Human elements of system safety:
Fatigue risk management
Introduction

• Safety improvement project
• Human elements of system safety:
  – Human factors integration
  – Fatigue risk management
• Practically oriented
• Share common issues
• Successes
• This visit not part of compliance program
Topics

• Importance of managing fatigue-related risk
  – Fatigue, safety and productivity
• Fatigue risk management in practice
• Achieving compliance
Your needs and expectations?

- How do we know if we have 'safe' hours of work?
- What sort of breaches of work hours have to be reported to the regulator?
The regulatory context

- Human factors taken into account in
  - SMS development,
  - SMS operation
  - SMS maintenance

- Human factors principles/knowledge integrated into operational and business systems

National Regulations Schedule 1 Cl 17
Fatigue is one of many performance influencing factors.
The regulatory framework

- **General duty**
  - RSW not fatigue ‘impaired’
- **FRMP integrated into SMS**
- **Regulations:**
  - Risk based approach
  - Specified fatigue hazards to be considered
  - Monitoring of planned vs. actual hours
  - Occurrence reporting (breaches of scheduling practices)
  - Notification of change (work scheduling practices)
The regulatory framework

RISSB Fatigue Risk Management Guidance

- Information on research and technologies
- Case studies
Importance of managing fatigue related risk
Fatigue, safety and productivity
The context of rail operations

- 24/7 operations
- Sustained attention tasks
- Busy one hour, monotonous the next
- Systems depend on human performance
Fatigue

• Largest identifiable and preventable cause of accidents in commercial transport modes
• 15-20% of all accidents
• More than drug/alcohol incidents
• Often underestimated

Akerstedt 2000
Incident cost – US rail data

Source: US Department of Transportation Federal Railroad Administration 2011
Fatigue and risk
Sources of fatigue

- Work environment
- Task dimensions
- Social/psychological factors
- Rest environment
- Human physiology

Blocks image credit: www.freeimages.co.uk
Sources of fatigue – human physiology

- Circadian (body clock) rhythm effects
- Time awake
- Sleep inertia
- Sleep loss over days (chronic sleep loss)
Sources of fatigue – sleep physiology

- Circadian (body clock) rhythm effects

MODEL OF SLEEP

↑ (circadian) cyclical alerting process
Sources of fatigue – sleep physiology

- Circadian (body clock) rhythm effects
- Time awake

MODEL OF SLEEP

- \( \downarrow \text{Sleep process} = \text{drive to sleep with time awake} \)
- \( \uparrow C \) (circadian) cyclical alerting process
Sources of fatigue – sleep physiology

- Circadian (body clock) rhythm effects
- Time awake
- Sleep inertia (grogginess)

MODEL OF SLEEP

$S$: Sleep process = drive to sleep with time awake
$C$: (circadian) cyclical alerting process
$I$: Sleep Inertia = transient grogginess
Sources of fatigue – sleep physiology

Source: Wright et al 2013
Sources of fatigue – sleep physiology

Combined effect of circadian rhythm and extended wakefulness
Circadian effects on performance

Source: Folkard and Tucker 2003
Circadian effects on incident risk: UK SPADs

Source: RSSB 2010 Research Programme T699 Appendix F
Circadian effects on train driver sleep

Source: Roach et al 2003

Arbitrary line at 5 hours for comparison purposes
Effect of longer break = more sleep

Source: Roach et al 2003
Sources of fatigue – physiology
Chronic sleep loss effects

Van Dongen et al 2003 (Figures from Hursh 2010)
Sources of fatigue – physiology
Chronic sleep loss effects

Source: Van Dongen et al 2003
Sources of fatigue – physiology
Sleep loss and performance

Source: Van Dongen & Hursh 2010
Number of consecutive shifts and incident risk: UK SPADs

Data source: RSSB 2010 Research Programme T699 Appendix F
Sources of fatigue – physiology
Recovery from sleep loss

7 days of restricted sleep
recovery sleeps restricted to
8 hours time in bed

Belenky et al 2003
Sources of fatigue – task effects

- Time on task
Continuous hours worked and incidents - UK SPAD data

Data source: RSSB 2010 Research Programme T699 Appendix F
Sources of fatigue – social/psychological factors

**SHIFTWORK**
- Sleep loss
- Unpredictable hours
- Irregular hours
- Limited control
- Penalty rates

**HEALTH**
- Obesity
- Shiftwork sleep disorders
- Diseases

**MENTAL STATE**
- Mood
- Emotional control
- Stress
- Depression

**SOCIAL WELL BEING**
- Relationships
- Family harmony
- Financial security

**Productivity and Safety**
Recap – sources of fatigue

• Physiological factors
  – Circadian
  – Time awake
  – Sleep inertia
  – Sleep loss over days
• Task and workload
• Social/psychological
  Others:
  – Work environment
  – Rest environment
  – Commuting
  – …

What controls are in place for these hazards?
1. ………
2. ………
3. ……
Fatigue and risk

MECHANISM

Fatigue → TASK → Errors, Violations → Fatigue-related incident
Attention

• Decreased attention span
• Lapses on attention rich tasks (eg monitoring, driving)
• Tunnelling – narrowing of field of attention
• Micro-sleeps
• Sleep incapacitation
Video extract from documentary *Dead Tired* has been removed
Cognition (thinking)

• Slower to interpret and integrate information
• Short term recall, working memory
• Reduced ability to learn
• Decision making
  ➔ Difficulty weighing up options
  ➔ Persist with ineffective responses
Motivation and insight

• Compensatory effort to maintain performance
• Initiate tasks ok but then deteriorates
• Divert attention to interesting tasks
• Neglect tasks judged to be non essential
• Less interested in outcomes
• Less likely to pick up someone else’s errors
• End goal seduction
Emotional control

• Feeling low and irritable
• Inability to suppress responses
• Terse communications
Summary: fatigue effects on performance

- Increased error probability
- Decreased error detection and recovery
Summary: fatigue effects on performance

- Short cuts & violations more likely
- Decreased likelihood of detecting problems
Fatigue risk management in practice:
Developing and reviewing the FRMP
Multiple layers of defence

- **Optimise sleep**
  - Staffing
  - Work scheduling
  - Fitness for task

- **Optimise alertness & performance**
  - Job/task design
  - Work environment

- **Manage errors**
  - Error detection and recovery
  - Engineered controls

- **Investigate incidents and initiate corrective action**

*Layers of defence and accident trajectory concepts based on Reason, J 1997. Managing the risks of organizational accidents, Ashgate, Aldershot*
Scoping the fatigue management program

- Risks of tasks
- Likely exposure to fatigue
- Low risk tasks, low fatigue exposure = basic program
- High risk tasks, high fatigue exposure = detailed program

Scope of fatigue risk management program
The fatigue risk management cycle

1. Establish the context
2. Identify risks
3. Analyse risks
4. Evaluate and treat risks
5. Check controls
Fatigue risk management cycle

1. Identify the tasks
   - providing authority to work on track
   - authorising driver to pass signal at stop
   - test track circuits
   - driving hi-rail
   - lookout protecting worksite

2. Identify the operating context

3. Identify business and stakeholder requirements
Fatigue risk management cycle

1. Identify sources of fatigue relevant to job context
   - Biological factors
   - Schedule design
   - Predictability
   - Job design
   - Work environment
   - Sleep environment
   - Social factors, health
   - Commuting, second job

2. Identify the effect of fatigue on task performance
   - errors
   - violations

3. Identify risks arising from errors and violations
   Broken rail leading to derailment.
   Safeworking irregularity leading to trackworker struck by train

Task → Errors → Violations → Fatigue-related incident

Check controls

Identify risks

Analyse risks
Fatigue risk management cycle

1. What are the controls for risks due to errors and violations?
   - Engineered controls
   - Controls on work hours
   - Rules and procedures
   - Rail resource management
   - Supervision, training competency

2. How effective are current controls?
   - Are rosters minimising fatigue?
   - Is our staffing right?
   - How effective are engineered controls?

3. What is the current level of risk?

<table>
<thead>
<tr>
<th>Task</th>
<th>Errors</th>
<th>Violations</th>
<th>Controls</th>
<th>Fatigue-related incident</th>
<th>Risk</th>
</tr>
</thead>
</table>

Establish

Identify risks

Analyse risks
Fatigue risk management cycle

1. Are risks tolerable? What else could be done?
   - Changed rosters
   - Better predictability
   - Improved work design
   - Improvements to engineered controls
   - More workers /redistribution
   - Controlled napping

2. How do benefits compare with costs?

Evaluate and treat risks
Fatigue risk management cycle

1. Monitor
   Compliance with controls (planned vs actual hours) (management of schedule changes)

2. Evaluate
   Operational performance
   Errors
   Are people feeling drowsy
   Are people getting enough sleep

3. Investigate
   Incidents accidents
   Collect work history

4. Analyse data and report
Same approach as for other risks:

1. Establish the context
2. Identify risks
3. Analyse risks
4. Evaluate and treat risks
5. Monitor Review

This cycle outlines the steps for managing risks, including establishing the context, identifying risks, analysing risks, evaluating and treating risks, and monitoring the outcomes through review.
Fatigue models in risk management

- Not valid for individuals
- Different models predict different things
  - Fatigue (sleepiness),
  - Performance,
  - Incident risk
- Generally less predictive if continued sleep loss
- Rostering principles are essential
Use of fatigue models

• Distribution of fatigue across business units
• Check staffing levels
• Analyse roster options

Source: Cabon, Lancelle and Mollard 2009
Use of fatigue models

Use for roster scenario testing

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**Night work 21:30 to 05:30**
Sleep estimate = 4.3 hrs
Peak FAID score ceiling = 100

**Night work 23:30 to 05:30**
Sleep estimate = 4.6 hrs
Peak FAID score ceiling = 79

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Risks Index

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Effectiveness (%)
Establishing tolerable boundaries for hours of work (safe hours of work)

**Regulation 29:** FRMP must specify work scheduling practices that provide for **safe** hours of work

*...hours are work taken to be safe if the effect of implementing those hours is sufficient to manage risks arising from fatigue SFAIRP*
Example scheme:

- Emergency hours
- Extended hours
- Normal hours

Tolerable boundary for safe hours of work
Example scheme:

**Normal hours**
- Based on risk of tasks and foreseeable range of operating conditions
- Caters for leave, attrition, common delays and equipment failures
- Planned to cover majority of the work
Extended hours
• Defined infrequent events
• Not foreseeable and no practical alternate
  (e.g., major equipment/infrastructure failure, breakdown, or unplanned leave & no reliever available)
• Undesirable but risk tolerable if exposure limited and additional risk controls

Example scheme:

Extended hours
Tolerable boundary for safe hours of work

Normal hours
Example scheme:

Emergency hours
- Extraordinary events (accident or natural disaster or unusual event that affects network and multiple trains).
- Life threatening or extreme loss implications
- High risk due to combination of degraded human performance and technical systems
- Outside risk tolerance

Tolerable boundary for safe hours of work
Boundaries determined by risk

Risk assessment has determined:
• High task related fatigue
• Unpredictable hours
• Unfavourable work environment
• Unfavourable rest environment
• Commuting long distances
• Systems not error tolerant
• Consequences of error are high
• ........
• ........

Decision: narrow envelope for tolerable hours
Boundaries determined by risk:

Risk assessment has determined:
• Lower risk tasks
• High number of rest breaks
• Opportunity for naps
• Error tolerant systems
• Safety assurance processes monitoring sleep and performance

= wider envelope for tolerable hours
Monitoring (example)

- Monitor exposure to extended zone (e.g., planned vs actual)
- Monitor implementation of additional risk controls
- Tolerable limits
Reporting (example)

- Emergency hours
- Extended hours
- Normal hours

Report breaches of tolerable limits as Cat B occurrences

Notify changes in boundaries of normal or extended
Achieving compliance: future ONRSR work
Future ONRSR Checklist (draft)

- RTO consults with workers in development/review of FRMP
- Identifies and assesses unique sources of fatigue:
  - Timing of work and breaks
  - Circadian and time awake factors
  - Time on task and workload
  - Call outs and on call
  - Commuting
  - Changes such as lift up and lay back
  - Staffing levels and relief
  - Work environment
  - Rest environment
Compliance checklist (draft)

- Assesses risk under normal/abnormal/degraded & emergency conditions
- Analyses tasks to identify main errors and violations and associated risks
- Identifies current controls for fatigue-related hazards and risks
- Evaluates effectiveness of controls
- Identifies options for improved or new controls
- Rejects or adopts controls according to risk criteria
Compliance checklist (draft)

- Identifies tolerable boundaries of work scheduling practices
- Provides adequate staffing/relief
- Provides education/training to RSW
- Monitors compliance with risk controls
  - Planned vs actual hours
  - Changes due to overtime, shift swapping
- System to report scheduling breaches to ONRSR as Cat B
- System to report change boundaries of work scheduling practices
Resource: www.railroadersleep.org
Summary and conclusions

- Theory of sleep
  - Fatigue, safety and productivity
- Fatigue risk management in practice
- Achieving compliance
- Next steps
- Have we met your needs and expectations?
- Any questions??