (Z - Y)$ where $x<6$ and $Y<12$. In this scenario that equates to:

X = sleep in prior 24hrs

Y = sleep in prior 48hrs

Z = time since last sleep longer than 2 hours

We are missing some data in this scenario so let us assume in this instance John gets 4hrs sleep last night as he has a young baby but 7hrs the night before that.

X = 4 and,

Y = 11

The Z value would depend on what time you are doing the assessment for (start of shift, halfway through shift, end of shift, etc.). If it is at the end of his shift, we must first have John's wake time, which, if he starts at 0600hrs and has a 30-minute commute, could be reasonably assumed to be 0445hrs. So 1hr 15min to a 0600hrs start then adding the hours of the working day 13, making it 14 hours 15 minutes since last sleep. This would mean Z = 14 hours 15 minutes.

So the workings of the equation start to look like the following:

$(6 - X) \times 4 + (12 - Y) \times 2 + (Z - Y) =$

$(6 - 4) \times 4 + (12 - 11) \times 2 + (14.25 - 11) =$

$(2) \times 4 + (1) \times 2 + (3.25) =$

$8 + 2 + 3.25 = 13.25$

So, when checking 13.25 on the PFLS calibration below, it is a 12+ (in white) which states John is expected to be struggling to stay focused on tasks, difficulty concentrating, micro-sleeps likely.

Table: 8 PFLS calibration

PFLS	Descriptor
12 +	Struggling to stay focused on tasks, difficulty concentrating, micro-sleeps likely.
10	Clear loss of motivation. Significant loss of situational awareness. Task performance impaired.
8	Clear evidence of behavioural impairment. Difficulty sustaining attention on simple tasks.
6	Difficulty concentrating. Occasional lapses of attention. Poor judgement on complex tasks.
4	Difficulty maintaining extended concentration for complex tasks.
2	Slowed cognition. Occasional minor fatigue behaviours. Minor mood changes observable.
0	Not fully alert but able to perform tasks safely. Few external signs of fatigue.

DRAFT FOR CONSULTATION

Against the likelihood *ISO 31000* key provided below this level 2 PFLS result translates to a likelihood of 5 which is an indication that Johns is almost certain to have a fatigue related event.

Table: 9 ISO 31000 key

Likelihood (ISO31000)	Level 1 Five dimensions	Level 2 PFLS	Level 3 KSS
1	0-5	0	1-2
2	6-11	1-3	3-4
3	12-20	4-8	5-6
4	21-25	9-12	7-8
5	25+	12+	9

Again, you would hopefully understand the consequences of tasks within his role, and this would lead you to calculate the risk level so you can take the appropriate actions required to mitigate risk.

If you want to add a further assessment (in this case, you shouldn't need to) to give you scientific depth in your approach the *Karolinska Sleepiness Scale* (KSS) can be used.

John would pick where on the scale he is currently feeling, and you would then transpose that to the *ISO31000* risk standard matrix. Let us say John identifies as an eight shown below (in white).

Table: 10 Karolinska Sleepiness Scale

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

This is then a four on the likelihood *ISO31000* matrix Level 3 KSS (in white)

Table: 11 ISO31000 matrix Level 3 KSS

Likelihood (ISO31000)	Level 1 Five dimensions	Level 2 PFLS	Level 3 KSS
1	0-5	0	1-2
2	6-11	1-3	3-4
3	12-20	4-8	5-6
4	21-25	9-12	7-8
5	25+	12+	9

Given you now have a 3, a 4, and a 5 shown below this guidance suggests you are conservative and take the highest level of likelihood, a five in this case and treat the calculated risk level with the most appropriate response.

Table: 12 calculated risk level

Likelihood (ISO31000)	Level 1 Five dimensions	Level 2 PFLS	Level 3 KSS
1	0-5	0	1-2
2	6-11	1-3	3-4
3	12-20	4-8	5-6
4	21-25	9-12	7-8
5	25+	12+	9

Helen's working example

Helen is typical of a vast number of executive or office-based roles where the salary/pay is for 40 hours but much more is expected and therefore completed to get ahead.

Helen is an Electricity Distribution Executive who is based in Wellington but spends a lot of time travelling for the role. Although Helen is contracted for 40 hours per week, Monday-Friday, Helen, however, typically works 10 hours (0800-1800), plus whatever else is needed at nights and on weekends. After a standard Monday-Wednesday in the office (3x 10hr 'shifts'), Helen is called away for some urgent travel on Thursday/Friday, which means the following:

Thursday	start at 0600hrs, drive 4 hours to site, be in meetings from 1000hrs to 1700hrs. Likely do some work in the hotel after dinner.
Friday	– attend the pre-start at 0700hrs; attend an urgent customer meeting from 0830-1130hrs and another meeting from 1230 – 1430hrs, before starting the 4-hour drive home at 3pm (arriving at 1900hrs).

Will Helen's work quality and safety be affected by fatigue?

What controls could be adopted to support Helen in completing the work week safely?

First, the five-dimension assessment of the roster.

Table: 13 five-dimension assessment of the roster

Roster Dimension Scoring	0	1	2	4	8
Max Hours per 7 days	≤36h	36-43h	44-47h	48-54h	55+
Shift Duration	≤8h	8-10h	10-12h	12-14h	≥14h
Short break duration	≥16h	16-13h	12-10h	10-8h	≤8h
Max hours of night shift work per 7 days	0h	1-8h	8-16h	16-24h	≥24h
Days between Resets	<6d	6d	7-10d	11-12d	12+d

The better the quality of data available the more accurate the assessment and the less assumptions need to be made. In this case some assumptions have been made.

1. On a typical week, Helen works a 10-hour day and then in the evenings at home another hour on the phone and reading emails and meeting agenda content. She sometimes even works an hour or more on Sunday to prepare for the following week. This equates to 55+ hours a week and a score of 8 (in white above)

2. The above being true the shift duration is 10hrs at work plus 1 at home. 11 hours so the 10–12-hour box and a score of 2. (in white above)

DRAFT FOR CONSULTATION

3. The short break duration is about the opportunity to sleep so if Helen works a 10hour day from 0800-1800 and lives 1/2hour from work. This would give the opportunity to sleep the 12-10hour box allowing time for nutrition, homelife, and sleep. A score of 2. This is irrespective of night work and weekend work as it is up to the individual to maximize the opportunity to sleep. One would suggest workload needs adjustment to allow for a work life balance and no work to be required nights and weekends.
4. The maximum hours of night shift is 0 hours and a score of zero.
5. Days between resets as it is officially a 5-day work week <6 so a score of 0.

The 5-dimension assessment totals 12 which is a 3 on the likelihood scale.

Table: 14 likelihood scale

Likelihood (ISO31000)	Level 1 Five dimensions	Level 2 PFLS	Level 3 KSS
1	0-5	0	1-2
2	6-11	1-3	3-4
3	12-20	4-8	5-6
4	21-25	9-12	7-8
5	25+	12+	9

Second is the PFLS noting this is not about opportunity like the roster assessment, it is about how much sleep you did get.

To understand the PFLS we need to know sleep in the last 24hours (Thursday night) (X) which we will say is 5 1/2 hours due to not being in own bed, potentially restless and working late in the hotel evidence of emails sent at midnight while trying to catch up on what was planned work before the urgent travel interrupted Helen's workflow. We also assume it took ½ hour to get to sleep after screen time with a 0600hrs wake time with 0700hrs start, so X = 5.5.

As Y is the amount of sleep in the last 48 hours, so Helen slept 5.5 hours on Thursday night and 6 hours on Wednesday night So Y = 11.5

Z = the number of hours awake since last sleep greater than 2 hours.

In this instance it would be best to calculate the Z figure before the car trip home and after to see interventions/controls are needed before the drive home as part of good practice journey management.

So, Z will assume Helen woke up on Friday at 0600hrs to get to the prestart meeting at 0700hrs.

Out of interest we will also calculate what the PFLS would be after Helen's drive home. If the drive is planned to start at 1500hrs and finish at 1900hrs then:

Z = 9 hours and Z = 13 hours respectively.

This means the workings of the equation looks like the following:

(6 - X) × 4 + (12 - Y) × 2 + (Z - Y) where X<6 and Y<12. This is critical as if X is not less than 6 or Y is not less than 12 the minimum sleep period has been exceeded and the assumption must be that Helen in that case would not be likely to have a fatigue related event from lack of sleep.

So, then (6 - 5.5) × 4 + (12 - 11.5) × 2 + (9 - 11.5) =

Then 0.5 × 4 + 0.5 × 2 + 9 - 11.5 =

Then 2 + 1 + -2.5 = 0.5

Meaning when checking 0.5 on the PFLS score Helen at the time of needing to travel home is "Not fully alert but able to perform tasks safely. Few external signs of fatigue".

At the end of the trip the PFLS is as follows:

X = 5.5, Y = 11.5 and Z = 13

This means the workings look like the following:

(6 – X) × 4 + (12 – Y) × 2 + (Z – Y)

Then 0.5 × 4 + 0.5 × 2 + 13 -12

Then 2 + 1 + 1 = 4

Meaning at the end of the trip (4hr drive home) Helen's PFLS score would correlate to "Difficulty maintaining extended concentration for complex tasks."

Before Helen's trip 0.5 in the likelihood *ISO31000* key correlates to a likelihood of 1. This score would suggest it would be rare for Helen to be involved in a fatigue-related event at the start of her journey. However, a score of 4 would equate to a likelihood of 3. This score would suggest by the time the trip Helen's likelihood of a fatigue related event has gone from rare to possible.

As we know the potential consequence of falling asleep at the wheel or even micro sleeps while driving then to protect both Helen and other road users some sort of journey management needs to take place as part of risk mitigation.

As the last thing Helen is doing is a 4hr drive the simplest thing to do would be to complete the KSS and see how Helen feels then correlate that number from the KSS to the *ISO31000* key.

Let's say after a big week Helen identifies as a 9 on the KSS. This means a likelihood Helen will have a fatigue related event of "almost certain."

Table: 15 KSS to the ISO31000 key

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

Then the company should insist Helen stay the Friday night in the hotel and drive in the morning when she has had a decent sleep opportunity. Work cannot stop Helen doing work on the Friday night in the hotel as that is for Helen to ensure she maximizes the sleep opportunity provided.

A good employer would also ensure Helen starts later on the Monday to get the 4 hours back to achieve a work life balance.

Journey management needs to be a priority in this case and direction should come from the PCBU.

The ISO 31000 key for Helen would look like the below over the three levels.

Table: 16 ISO key

Likelihood (ISO31000)	Level 1 Five dimensions	Level 2 PFLS	Level 3 KSS
1	0-5	0	1-2
2	6-11	1-3	3-4
3	12-20	4-8	5-6
4	21-25	9-12	7-8
5	25+	12+	9

Shannon's working example

Shannon is a line mechanic who usually works five (MON-FRI) 8-hour day shifts (0800-1630) per week. Shannon is often on-call for faults. During a significant storm event response, Shannon has worked the following times to reconnect the essential service of power/electricity to the communities in the area:

Monday	0800-1500 normal work	15.00-23.00 storm faults = 15 hours.
Tuesday	07.00-11.00 sent home to rest	16.00-22.00 storm faults = 10 hours
Wednesday		07.00-19.00 storm faults = 12 hours
Thursday	Rest	
Friday	07.00-13.00 sent home to rest	19.00-23.00 = 10 hours
Saturday	To be determined	

Shannon has had a sleep opportunity (without knowing his commute) both Wednesday and Thursday to reset and recover. Journey management needs to be a priority in this case and direction should come from the PCBU.

Assumptions made are:

Shannon did not work, had no faults on Sunday, or only started on faults on Monday.

Shannon actually gets rest on Tuesday and Friday but cannot sleep as he is in superhero mode, and it is also not his normal bed time.

On call is not easy to calculate with the five dimensions assessment but we will focus the weeks information provided

Shannon has a 30min commute to and from work but uses the fault ruck while on call.

All distribution networks and contractors have hour limits on days/weeks/months, however as electricity is an 'essential service' in an emergency environment these limits can be flexible but must be managed.

Shannon may work Saturday and Sunday on restoration work caused by the storm.

Shannon's normal sleep duration is 8 hours. Between 2200hrs and 0600hrs

First the five dimensions roster assessment. Below are the scores for Shannon on the figures provided with squares whited out as previously shown in this document.

Table: 17 Roster Dimension Scoring

Roster Dimension Scoring	0	1	2	4	8
Max Hours per 7 days	≤36h	36-43h	44-47h	48-54h	55+
Shift Duration	≤8h	8-10h	10-12h	12-14h	≥14h
Short break duration	≥16h	16-13h	12-10h	10-8h	≤8h
Max hours of night shift work per 7 days	0h	1-8h	8-16h	16-24h	≥24h
Days between Resets	<6d	6d	7-10d	11-12d	12+d

1. Max hours per 7 day (for the week figures provided 15 + 10 + 12 + 10 = 47 so a score of 2
2. Shift duration is variable so being conservative take the average over 4 days which is 11.75, so a score of 2
3. Short break duration is also variable so take the average with commute considerations.

Monday to Tuesday 7 hours / Tuesday to Wednesday 8 hours / Wednesday to Thursday NA / Thursday to Friday NA / Friday to Saturday To be determined. We have counted his commute time of ½ hour each way into the short break duration. If we take the average of the two, we get a score of less than or equal to 8 hours, so a score of 8.

4. Max hours of night shift per 7 days is 0 as we define night shift as working at least 3 hours between midnight and 0500hrs (Stevens, et al., 2011)
5. Days between resets if the storm is large, it is safe to say Shannon may work both Saturday and Sunday so in this instance the days between rests are 7-10 days. A score of 2.

A total score with the 5 dimensions assessment for Shannon is 2 + 2 + 8 + 2 = 14. Using the Likelihood key this is a 3 (possible).

Next is the PFLS:

$(6 - X) \times 4 + (12 - Y) \times 2 + (Z - Y)$ where $X<6$ and $Y<12$

In this instance as Shannon had Thursday off we need to assume he had his normal 8 hours which affects his Y value and even if Shannon is needed at 0700hrs on Saturday and had finished the night before at 2300hrs with a commute of ½ hour and assuming sleep happens ½ hour after Shannon arrives home , 2400hrs and awake by 0600hrs for breakfast, shower shave etc., with the ½ hour commute back to work by 0700hrs that is another 6 hour sleep opportunity.

This would mean X = 6 and Y = 14 which goes against the formula as in this instance X is greater than 6 and Y is greater than 12. Which means as Shannon has had over the minimum sleep requirement, he is not likely to be involved in a fatigue related event.

This renders the PFLS tool useless for Shannon's assessment, however the KSS can be used. If Shannon identifies as a 5 you would use the likelihood key giving you a 3 reinforcing the roster assessment.

Table: 18 KSS

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

Table: 19 Likelihood (ISO31000)

Likelihood (ISO31000)	Level 1 Five dimensions	Level 2 PFLS	Level 3 KSS
1	0-5	0	1-2
2	6-11	1-3	3-4
3	12-20	4-8	5-6
4	21-25	9-12	7-8
5	25+	12+	9

Exactly as the other examples having the likelihood lets you work out your risk on your risk matrix and lets you choose what controls are needed to treat the level of risk present.

11. Creating additional resilience

Performing an on-call shift over-night or a nightshift can result in a significant reduction of sleep quality (*Ferguson, Paterson, Hall, Jay, & Aisbett, 2016)*. The sleep wake cycle (the circadian rhythm) follows the environmental cues of light/dark alternation *(Galinier, et al., 2021).* Even when not working, research suggests that being on stand-by negatively impacts sleep duration and quality *(Wuyts, et al., 2012).* Therefore, the work patterns of both Network Controllers and Fault Responders may lead to fatigue – and subsequently impact the ability of both roles to perform optimally in a high-risk environment. This is compounded when the scale of the event escalates like it can and does in storm response. The larger the scale, the more important it is to understand the body of work which needs to be completed and the state of the individuals who are tasked with its completion.

Other things to consider when managing fatigue in the electrical supply industry:

- Induction: outline expectations. Provide information on sleep hygiene, exercise, and diet.
- Mentoring: provide mentoring for the role and bridge the gap between the workforce and management.
- Education: information to give to the workers, colleagues, and workers' family so they can understand what the effects of fatigue can have on an individual.
- Fatigue reduction and fatigue proofing need to work together. Companies should have instruction on working limits but must look past the only control being restricting hours and create influential guidance for worker activity outside the hours a pay with respect to the importance of sleep.
- Acknowledge the body clock: Provide the opportunity and the facility for sleep and rest without any cognitive load between 2-5am where possible.
- Guidance: write company standards/polices that are easy to understand and easier to follow.

12. Summary

Fatigue is still, after over 100 years of effort to define it and understand its causality a complex and dynamic phenomenon *(Phillips, 2014).*

This guide provides you with several tools which, when used in tandem with the already existent fatigue reduction strategies (rules around hours of work) give you the ability to be operationally flexible. This is achieved with higher accuracy when defining likelihood in your risk assessment through the reduction in subjectivity with the use of scientifically proven methods. The result of better information is better information. It is up to each PCBU to decide its risk tolerance, and which controls it will use for every situation.

13. References

Berastegui, P., Jaspar, M., Ghuysen, A., & Nyssen, A.-S. (2018). Fatigue-related risk management in the emergency department: a focus group study. Internal and Emergency Medicine, 1273-1281.

Chan, M. (2011). Fatigue: The most critical accident risk in oil and gas construction. Construction Management and Economics, 341-353.

Dawson, D., & McCulloch, K. (2005). Managing Fatigue: It's about sleep. Sleep Medicine, 365-380.

Dinges, D. (1995). An overview of sleepiness and accidents. Sleep Research, 4-14.

Ferguson, S., Paterson, J., Hall, S., Jay, S., & Aisbett, B. (2016). On-call work: To sleep or not to sleep? it depends. Chronobiology International, 678-684.

Ferns, S. (2021, June 21).Propect. Retrieved from Problem of fatigue haunts electricity industry: https://Prospect.org.uk/news/probelm-of-fatigue-haunts-electricity-industry/

Galinier, J., Becquelin, A., Bordin, G., Fontaine, L., Fourmaux, F., Ponce, J., & Zilli, I. (2021). Anthropology of night. Current Anthopology, 871-847.

Lorist, M., Boksem, M., & Ridderinkof, K. (2000). Mental fatigue and task control: planning and preparation. Psychophysiology, 614-625.

Muzur, A., Pace-Schott, E., & Hobson, J. (2002). The prefrontal cortex in sleep. Trends in Cognition Science, 475-481.

Phillips, R. O. (2014). What is fatigue and how does it affect the safety performance of human transport operators? Oslo: Institute of Transport Economics.

Sadgrove, M. (2023, November). The management of safety risks associated with night shift in New Zealand electrical distribution industry, New Zealand.

Stevens, R., Hansen, J., Costa , G., Haus , E., Kauppinen, T., Aronson, K., & Straif, K. (2011). Considerations of circadian impact for defining "shift work" in cancer studies. Occupational and Environmental Medicine, 154-162.

Techera, U., Hallowell, M., Stambaugh, N., & Littlejohn, R. (2016). Consequences of Occupational Fatigue: Meta-Analysis and Systems Model. Journal of Occupational and Environmental Medicine, 961-973.

Wagstaff, A., & Lie, J. (2011). Shift and night work and long hours - a systematic review of safety implications. Scandinavian Journal of Work Environment & Health, 173-185.