Institute of Transport Economics
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Summary:

Countermeasures for use in fatigue risk management

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Increased safety in land- and sea-based transport can be achieved if more employers manage the risks related to operator fatigue. An effective way to do this is to select and apply up to 15 types of countermeasure to manage fatigue along a risk trajectory, beginning with the nature and timing of work and ending with the manifestation of fatigue in incidents and poor health outcomes. The 15 types of countermeasure are: adequate manning; schedule design; breaks and naps; monitoring of actual hours worked; optimisation of work quality; sleep monitoring; health screening and treatment; promotion of recovery from work; recovery monitoring; identification of fatigue symptoms; containment of fatigue while operating; performance assistance; and fatigue-proofing. By grouping these countermeasures according to the location on the risk trajectory of the fatigue hazard addressed, a model of fatigue mitigation is obtained for use in fatigue risk analysis and countermeasure selection by transport risk managers. These managers would be further assisted by knowledge on the effectiveness of interventions using countermeasures, on business drivers for fatigue risk management, and on measures to encourage other transport chain actors to consider fatigue. The use of countermeasures in fatigue risk management has the potential to improve the wellbeing and safety of any employee driving for work.

Work-related fatigue is a threat to safe transport, with considerable environmental, economic and health costs. There is increasing recognition that organisations should do more to manage fatigue in any employee who must operate a vehicle or vessel in the course of their work.

Setting the context: fatigue and its mitigation

There are many definitions of fatigue, but many share the idea that it is a state caused by exertion that can manifest itself physiologically, cognitively or emotionally, and which can affect work performance and health over the shorter or longer term. As there are many possible forms of exertion, safety practitioners must assess fatigue caused by exertion in all aspects of work and non-work life.

Western society is sleeping less than it used to and globalisation demands transport operations at all times of the day or night. At the same time operators must carry out a large variety of tasks, and face increasing competition and tighter deadlines. Due to advances in automation, the main operator task may be becoming more monotonous and there is reason to believe that this will have deleterious effects on both fatigue and safety performance levels. Research studies have surveyed many of the overlapping and interacting factors that influence fatigue, and grouped them as relating to (i) sleep and schedules worked, (ii) occupation or branch being considered, (iii) individual health, (iv) life outside work, or (v) demographics.

There is good evidence linking sleep-related fatigue to poorer performance, and linking sleep-related performance decrements to safety levels. Links between task-related fatigue and operator performance decrements are also established. Despite this knowledge, fatigue continues to cause a substantial share of serious transport

accidents and incidents. One possible explanation for this is that too little emphasis has been placed on fatigue management by organisations. Drivers and crew have traditionally been held responsible for managing their own fatigue levels, and legislation has encouraged organisations to focus on the management of hours at work / operating, even though this is only one of several causes of fatigue. Sleep deprivation has also been underappreciated generally as a public health problem.

Fatigue risk management by organisations is a growing trend, promoted by theoretical developments, regulatory changes, and new technology. However, it is still not clear whether there will be wide uptake in the road and maritime sectors. Part of the problem is that there may be under-appreciation of the operational advantages offered by comprehensive risk management, which in turn may be due to a lack of robust evaluation of fatigue risk management interventions.

Reviews conclude that transport organisations wishing to tackle fatigue have tended to rely on one-off countermeasures, most often training courses lasting no more than one day, attempts at schedule management, or screening and treating operators for sleep disorders. While these measures may be effective, there is scope for a more comprehensive and effective approach to fatigue management, even for small outfits with few resources. One way to achieve this is by initiating a fatigue risk management system (FRMS), which is a safety management system focused on a single risk: fatigue. In line with safety management systems, the central tenets of an FRMS are fatigue management policy, fatigue risk management (risk assessment and mitigation), fatigue reporting systems, fatigue incident investigation, fatigue training, and continuous monitoring of system effects.

Fatigue risk management, which is at the core of FRMS, involves selecting countermeasures for fatigue according to standard risk analysis procedures. First, undesirable fatigue-related health or safety incidents will be reviewed and selected, and then prioritised for mitigating action by assessing the likelihood that they will occur and seriousness of their consequences. The causes of prioritised undesirable events will then be assessed, such that countermeasures can be put in place. The mitigation of fatigue is structured most effectively by considering that fatigue manifests itself along a five-step fatigue risk trajectory. The trajectory begins when work causes fatigue (level 1). If the operator then fails to recover from work (level 2), fatigue symptoms become manifest (level 3), and if they are not addressed fatigue-related errors will occur (level 4), which if left unchecked will lead to fatigue-related incidents (level 5). Effective fatigue risk management requires that the risks in each level along this trajectory are monitored and controlled by effective countermeasures.

Review of available countermeasures

The main aim of this report is to review, structure and simplify existing knowledge on countermeasures using knowledge available in the peer-reviewed literature. In particular, we identify and describe 15 groups of countermeasures, arranged according to where along the risk trajectory the mitigated fatigue hazard is located. The countermeasures and corresponding hazard levels are shown in figure S1.

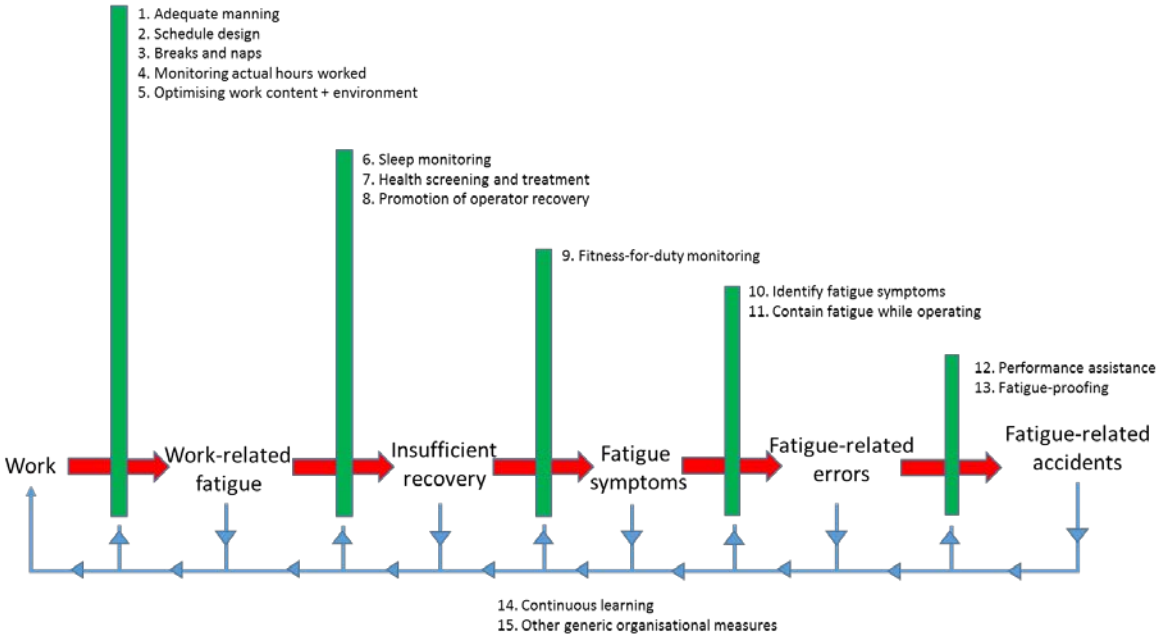

Figure S1. Countermeasure groups for fatigue in human transport operators arranged along a fatigue risk trajectory. After an initial risk analysis, barriers (in green) should be put in place to minimise the chance that work causes fatigue-related accidents. The manifestation of fatigue should be monitored at each step of the trajectory, and used to evolve and evaluate the barriers preceding that step, as indicated by the blue arrows.

Each of the countermeasures 1-15 in Figure S1 is explained and exemplified in Table S1. The particular choice of countermeasure and final barrier structure will depend not only on the nature of the transport operation and hazard to be mitigated, but on the resources available to the employer, the current approach to safety risk management, and the scope of fatigue risk management required.

Countermeasure effectiveness and future research needs

Countermeasures which have been shown to affect fatigue outcomes should be prioritised. These include job design interventions, health screening and treatment, and stopping to sleep or drink caffeine during longer operating periods. More evaluations are required to compare interventions with different types of countermeasure or barrier on standard outcome measures, in order to be able to rank countermeasure combinations in terms of effectiveness. Evaluations of implementations of whole systems of fatigue risk management are also required.

Answers to the following questions are also needed to promote effective fatigue risk management by transport employers:

- What evidence is there that fatigue risk management brings business benefits to employing organisations? On a related point, what drives employers to implement fatigue risk management systems?
- What opportunities are there for centralised monitoring of employee fatigue as it manifests itself along the risk trajectory?
- What role can transport buyers or other transport chain actors play in fatigue risk management, and how can their participation best be encouraged?.

- How can the experience and knowledge of consultant practitioners in fatigue risk management be made more widely available to better map the
- possibilities available to organisations wishing to manage fatigue risks in transport operators?

Table S1. Specific examples of each countermeasure group, one for a simple approach to fatigue risk management by a company with limited resources, and one for a comprehensive approach where more resources are available.

Countermeasure group		Example of specific countermeasure	
		Simple approach	Comprehensive approach (e.g. FRMS)
1	Adequate manning	Increase number of operators	Increase number of operators
2	Schedule design	Use of simple formula or guidelines	Schedule optimisation based on biomathematical modelling software with input data on actual sleep times
3	Breaks and naps	Plan rest stops in advance	Evaluation of strategic napping intervention
4	Actual hours worked	Compare self-reports / logs of actual working hours with planned schedules	Analyse change in fatigue risk index for actual schedules worked versus those planned
5	Optimise work content	Simple survey to identify and reduce secondary tasks causing fatigue	Human factors / task analysis and optimisation by independent consultant
6	Monitor actual sleep	Wearables giving feedback and tips on sleep improvement via mobile app	Centralised collection of actigraph data to feed into schedule design
7	Health screening and treatment	Develop fatigue checklist in collaboration with doctor to be used at annual check-up	Monthly screening by occupational health service with follow up of disorders influencing fatigue
8	Promote operator recovery	Provide taxi to/from ship/depots after long operating periods	Sleeping facilities at depots, sleep contracts, family training
9	Monitor fitness-for-duty	Mobile app-vigilance test	Vigilance test with results fed into FRMS
10	Monitor fatigue symptoms while operating	Self-assessment with Tiredness Symptoms Scale	Embedded performance monitoring, facial/eye technology
11	Contain fatigue while operating	Promote stopping and sleeping	Promote stopping and sleeping
12	Performance assistance technology	-	Requires further validation
13	Fatigue-proofing	Increase customer awareness and involvement	Technological safeguards
14	Continuous learning	Regular review and optimisation of countermeasures	Safety assurance, data-driven evaluation of each risk level at regular meetings
15	Other organisational measures	Recruitment	Safety culture development Needs analysis