

A Comparative Approach to Seafarers' Fatigue

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Abstract

Against a background of widespread concern amongst maritime regulators, responsible ship owners, P and I clubs, seafarers' welfare organisations and trade unions, two recent pieces of our research provide insights into different aspects of the problem of maritime fatigue. A long history of research into working hours and conditions and their performance effects in process industries, road transport and civil aviation, where safety is a primary concern, can be usefully compared to the situation in commercial shipping. Where prevention and management of fatigue is more advanced in these other sectors, it should be possible to "fast-track" the approach to maritime fatigue. The extensive research and evidence base from other industries can be extrapolated to apply to seafarers' fatigue. The present paper will compare our knowledge of seafarers' fatigue and fatigue in other industries. Existing literature will be reviewed and empirical results on the prevalence and outcomes of fatigue presented.

Keywords

Seafarers' fatigue; rail transport; road transport; air transport.

1. Introduction

Global concern with the extent of seafarer fatigue and its potential environmental cost is widely evident across the shipping industry. Maritime regulators, ship owners, trade unions and P and I clubs are all alert to the fact that with certain ship types a combination of minimal manning, sequences of rapid port turnarounds, adverse weather conditions and high levels of traffic may find seafarers working long hours and with insufficient recuperative rest. In these circumstances fatigue and reduced performance may lead to environmental damage, ill-health and reduced life-span among highly skilled seafarers who are in increasingly short supply. A long history of research into working hours and conditions in manufacturing as well as road transport and civil aviation industries has no parallel in commercial shipping. There are huge potential consequences of fatigue at sea in terms of both ship operations (accidents, collision risk, poorer performance, economic

cost and environmental damage) and the individual seafarer (injury, poor health and well-being,). Not only has there been relatively little research on seafarers' fatigue but what there has been has been largely focused on specific jobs (e.g. watch keeping), specific sectors (e.g. the short sea sector) and specific outcomes (e.g. accidents). This reflects general trends in fatigue research where the emphasis has often been on specific groups of workers (e.g. shift workers) and on safety rather than quality of working life (a crucial part of current definitions of occupational health).

2. Fatigue

2.1 What is fatigue?

The technical use of the term fatigue is imprecise. Indeed, the variety of fatigue inducing situations, time courses and outcomes suggests that it is unlikely that we are considering a single set of processes leading to a specific underlying state. This makes integration of the existing literature very difficult. A person may feel fatigued, performance may deteriorate and the body's physiological functioning may be affected. These three outcomes, subjective perceptions, performance and physiological change are usually recognised as the core symptoms of acute fatigue. The condition is usually recognised by the reporting of fatigue and the objective outcomes then assessed. Estimates of the prevalence of fatigue will vary depending on which aspect of the fatigue process one uses as the indicator of fatigue. For example, if one assumes that doing shift work is a risk factor for fatigue one might simply use the number of workers doing shift work as an indicator of prevalence. However, this is based on the assumption that shift work automatically leads to fatigue which one finds is not always the case. Similarly, fatigue may be measured by the presence of negative outcomes, but the extent of the problem will often depend on the indicator chosen. There is no single "right" approach: all aspects of the fatigue process must be assessed and considered.

2.2 Risk factors for fatigue

Acute fatigue may be induced by a number of factors: lack of or poor quality sleep, long working hours, working at times of low alertness (e.g. the early hours of the morning), prolonged work, insufficient rest between

work periods, excessive workload, noise and vibration, motion, medical conditions and acute illnesses. Chronic fatigue can either be due to repeated exposure to acute fatigue or can represent a failure of rest and recuperation to remove fatigue. Many working patterns induce acute fatigue and also lead to more chronic patterns. For example, working at night is associated with reduced alertness during the shift and may also produce cumulative problems because of poor sleep during the day. Risk factors for fatigue have been widely documented and can be split into factors which reflect the organisation of work (e.g. working hours, task demands, the physical environment) and characteristics of the individual (both stable traits, and current state). Many of the established risk factors for fatigue are highly relevant to seafarers. These potential problems often reflect organisational factors such as manning levels or the use of particular shift systems (e.g. 6 on, 6 off). Others may reflect the specific voyage cycle of the ship. What is important to recognise is that it is the combination of risk factors that is crucial; fatigue may be most readily observed when a large number of these are present.

Most regulatory bodies have, until recently, focused on work schedules as the most important predictor of fatigue with the role of psychological and emotional factors not studied to the same extent. Moreover, few studies have examined how risk factors might combine in terms of their effects, or attempted to benchmark the different risk factors (e.g. what are the relative contributions of factors such as isolation, long working hours and high job demands to fatigue levels?). Recent studies have shown that psychosocial workplace stressors tend to demonstrate cumulative associations with self-reports of work stress and poor health outcomes. In a large survey of the general working population, high demands, high effort, low control, low support, low reward and exposure to physical hazards, combined with shift-work and long hours, were found to demonstrate significantly greater associations with work stress when considered in an additive model rather than individually. Moreover, this combined stressor score was linearly related to the outcome (Smith, McNamara, and Wellens, 2004). Similar results have been demonstrated for a number of health outcomes. A combination of high job strain (high demands and low control) and an imbalance between perceived efforts and rewards at work has been shown in a case-control study to predict acute myocardial infarction better than either model alone (Peter, Siegrist, Hallqvist, Reuterwall, and Theorell, 2002). Additive models of stressors have also demonstrated linear patterns of association with accidents at work using the Ergonomic Stress Level (ESL) measure, an instrument designed to calculate body motion and posture, physical effort, active hazards and environmental stressors in the workplace (Luz, Melamed, Najenson, Bar, and Green, 1990).

2.3 Prevalence of fatigue in the workforce

Prevalence of fatigue in the general working population has been estimated to be as high as 22% (Bultmann, Kant, Kasl, Beurskens, and van den Brandt, 2002b) and

there exists a substantial literature relating work schedules and other work stressors (e.g. high demands) to fatigue in onshore populations. High job demands and role conflict were found to be associated with fatigue in a sample of NHS trust employees (Hardy, Shapiro, and Borrill, 1997), and findings from the Maastricht Cohort Study of 'Fatigue at Work' suggest that work schedules and psychosocial work stressors such as high demands (physical and emotional) and low control contribute to high levels of fatigue. Overtime and shift work were significantly associated with increased need for recovery from work-related fatigue in a large sample [n=12,095] of the general working population (Jansen, Kant, Van Amelsvoort, Nijhuis, and Van den Brandt, 2003; Jansen, Kant, and van den Brandt, 2002), and in a sub-sample of men within the same cohort, psychological, physical and emotional work demands (with a protective effective of high job control) were linked with cumulative fatigue incidence during a 1-year follow-up study (Bultmann, Kant, van den Brandt, and Kasl, 2002a).

2.4 Consequences of fatigue

There is extensive evidence from both laboratory and field studies showing that acute fatigue is associated with impaired performance and compromised safety. Smith (Smith, 1999) has reviewed the effects of fatigue on performance and concluded that many of the risk factors for fatigue are present offshore. Similarly, reviews of fatigue and safety at work (e.g. (Costa, 2003; Folkard, Lombardi, and Tucker, 2005; Folkard and Tucker, 2003)) conclude that the move to less standardised working requires a new understanding of adaptive processes. Such trends have always been present at sea where 24 hour flexibility is an essential part of the industry. A cross-industry review by Folkard and Tucker (Folkard and Tucker, 2003) concludes that working at night can lead to compromised levels of safety with productivity inevitably also likely to suffer. Similarly, when reviewing the literature on working patterns and shift schedules, Folkard, Lombardi and Tucker (Folkard, Lombardi, and Tucker, 2005) highlight three key trends which have emerged from research into shift schedules and safety: (1) risk of an accident is higher when working at night (and to a lesser extent when working in the afternoon) compared to the morning, (2) risk of an accident increases over a series of shifts, again especially at night and (3) risk of an accident increases as total shift length increases over 8 hours (in any 24 hour period).

It is often the combination of risk factors that leads to impaired performance and reduced well-being and few would deny that seafarers are exposed to these high risk combinations. For example, if an individual is sleep deprived then this fatigue will be amplified by other factors which also induce fatigue (e.g. doing a boring task or having to work at night). In transport many jobs are often "safety critical" and one would expect a strong association between risk factors for fatigue and reduced safety. This can be seen very clearly in road transport. Recent results in accident research (road transport) indicate that the

risk of accidents at work is a function of hours at work and sleep deprivation. There is an exponentially increasing accident risk beyond the 9th hour at work. The relative accident risk is doubled after the 12th hour and tripled after the 14th hour at work. In general, it is recommended to have at least 8 hours of rest per 24 hours. In the majority of industries there is appropriate regulation to minimise the risk of accidents. Ships have the potential to cause billion dollar accidents making the evaluation and audit of regulations crucial. To date, however, such evaluation has been minimal.

Among the general working population, fatigue has been associated with accidents and injuries (Bonnet and Arand, 1995; Hamelin, 1987). It has also been clearly linked to ill health (Andrea, Kant, Beurskens, Metsemakers, and van Schayck, 2003; Barger, Cade, Ayas, Cronin, Rosner and Speizer, 2005; Chen, 1986; Costa, 2003; Folkard, Lombardi, and Tucker, 2005; Huibers, Bleijenberg, van Amelsvoort, Beurskens, van Schayck, Bazelmans and Knottnerus, 2004; Knutsson, 2003; Koller, 1983; Leone, Huibers, Kant, van Schayck, Bleijenberg and Knottnerus, 2006; Mohren, Swaen, Kant, Borm, and Galama, 2001; van Amelsvoort, Kant, Beurskens, Schroer, and Swaen, 2002), as well as poorer work performance (Beurskens, Bultmann, Kant, Vercoelen, Bleijenberg and Swaen, 2000; Charlton and Baas, 2001), sick leave and disability (Janssen, Kant, Swaen, Janssen, and Schroer, 2003; van Amelsvoort, Kant, Beurskens, Schroer, and Swaen, 2002), and is a common factor in workers' consultations with GPs (Andrea, Kant, Beurskens, Metsemakers, and van Schayck, 2003). Furthermore, the concept of a *process* from negative work conditions, to fatigue, to illness has been suggested. Prospective studies have shown that psychosocial work characteristics significantly predict fatigue onset (Bultmann, Kant, van den Brandt, and Kasl, 2002a), and that preceding fatigue is significantly related to illness (Mohren, Swaen, Kant, Borm, and Galama, 2001). Although the direction of the relationship between risk factors for fatigue, perceived fatigue, and ill health has not always been conclusively established, the implication that fatigue may be a mediator between work risk characteristics and illness is apparent. Like most areas of fatigue research, the link between fatigue and health requires further investigation. Research usually starts by studying short term effects of fatigue, which in the case of health usually means an increase in mental health problems. Impaired mental health is a risk factor for more serious disease (e.g. cardiovascular disease) which clearly provides a path from fatigue to increased mortality risk.

In summary, fatigue can affect the individual by impairing performance, reducing safety, affecting well-being, increasing mental health problems and, possibly by increasing risk of chronic disease. These health problems may lead to disability and an inability to work. Fatigue can also lead to poorer social interaction with other workers which can extend to life outside work. Reduced safety due to fatigue will increase the risk of accidents that may lead to loss of life, environmental damage and huge economic cost.

3. Fatigue research in other transport sectors

There is a long history of investigating the impact of fatigue in other transport sectors and this topic has been developed from three main areas. The first sources of information are anecdotal reports of the impact of fatigue. Secondly, there has been extensive research on the effects of fatigue in the laboratory, much of it starting over half a century ago (e.g. Bartley and Chute, 1947; Ryan, 1947; Floyd and Welford, 1953) and reviewed in detail many times (e.g. symptoms of acute and chronic fatigue – see Craig and Cooper, 1992; sleep deprivation – see Tilley and Brown, 1992; night work – see Smith, 1992; disruption of circadian rhythms – see Campbell, 1992; sustained work – see Nachreiner and Hanecke, 1992). Finally, there is a long history of research on fatigue in military transport operations (e.g. Bartlett, 1943) and in the process industries (e.g. Wyatt, Langdon and Stock, 1929). These types of research have led to more focused studies of transport, with driving receiving the most attention (e.g. Crawford, 1961; Brown, 1994, 1997). This probably reflects the fact that the problem of driver fatigue is a public health issue rather than being restricted to the occupational context. International meetings (see Hartley, 1997; Akerstedt and Haraldsson, 2001) have provided overviews of the area and developed a framework for evidence-based countermeasures. The overall consensus is that transport fatigue is a major problem that has previously been under estimated (Akerstedt and Haraldsson, 2001) and where appropriate strategies for prevention and management are required. Indeed, Jones, Dorrian, Rajaratnam and Dawson (2005) have compared laws and regulations that limit working hours for safety purposes in the different transport sectors and evaluated them against eight fatigue-related criteria based on current scientific knowledge. None of the regulations assessed addressed all eight criteria. It was proposed that fatigue can best be dealt with by a hybrid approach incorporating both a prescriptive “hours of service” system and a non-prescriptive, outcomes-based approach.

The extent of recent research on transport fatigue can be seen by examining the papers presented at the *International Conference on Fatigue Management Transportation Operations 2005* (see Appendix 1 for a bibliography). The papers demonstrate the range of issues being studied – laboratory studies of fatigue on fundamental skills required in transport operations; epidemiological studies of fatigue; evaluation of countermeasures; and assessment of fatigue management programmes. What is also apparent is the limited research activity focusing on the maritime sector – 4% of the papers.

3.1 Road transport

There is a strong evidence-base confirming that fatigue increases the risk of road accidents (e.g. Connor, Whitlock, Norton and Jackson., 2001; Hakkanen and Summala, 2000). Much of this research has been based in the USA, Europe and Australia but recent studies confirm that the effects of fatigue are present in many different countries (e.g. Greece – Tzamalouka, Pa-

padaki, and El Chiaoutakis, 2005; Yugoslavia – Milosevic, 1997; Peru – Rey de Castro, Gallo and Loureiro, 2004; Israel – Sabbagh-Erlich, 2005; and Norway – Sagberg, 1999) A series of studies by the National Transportation Safety Board (NTSB) in the USA have pointed to the significance of sleepiness as a factor behind accidents involving heavy vehicles (NTSB, 1990; NTSB, 1995; Wang and Knippling, 1994). In the 1995 study, NTSB came to the conclusion that 52% of single vehicle accidents involving heavy trucks were fatigue-related, and in 17.6% of the cases, the driver admitted falling asleep. The 1990 NTSB study showed that fatigue was the most important cause (31%) of fatal accidents. A similar incidence of fatigue-related accidents has also been reported in the air-traffic sector (Philip and Akerstedt, 2006). Recent results in accident research (road transport) indicate that the risk of accidents at work is a function of hours at work and sleep deprivation (Philip et al., 2005). Other risk factors for effects of fatigue on driving have been shown to include increased day time sleepiness (e.g. induced by sleep apnoea – Haraldsson, Carenfeldt, Diedrichsen, Nygren and Tingvall, 1990), sedative drugs, changes in sleep/wake cycles (Philip, Ghorayeb and Stoohs, 1996; Phillip, Taillard, Guilleminault, Quera Salva, Bioulac and Ohayan, 1999), working at night (Gold, Rogacz and Bock, 1992; Hamelin, 1987), driving in the early morning (the risk of having an accident at this time is increased 5.5 times and the risk of a fatal accident 10 times – Akerstedt, Kecklund and Horte, 2001; Akerstedt and Kecklund, 2001) and combinations of sleep loss/circadian troughs and alcohol (Keall, Frith and Patterson, 2005). Organisational factors are also related to the frequency of road accidents. For example, Goodwin (1996) found an increased frequency of crashes as truck fleet size decreased. Arnold and Hartley (2001) state that “one of the characteristics of practices of the long distance transport industry is the absence of supervisory oversight during driving --- they do not have moment-to-moment knowledge of what is going on”. These issues of manning and working in isolation will be returned to when considering the maritime sector. The countermeasure for accidents caused by work/rest schedules is obviously a change of pattern, such as reducing night driving or early starts. Other countermeasures include introducing naps, which seem to reduce accident risk, or even a rest break (Landstrom, Akerstedt, Bystrom, Nordstrom and Wiborn, 2004). Another approach is to recommend consumption of caffeinated beverages (Reyner and Horne, 1997) or to use technological devices to detect fatigue and give the driver a warning (e.g. Dinges and Mallis, 1998; Lal, Craig, Boord, Kirkup and Nguyen, 2003). There are a variety of different forms of legislation that aim to prevent driver fatigue from developing (see Jones, Dorrian, Rajaratnam and Dawson, 2005). Several countries have also convened expert panels to review regulatory options for reducing heavy vehicle driver fatigue (e.g. National Road Transport Commission, 2001; Transport Development Centre, Transport Canada, 1998; University of Michigan Transportation Research Centre, 1998). Methods of auditing potential risk factors have also

been established (e.g. the Circadian Alertness Simulator – Moore-Ede, Heitman, Guttkuhn, Trutschel, Aguirre and Croke, 2000) and modelling of fatigue has been carried out (e.g. Folkard and Akerstedt, 1992; Jewett and Kronauer, 1999; Belyavin and Spencer, 2004; Dawson and Fletcher, 2001; Van Dongen, 2004). Training in fatigue awareness and management is also in place in a number of organisations (see Gander, Marsha, Harris and Reid, 2005; AWAKE, 2006), and this has been supported by information campaigns aimed at drivers in general (e.g. *THINK – Tiredness kills. Make time for a break*: UK Department of Transport, 2006; Fletcher, McCulloch, Bauk and Dawson, 2005) not just in the commercial sector.

3.2 Rail transport

Fatigue and railway operations has been studied for many years (e.g. Grant, 1971) with much of the interest being in the association between fatigue and critical incidents (e.g. signals passed at danger – Buck and Lamonde, 1993). The approach to driver fatigue has been very similar to that seen in road transport. Indeed, studies using train simulators have shown that train drivers’ performance is also impaired by fatigue (Dorrian, Roach, Fletcher and Dawson, 2006a, b; Roach, Dorrian, Fletcher and Dawson, 2001). Studies from many different countries (e.g. Poland - Malgarzeta, 1982; China - Zhou, 1991) have confirmed the impact of fatigue in rail transport. Major developments in rail fatigue research have occurred since the advent of the Federal Railroad Administration’s Fatigue Research Program. Sussman and Coplen (2000) and Pilcher and Coplen (2000) have reviewed the potential for fatigue in the rail industry. These problems can be summarised as: working 24/7 under a range of physical conditions and service demands; being on call; shorter than 24-hour work rest cycles (in over one third of locomotive engineers); and reduced sleep duration and quality. Coplen and Sussman (2001) discuss the aims of the rail fatigue research program. This program adopts a non-prescriptive approach to:

1. Developing better data collection methodologies.
2. Developing better measurement and evaluation tools.
3. Developing more effective fatigue countermeasure strategies.

The program has led to the North American Rail Alertness Partnership which has been important in identifying specific areas of concern, developing co-operation between government, unions and industry, and also disseminating information. It has been acknowledged that fatigue is a problem in many jobs in the rail industry (train crews, signalmen, and track workers) and that prevention of fatigue, alertness enhancement strategies and advanced technologies need to be used to address the issue. Better labour management agreements are needed, as are fatigue-related educational programs, improved schedule regularity and more practical and adaptable federal laws and regulations.

One interesting development in the UK has been the application of the HSE Fatigue index (Spencer, Robert-

son and Folkard, 2006) to the railway industry (Stone, McCuffog, Spencer, Turner and Mills, 2005). The research consisted of diary studies of factors influencing fatigue (shift timing and length, continuous driving time, hours worked per week, consecutive shifts, shift variability, rests between shifts). Associations between these and number of signals passed at danger were then examined. On the basis of the results the following recommendations were made:

1. A reduction in shift length by limiting night and early shifts to 10 hours would mitigate fatigue.
2. Continuous periods of driving should be restricted to four hours.
3. Limiting maximum hours over a rolling week to 55 would allow sufficient recovery time between shifts.
4. Consecutive night shifts should be limited to three before a rest day, early shifts to five before a rest day, and other shifts to seven before a rest day.
5. Controlling the variability of shifts will reduce fatigue and a rapid change from a late finish or night shift to an early start should be avoided.
6. A rest period of 14 hours between consecutive night shifts is desirable to allow sufficient recovery.
7. A change from nights to earlies should incorporate at least two rest days. All other shift changes should incorporate at least one rest day.
8. The HSE Fatigue Index is currently the best option for use in assessment of the shift patterns of safety critical rail workers.

This has led to the development of a good practice guide for drivers to help them cope with shift work and fatigue. New railway safety legislation in the UK will include an approved code of practice on managing fatigue in safety critical work. Use of the HSE fatigue index will help organisations to ensure that workers do not carry out safety critical work when they are already fatigued, or have work patterns that would be liable to cause fatigue. Similar approaches are being developed in other countries (e.g. Sherry, 2005; Jay, Lamond, Ferguson, Dorrian and Dawson, 2005).

3.3 Air Transport

Fatigue has been identified as a major potential problem for many parts of the air transport industry (aircrew; air traffic controllers; maintenance personnel). Concern with fatigue in aircrew developed during the Second World War and the results from these early studies showed quite clearly that prolonged flying resulted in performance decrements (Welford, Brown and Gabb, 1950). Problems of fatigue in aircrew became much greater as long haul flights became common place (Cameron, 1971; Grandjean, Wotzka, Schaad and Gilgen, 1971) and this led to a systematic series of studies from the NASA-Ames research group examining flight crew fatigue in commercial pilots (Gander, Graeber, Connell, Gregory, Miller and Rosekind, 1998 [I-VI]). These studies measured sleep, circadian rhythms and fatigue before and after scheduled commercial flights. Short haul fixed wing, short haul helicopter,

overnight cargo and long haul aircraft were studied. In all operations sleepiness increased over trips and in the overnight cargo and long haul flights there were impairments due to flying during circadian troughs. In addition, time zone shifts can increase fatigue. Recent research (e.g. Wright, Powell, McGown, Broadbent and Loft, 2005) has shown that fatigue can be detected by EEG or eye movement recording, and that measurement of wrist inactivity can be linked to a warning device that prevents unwanted sleepiness.

Again, fatigue risk management systems have been developed for the aircraft industry (see Booth-Bourdeau, Marcil, Lawrence, McCulloch and Dawson, 2006; McCulloch, Fletcher and Dawson, 2002) and the 'Fatigue Risk Management Toolbox' typically consists of:

1. Policy templates and guidelines to assist in the development of global and detailed corporate policies on the management of fatigue.
2. Competency-based training and assessment for employees, management and new staff.
3. Fatigue audit tools to assess work schedules, verify actual fatigue levels and monitor the fatigue risk management process.

4. Fatigue Prevention Legislation, Recommendations and Management Programmes for the Transport Industry

In civil aviation fatigue that can appear in air cabin crews is a recognised factor for flight safety. Therefore flight-time and the duty-time are regulated by the ICAO (International Civil Aviation Organization) Agreement (1974). The aim of the ICAO agreement is to prevent the influence of fatigue on air-safety by limiting the workload which is achieved by reducing the duty hours in the case of extended flight requirements, by reducing the night-flying hours and by defining the time necessary for rest. The regulations of ten countries, all ICAO members, have recently been compared (Missoni, Nikolic and Kovacevic, 2006). Two countries only consider the flight time, whereas the other eight members take into account the duty time and the flight time too. Only five countries emphasise in their regulations the rest time of the flight crew before duty. Only two member countries (Switzerland and Great Britain) emphasise in their regulations the significance of the daily duty time, and three (Germany, Scandinavia and Switzerland) of the night flying hours. Night sleep has a far better effect than sleeping during day, but only three member countries (Australia, France and Scandinavia) specifically stress its importance. Three member countries out of ten (Germany, Scandinavia and Switzerland) consider flying through time zones as a significant factor in determining the duty time. Every airport takeoff/landing represents a significant workload for the pilot, and this workload is additive with those due to other factors. The number of T/Ls (take-off/landings) is emphasised as an important factor by six member countries. Air-crew augmentation (one or more assistant pilots) as a factor influencing the crew duty time and the aircraft flight-range appears in the regulations of eight countries. All

the state authorities agree that it is necessary to restrict the duty time and the flight time of the aircrew during the day. This results in a conflict between the economic interests of airlines and the state regulations which set safety flight requirements. In their regulations the majority of countries rely more on the duty time than on the flight requirements as the criteria for the crew workload. In order to prevent the accumulation of fatigue all the ICAO member states provide restrictions to the total flight time per week, month and year. In Germany, Switzerland, USA and Croatia the law on air traffic restricts the annual flight operations of a pilot to 1000 hours, and duty period of up to 1600 hours. Crews of other countries have shorter annual operations in a range from 700 to 800 (Russia and Japan) and 900 – 935 (Great Britain and France). Similar regulations could be applied to seafarers and regulations such as those described above act as a good model from which to develop maritime legislation. However, the above section shows that it is very difficult to get a unanimous approach across different countries. Transport fatigue has also been reviewed at the national level and recommendations made for appropriate regulation (e.g. the US National Transportation Safety Board, 1999). The Australian National Transport Commission Fatigue Expert Group (2001) has produced the following comprehensive recommendations for the sleep, shift work, night work and duration of working hours of truck drivers:

Sleep - A minimum sleep period in a 24-hour period is required to maintain alertness and performance levels. Continuous and undisturbed sleep is of higher quality and more restorative. The group concluded that the minimum sleep requirement in a single 24-hour period is six consecutive hours of sleep (although the average required on a sustained basis is about seven to eight hours). The group then considered the length of break that would enable the six-hour minimum which is necessarily longer than the six-hour sleep minimum period. Breaks need to take account of the activities of daily living including preparation for sleep and return to work. The impact of the circadian biological clock is critical in determining appropriate breaks in which sleep opportunity is possible. The group recommended the minimum sleep opportunity per 24 hours should be sufficient to allow for six consecutive hours of sleep.

The cumulative nature of fatigue and sleep loss - Minimum sleep opportunities have to be considered over longer periods because of the cumulative nature of sleep loss and fatigue. The expert group agreed that the six hour minimum sleep requirement is adequate on one day, but not sufficient on an ongoing basis.

Recovery sleep - Recovery sleep after an accumulated sleep debt is usually deeper and more efficient, and the lost hours of sleep do not need to be recovered hour-for-hour. Repaying the debt, to restore normal waking function, usually requires two nights of unrestricted sleep. As a consequence the group recommended that schedules should permit two nights of unrestricted sleep on a regular basis (preferably weekly) to provide drivers with the opportunity to recuperate from the effects of accumulating sleep debt.

Night work - Driving at night was considered an important factor for the expert group as it brings together the elements that generate fatigue risks. Working at night produces an elevated risk of fatigue-related impairment, because it combines the daily low point in performance capacity with the greatest likelihood of inadequate sleep. The group concluded that the combination of risk factors associated with night driving should be recognised by ensuring that the length of breaks to enable sleep following night work are suitable and that opportunities for night sleep are available in a seven-day period. Additionally the group proposed a limitation to the number of hours (a limit of 18 hours) that could be driven in the 0000-0600 period after which two nights of unrestricted sleep should be available.

Rest breaks - The expert group recommended that in a one-day period the driver should take non-work breaks equal to 10% of the total working time; these breaks should be taken at the discretion of the driver but they should not be accumulated to form long breaks. As a minimum, short rest breaks should include a non-work break of 15 minutes after every five hours work. A less flexible means of achieving non-work breaks equal to 10 per cent of total working time would be to require a 30 minute non-work break to be taken after every 5 hours of work.

Duration of working time - The expert group concluded that a “safe” threshold for daily working time on a sustained basis will vary according to other factors like time of day, but the upper limit is in the 12-14 hours zone. There was evidence that longer trips could be undertaken on a one-off basis but that repeated long trips rapidly escalated fatigue risk factors. Whilst the group believed flexibility for these longer trips should be provided they needed to ensure that long trips were not combined with risks associated with night driving and circadian low points. To underpin this short term flexibility, the expert group recommended that any one-off long trips involving over 12 hours work should not extend into the 0000-0600 period and that during a seven-day period there should be no more than 70 hours of working time.

Recent research (Rhodes, Gill, McCulloch and Fletcher, 2005) evaluated fatigue management processes and approaches in the transport sectors with the aim of determining best practices. The review concluded that few existing programmes consist of the crucial key components and that few have been properly evaluated. Good fatigue management programmes should have the following key components:

1. Organisational commitment to the requirements of a ‘Fatigue Management Programme’.
2. Establishment of a ‘Fatigue Management Policy and Process’.
3. Involvement of all stakeholders throughout the process.
4. Competency based educational modules.
5. Effective change to the scheduling, dispatching and compensation processes.
6. Objective and subjective measures of fatigue management effectiveness.
7. Continual monitoring and improvement.

5. Implications of the approach to fatigue in other transport sectors for seafarers' fatigue.

It is apparent that the issue of fatigue has been approached in a more systematic way in other transport sectors than it has in the maritime sector. There are probably many reasons for this, the first being historical, the second being the extent to which occupational issues become public health issues (e.g. road transport is a public health issue as well as an occupational issue), and the final reason reflecting the extent to which the sectors reflect international or national (local) concern.

The different transport sectors clearly have some similar fatigue-related issues and the scientific approach to fatigue has attempted to define general principles that should apply to all sectors. Indeed, this forms the basis of general attempts to regulate working hours but these are often thwarted by sectors or countries with vested interests in particular sectors opting out from the regulations. Research also suggests that a "one size fits all" approach to regulation may be inappropriate. For example, while our knowledge of appropriate times for sleep is well established, this may not apply to situations where sleep quality is reduced, as is often the case at sea.

Although there has been more attention to fatigue in other transport sectors it would be wrong to assume that current approaches represent "best practice". Rather, it is the case that prevention and management of fatigue is more advanced in other sectors and, on the basis of the experience of these sectors, it should now be possible to "fast track" developments in the prevention and management of fatigue at sea. Indeed, if one looks at all of the possible approaches to the prevention and management of fatigue (regulation, enforcement, awareness campaigns, training, and guidance) one finds that every one is deficient in the maritime sector. One reason for the well developed approach in other sectors has been the knowledge base that now exists about fatigue in these industries. This extensive research on fatigue in other transport sectors (and other occupations) can now be applied to seafarers' fatigue. The need for this will become apparent after the review of studies on fatigue in the maritime industry. A second reason for developments in this area in other sectors has been the interaction of all the stakeholders to advance our understanding of what underlies fatigue and what can be done to prevent and manage it.

6. Comparing the fatigue of seafarers with other groups

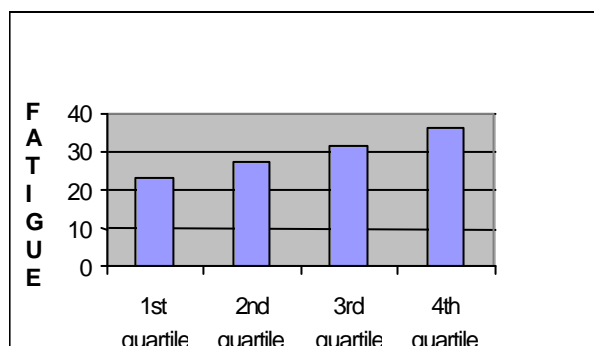
6.1 Support shipping for the offshore oil industry and installation workers

In this phase comparisons were made between the seafarers in the offshore oil support industry, those working on installations and an onshore comparison group (see (Smith, Lane, and Bloor, 2001; Smith, 2003) for details). The results showed that a significant proportion of oil installation workers feel that their working hours

and shift patterns are detrimental to their health and personal safety, and that the effects of working offshore impinge considerably on leave time. Detailed analyses of the survey data suggested that rotating shift patterns, long work hours and poor sleep all have a negative impact on health and well-being, both physical and psychological. However, these issues were less of a problem amongst offshore workers than might be expected. Indeed, seafarers appeared considerably more robust than either installation workers or a comparison group of onshore workers. Furthermore, it would appear that the somewhat poorer health of installation personnel can be explained, in part at least, by poor adaptation to complex (i.e. rotating) shift systems. There was also the perception that things were considerably worse on installations than in the past whereas many of the seafarers were ex-fishermen and found their current jobs to be less demanding than being a fisherman. This suggests that perceptions of fatigue may reflect not only current working conditions but the contrast with past employment. Further studies of those starting a seafaring career are necessary to avoid the impact of previous working conditions. It would also be interesting to ascertain from future research whether the greater well-being observed amongst some groups of offshore personnel is a product of self-selection and regular health screening. This is a topic which can only be examined by a longitudinal health study following a cohort of seafarers and ex-seafarers over time.

Smith and McNamara (Smith and McNamara, 2002) examined reports of disturbed sleep in seafarers, oil installation workers and an onshore sample. Both seafarers and oil installation workers reported more sleep disturbance than the onshore sample and over 40% of the offshore workers reported noise disturbed sleep. Motion also produced sleep problems in over 40% of the seafarers. Lack of sleep was significantly related to perceptions of physical and mental fatigue amongst both seafarers and installation workers. Poor concentration was significantly related to sleep quantity amongst both groups of offshore workers. Of respondents who reported too little sleep, 70.5% of installation workers, 67.2% of seafarers and 46.9% of onshore workers felt that their working patterns seriously compromise personal safety. A similar pattern of results was observed for operational safety. These results confirm the potential problems associated with disturbed sleep. However, individual factors rarely occur in isolation and this phase of the project included the first analysis of the combined effects of risk factors for fatigue.

McNamara and Smith (2002) examined the combined effects of risk factors for fatigue in both seafarers and installation workers. These results confirm that those exposed to a large number of potential risk factors are most likely to report fatigue and impaired health (Fig-



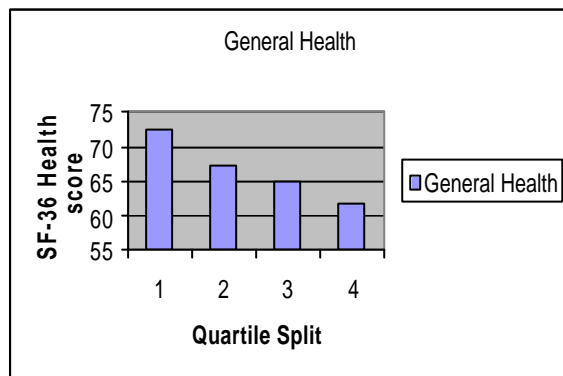
ures 1 and 2)

Figure 1: Combined effects of work hazards and scores on the PFRS Fatigue scale

(High scores=greater fatigue. Fatigue is plotted against reports of work hazards, with the first quartile representing the lowest number of hazards and the 4th quartile the highest number of hazards)

Figure 2 Combined work hazards and the General Health Score from the Short Form Health Questionnaire [SF-36]

(High scores=better health. Health is plotted against reports of work hazards, with the first quartile representing the lowest number of hazards and the 4th quartile the highest number of hazards)



6.2 Comparisons between seafarers from the offshore support sector, short sea sector and deep sea sector with onshore groups

McNamara et al. (McNamara, Allen, Wadsworth, Welens, and Smith, Submitted) report the results from respondents in the three different sectors investigated in the project. The main features of the study are outlined below.

The final total sample comprised 1856 seafarers. This sample is the combination of respondents from the three phases of the research, which corresponded to industry sectors.

6.2.1 Offshore support sector

In the initial phase of the survey, letters detailing the nature and purpose of the study and a copy of the questionnaire were sent to 1600 members of NUMAST selected as working in the offshore oil support sector between 2000 and 2001. A letter of support from a union official was also included with the mail shot, along with a freepost envelope in which to return the questionnaire. 439 completed questionnaires were received (a response rate of 27.4%). Questionnaires were also distributed to seafarers onboard offshore oil support vessels by visiting researchers: the total number of re-

spondents from 6 vessels was 124, yielding a total sample of 563. In terms of vessel types, the sample was most highly represented by seafarers working on supply vessels (29.3%, n=164), support vessels (26.3%, n=147), standby vessels (13.8%, n=77), pipe layers (35, n=6.3%) and dive support vessels (6.8%, n=38).

6.2.2 Short sea and coastal sector

Three recruitment methods were used to access a representative sample of seafarers. 2740 questionnaires were sent to NUMAST members identified by a union representative as operating in the short sea and/or coastal sectors. Secondly, 1120 questionnaires were sent to employees of four shipping companies (2 ferry [n=760] and 2 tanker operators [n=360]). A total of 791 completed questionnaires were received using these two sampling methods (a combined response rate of 20.5%). Questionnaires were also distributed by researchers visiting short-sea vessels: a total of 145 questionnaires were completed by seafarers on 7 vessels. The total sample comprised 936 short sea and coastal workers. In terms of vessel types the short-sea sample was primarily made up of seafarers working on passenger ferries (41.4%, n=383), freight ferries (20.3%, n=188), high-speed ferries (8.5%, n=79) and products tankers (14.4%, n=133).

6.2.3 Deep sea sector

The method of recruitment differed slightly for the deep sea sector: the initial mail shot comprised a letter from a union official detailing the nature and purpose of the survey sent to 3,179 potential participants. The final sample comprised 302 participants equating to a response rate of 11.2%. A key reason for achieving a lower response rate than previous phases was that deep sea workers are generally away for longer tours of duty which makes them less likely to receive and return questionnaires. A total of 18 completed questionnaires were received from members of the Transport and General Workers union (TandG) although a response rate cannot be calculated due to independent survey distribution. Finally, 36 completed questionnaires were received as a result of distribution among crew on 3 vessels visited in the third phase, producing a total deep sea sample of 356. In terms of vessel type the deep sea sample represented seafarers working on a broader range of ships including containers (19.0%, n=66), gas tankers (12.9%, n=45), products tankers (9.8%, n=34), cruise ships (9.8%, n=34), and other tankers not previously listed (17.2%, n=60).

The following analyses were carried out among the cross-phase sample (i.e. on the 1856 seafarers who completed the survey from the three industry sectors).

6.3 Risk factors for fatigue

Analyses showed consistent associations between fatigue and a number of variables: occupational and environmental factors were most highly associated with

fatigue.

All these factors were included in multivariate models. Tour length, sleep quality, environmental factors, job demand and work stress were associated with all three fatigue measures. Switching from sea to port work and age were associated with both PFRS fatigue and fatigue at work. Variable working hours and job support were associated with fatigue at work and fatigue after work. Role, rank and smoking were associated with both PFRS fatigue and fatigue after work. Physical hazards, job security and flag were associated with PFRS fatigue and, port frequency was associated with fatigue at work. Increased risk of general fatigue was associated with shorter tours of duty – that is, those on shorter tours of duty were consistently more likely to report high fatigue levels. This may reflect aspects of the work inextricably linked to tour length, such as vessel type, sector etc. It was also associated with: fatigue when switching to port; being younger; poor sleep quality; high exposure to physical hazards; high exposure to negative environmental conditions; low job security; high job demands; high levels of stress at work; having a rank other than officer; being a smoker; and serving on a ship with a non-British flag. The association between fatigue and younger workers (those under the sample median of 45 years) may reflect seafarers' adjustment with experience, some self-selection, or both these factors. Increased risk of fatigue at work was associated with: shorter tours of duty; working more than 12 hours a day; working 6 or 12 hour shifts; fatigue when switching to port; high port frequency; being younger; poor sleep quality; high exposure to negative environmental factors; little variation in work hours; low social support; high job demands and high stress.

6.4 Consequences of fatigue

The survey contained questions that measured cognitive failures (errors of attention, memory and action). It also assessed the extent to which seafarers perceived that their working hours presented a danger to themselves and the ship. Wadsworth et al. (Wadsworth, Allen, McNamara, Wellens, and Smith, Submitted) examined the associations between perceived fatigue, risk factors for fatigue and cognitive failures. The results showed that those who reported high levels of fatigue were at a greater risk of making frequent cognitive failures. Frequent cognitive failures were also more likely to be reported by: those doing shorter tours of duty; those doing 6 or 12 hour shifts; those with poor sleep quality; those exposed to physical or environmental hazards; those with high job demands; those with high levels of stress at work; officers; and older workers (an association between older workers and more frequent cognitive failures is consistent with findings from general workers surveys (e.g. (Simpson, Wadsworth, Moss, and Smith, 2005)). These findings suggest that, as well as general fatigue risk factors, seafaring is subject to additional specific fatigue risk factors that are particularly linked to poorer cognitive function. McNamara et al (McNamara, Allen, Wadsworth, Wellens, and Smith, Submitted) examined the associations between risk

factors for fatigue and the extent to which seafarers perceived that their working hours presented a danger to themselves and the ship. In total 870 (48%) respondents considered their working hours sometimes presented a danger to their personal safety, and 668 (37%) considered that their working hours sometimes presented a danger to the safe operations of their ship. Those who felt their working hours were a danger to themselves or the ship's operations had much higher levels of both perceived fatigue and perceived symptoms of fatigue. The perceptions of personal and operational risk from fatigue were strongly associated, with 613 seafarers reporting both (92% of those who reported a danger to the ship also felt hours were a danger to their personal safety; and 71% of those who reported a danger to themselves also felt hours were a danger to the ship). McNamara et al (McNamara, Allen, Wadsworth, Wellens, and Smith, Submitted) examined the associations between risk factors for fatigue and the short term symptoms of fatigue. Shorter tour length, sleep quality, job demand and work stress were all associated with both measures of short term fatigue consequences. Wadsworth et al. (Wadsworth, Allen, McNamara, Wellens, and Smith, Submitted) report results from analyses examining associations between risk factors for fatigue, perceived fatigue and reports of well-being and health. The results showed that greater psychological distress, poorer general health and more frequent GP visits were all associated with both fatigue risk factors (such as work stress and job demand) and fatigue. The association with fatigue was independent of work characteristics that were risk factors for fatigue. The impact of fatigue over that of the other associated risk factors was more than additive. Worsening work characteristics were associated with increased fatigue over time, and increases in fatigue were associated with deterioration in psychological and general health. This study, using self-report measures of perceived fatigue and health, suggested that fatigue was strongly linked to poorer physical and mental health among seafarers. The impact of fatigue in the industry may, therefore, be much greater and more widespread than watch-keeping and accident statistics imply. In addition, reported fatigue could arguably be an important and measurable intermediary between fatigue risk factors and well being. One important question is whether the samples we have studied are representative of the industry. Smith et al. (Smith, Lane, Bloor, Allen, Burke and Ellis, 2003) found that the onboard samples studied were broadly representative of the participating companies, and those companies were also largely representative of the wider sampling frame. McNamara et al. (McNamara, Allen, Wadsworth, Wellens, and Smith, Submitted) continued this approach and found that the current sample should be considered representative of a 'good', if not 'best case scenario' in terms of seafarers who have extensive experience of working at sea and relatively little experience of suffering from fatigue when compared with a multi-national sample. Given this conclusion it seems tenable that problems identified here are likely to be a concern on a greater scale elsewhere.

6.5 Comparison with onshore workers

The onshore sample consisted of 99 working men. Their mean age was 40.0 (standard deviation 6.53) and all were married or living with a partner. They held a wide variety of jobs (e.g. train driver, baker, web designer, administrator etc) and worked an average 41.79 hours per week (standard deviation 9.44) (approximately eight hours per day). Comparing these respondents with seafarers showed that seafarers reported higher fatigue at work but had similar scores on the general fatigue scale of the profile of fatigue related states questionnaire and after work fatigue measures (Table 1). Seafarers also worked more hours per week with 97% reporting 50 or more hours compared to 20% of the onshore sample ($p < 0.0001$).

Table 1: Comparison of fatigue levels between seafarers and working men in the general population study; higher scores=higher fatigue

	GENERAL POPULATION MEAN (SE)	SEAFARERS MEAN (SE)
General fatigue	28.11 (1.37)	27.30 (0.33)
At work	3.18 (0.09)	3.67 (0.02)
After work	2.41 (0.06)	2.44 (0.01)

6.6 Comparison with road haulage drivers

In total 80 road haulage questionnaires were completed. All but 2 of the respondents were male, their mean age was 47.38 years ($sd=10.32$, $min=28$, $max=71$) and most were married or cohabiting (90%, $n=72$). Just over half (56%, $n=41$) mainly drove C+E category vehicles (large goods vehicles with trailers: vehicles over 3500kg with a trailer over 750kg), and a further 30% (22) mainly drove C1+E category vehicles (medium sized vehicles with trailers: vehicles between 3500kg and 7500kg with a trailer over 750kg – combined weight not more than 12000kg). The mean length of time they had worked in road haulage was 19.20 year ($sd=11.60$, $min=1$, $max=45$). Road haulage drivers and seafarers were compared on three measures of fatigue: PFRS fatigue, fatigue at work and fatigue after work. Their levels of fatigue at and after work were similar, but road haulage drivers had higher mean PFRS fatigue scores (Table 2). Comparing seafarers and road haulage drivers on risk factors for fatigue showed no differences in terms of support at work. However, a greater proportion of seafarers had poor job security (53% compared to 38%, $p=0.03$), high job demand (41% compared to 24%, $p=0.01$), physical hazards (52% compared to 25%, $p < 0.0001$), and worked 60 hours per week or more (89% compared to 16%, $p < 0.001$). Among the seafarers number of port turnarounds was related to fatigue and a similar trend was seen for the drivers, where those who made the most deliveries were more fatigued. This suggests that lorry drivers and seafarers show parallel trends in terms of fatigue and that fatigue can be observed in contexts which are to some extent operation-

ally comparable.

Table 2 Mean (se) fatigue levels among seafarers and drivers

	SEAFARERS	DRIVERS
PFRS fatigue	27.53 (0.32)	34.10 (1.77)
Fatigue at work	3.67 (0.02)	3.75 (0.11)
Fatigue after work	2.43 (0.01)	2.45 (0.07)

7. Conclusions

This research programme has provided an evidence base for the development of fatigue recommendations and guidance. These general recommendations for addressing seafarers' fatigue are summarised below.

Review how working hours are recorded. Fatigue is more than working hours, but knowing how long seafarers are working for is critical in terms of evaluating how safe current operating standards are. This study shows the current method for recording and auditing working hours is not effective and should therefore be reviewed.

Fatigue management training and information campaigns. Fatigue management training and information campaigns for seafarers are likely to prove effective but only as part of a unified approach involving all levels of authority. Such an approach will only be effective if crew are empowered to act on their training in terms of actively intervening with operations when required.

Establish an industry standard measure of fatigue. No 'gold standard' measure of fatigue currently exists which makes the task of comparing and evaluating the impact of research results extremely difficult. Work needs to be done which either sets out the case for adopting the use of one particular fatigue measure as the industry standard, or looks towards developing a new scale for industrial and research purposes. If all parties are using the same fatigue measure progress in this field will undoubtedly be accelerated.

Develop a multi-factor auditing tool. The study has shown that it is the combination of different risk factors that puts an individual at risk of fatigue. A taxonomic or checklist-style auditing tool therefore needs to be developed to include not only work characteristics known to be risk factors for fatigue but also subjective experience of this factor.

Our analysis has shown that it is the combined effect of a range of factors that is associated with fatigue. The consequence of this conclusion is that changing one or two factors can have a disproportionately large impact. The development, implementation, and, crucially, evaluation of strategies to address fatigue must be carried out jointly across all levels of the industry. However, their application must also be tailored, at a local level, to be appropriate and practical. Tackling fatigue at sea must involve the industry as a whole because it has the potential to benefit at an equally universal level. Another conclusion is that there are many more controls or regulations aimed at preventing fatigue in other comparable transport industries. It is apparent that the issue

of fatigue has been approached in a more systematic way in other transport sectors than it has in the maritime sector and, on the basis of the experience of these sectors, it should now be possible to “fast track” developments in the prevention and management of fatigue at sea. Indeed, if one looks at all of the possible approaches to the prevention and management of fatigue (regulation, enforcement, awareness campaigns, training, and guidance) one finds that every one is deficient in the maritime sector. One reason for the well developed approach in other sectors has been the knowledge base that now exists about fatigue in these industries. A second reason for developments in this area in other sectors has been the interaction of all the stakeholders to advance our understanding of what underlies fatigue and what can be done to prevent and manage it.

Another obvious conclusion is that current legislation and guidance on fatigue has not had the desired effect across the industry. Hours of work are likely to be under-recorded, either by management, or individual seafarers wary of jeopardising their current or future employment by bringing the company under legislative scrutiny. Similarly, guidance too often involves suggestions that are beyond the control of the individual and which cannot compete with economic pressures. One approach would be to improve on current measures addressing fatigue (e.g. improved guidance; enforcement of working time directives). Another would be to focus on specific aspects of the problem and deal with those using standard health and safety approaches. Looking at manning levels from a wider perspective, there may be reasons other than fatigue that would suggest that increases are needed (e.g. safety in emergencies). Other possible organisational changes, such as changes in shift patterns need to be evaluated, since knowledge about shift work onshore may not be directly applicable to circumstances offshore. Indeed, little is known about the effects of tour length with different shifts and recent research on oil installations (Smith, 2006) shows that even 2 weeks of 12 hour day shifts can lead to cumulative fatigue.

The evidence reviewed demonstrates that seafarers’ fatigue is common and widespread. There are clearly serious risks and consequences inherent in allowing vessels to be manned by fatigued seafarers. These can be summarised as follows:

1. Potential for more environmental disasters.
2. Economic costs due to fines for accidents, losses, and increased insurance premiums.
3. Serious health and safety implications for seafarers.

The way forward is to treat seafarers’ fatigue as a serious health and safety issue. A starting point must be to take a more robust approach to regulation. Manning levels need to be addressed in a realistic way that prevents economic advantage accruing to those who operate with bare minimums. Such an approach must consider more than the minimum levels necessary to operate a vessel rather it must address the need for maintenance, recovery time, redundancy, and the additional burden of the paperwork and drills associated with security and environmental issues. Another essential requirement is to enforce existing guidelines with manda-

tory provisions and take serious measures to overcome the problem of false record-keeping. This must be supplemented with appropriate training and guidance regarding avoidance of fatigue and the creation of optimum working conditions. Lessons can be learned from other transport industries and it is important to seek examples of best practice and apply these in an effective way to the maritime sector. Methods of addressing issues specific to seafaring are now well developed and a holistic approach to the problem of fatigue can lead to a culture that benefits the industry as a whole.

8. Acknowledgements

The research described in this report was supported by the Maritime and Coastguard Agency, the Health and Safety Executive, Nautilus UK, the Seafarers’ International Research Centre, Cardiff, and the International Transport Federation. We would also like to acknowledge the contribution made by the ship owners and their employees who have participated in the research. We would like to acknowledge the contribution of our steering committee especially Tony Lane and Mick Bloor who played major roles in the development of the research. Parts of the data collection and analyses have been carried out by Rachel McNamara, Alison Collins, Victoria Cole-Davies, Neil Ellis, Geoff Boerne, Jo Beale, Ailbhe Burke and Ben Wellens. The views expressed in the report are those of the authors and should not be taken to reflect the official position of the sponsors.

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