Foreword

Fatigue is a key component in many accidents where human error is a contributing factor. Many "headline hitting" catastrophes such as Three Mile Island, Bhopal, Chernobyl and Exxon Valdez have occurred at night. They have been at least partially attributed to fatigue or human error and have resulted in major costs. These costs are not only financial, but are also in terms of human life and environmental pollution. Indeed, the financial cost of sleep-related accidents in the USA has been estimated to be as high as $43-56 billion per year [1]. While this estimate has been challenged, even the most conservative estimate suggests that some 2.5% of all accidents may be attributable to "sleepiness" [2]. If this very conservative estimate of the proportion of accidents due to sleepiness is applied to UK data on work-related accidents [3], it yields an estimated annual cost of work accidents caused by "sleepiness" of some £115-240 million.

Many fatigue-related accidents reflect the fact that we have evolved as a diurnal species that is "designed" to wake up at dawn and to fall asleep in the evening when it gets dark. This diurnal nature is clearly evidenced in the fact that although we rely on vision far more than any of our other senses, we actually have very poor night vision, especially in comparison to nocturnal species. However society increasingly demands the provision of services, including rail transport, outside daylight hours and hence as many as 20-25% of those employed in the service sector work on some form of shift system. This can cause many problems for the individuals concerned, especially during the night when they are required to work when their bodies "expect" to sleep. Following the night shift they then try to go to sleep at precisely the time at which all their biological processes are set to wake them up. Indeed, requiring people to work at night is a little like requiring them to live in the sea. Our diurnal nature is just as strong an integral part of our biological make up as is the fact that we are a terrestrial rather than an aquatic species.

It is, however, not only the night shift that can cause problems. Another feature of our internal body clock is that it gears us down in anticipation of sleep in the evening, and that it is actually very difficult for someone to fall asleep much earlier than their habitual bedtime. This can cause enormous problems with early starts where a driver may have to wake up far earlier than normal in order to commute to their depot in time to book on. Indeed, it has been empirically estimated in one study that for each hour earlier that shiftworkers have to leave home to commute to work, they get 47 minutes less sleep because they only get to sleep about five minutes earlier. Thus when staff have to book on before about 07:00 their sleep is likely to have been substantially shorter than normal.

Reduced sleep duration and sleep disturbances may impact on safety in two main ways. First, it is clear that however conscientiously an individual tries to resist sleep as their fatigue increases, there will come a point where they are unable to prevent themselves from “nodding off”. Clearly a driver who falls asleep, however briefly, may compromise safety. Secondly, even if a driver maintains wakefulness, high levels of fatigue are likely to result in impaired performance, decision making, and judgement. Further, “lapses of attention” where a driver either fails to recognise a signal for what it is, or fails to respond appropriately, are substantially more likely in fatigued individuals. Indeed the magnitude of these effects is such that the fatigue associated with many work schedules may impair performance to the same, if not greater, extent as the legal limit of alcohol for driving. Although no Train Operating Company (TOC) would condone drivers turning up for work with the legal limit of alcohol for driving, it is probable that most of them inadvertently utilise work schedules that may sometimes compromise safety to a similar extent.

The body of this report summarises much of the research literature that relates to fatigue and safety to work schedules. There is a reasonably substantial scientific literature in this area, with some clear implications for good practice. Essentially work schedules should be designed in such a way as to (i) minimise the build up of fatigue by limiting features such as the number of successive night or early shifts, (ii) maximise the dissipation of fatigue by providing adequate breaks and rest days, and (iii) minimise the disturbances of sleep and of the “body clock”. In some cases the available evidence provides reasonably clear pointers. Thus, for example, the risk of accidents rises quite substantially over successive night shifts, suggesting that the number of successive nights should be limited to a maximum of two or three nights (unless those concerned are “permanent” nightworkers). However, in other cases the literature is more ambiguous, suggesting the need for further research.

An example of this is the length of duty periods. Although it is clear that excessively long duty periods should be avoided, the available evidence, including that on SPADs, often shows a transient peak in risk during the second to fourth hour on duty. Indeed the magnitude of this transient peak is such that it accounts for about 50% of all SPADs (Wharf 1993) [55]. This transient peak implies that work schedules that involve a lot of short duty periods may actually be less safe than those involving fewer, somewhat longer ones. Indeed, mathematical modelling of this effect suggests that the safest duty periods are those of between 8 and 10 hours in length. However, it also suggests that extending a duty period to 12 hours may be associated with no greater increase in risk than covering the same work with two six-hour duty periods. There are, however, unanswered questions relating to the transient two to four hour peak in risk, suggesting a need to refine the manner in which accidents and their precursors, for example SPADs, are recorded in the future. This would allow future analyses to determine more accurately the precise trend in risk relative to both the start of the work period and the timing of breaks.

Despite these uncertainties, there is a strong case to be made for developing and piloting a set of guidelines for good practice with one or more TOCs. This would involve getting representatives of the management and drivers to formulate a set of guidelines with the benefit of expert advice from various quarters, and then to implement these guidelines on a trial basis for a period of two to three years. The impact of the new guidelines could then be assessed by means of follow-up surveys at, say, six monthly intervals, as could any cost implications. In a related vein, research is also urgently needed on the work schedules actually worked by drivers with a view to determining the range of work schedules in operation, and how these may be affected by working overtime to cover for absent colleagues, or by swapping duties. It would clearly be inappropriate to produce guidelines for good practice for the entire network that were so strict that they could not be implemented.

The problem of fatigue is not a new one. However there is increasing demand for the provision of 24-hour services and increasing public pressure to maintain safety at acceptable levels. Fatigued workers may constitute an unacceptable risk to safe rail operations and this problem is likely to increase unless we develop usable guidelines for the drawing up of work schedules.

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October 2000

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CONTENTS

Published by Railtrack PLC Safety & Standards Directorate
Evergreen House 160 Euston Road London NW1 2DX

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1 Introduction

1.1 Background

In 2000, the Defence Evaluation and Research Agency (DERA) conducted a study on Visual and Mental Acuity in train drivers which included a review of shiftwork and fatigue [4]. A number of ideas were proposed for the re-design of rosters currently worked by these.

In light of this study, Railtrack Safety & Standards Directorate (now Railway Safety) decided to review the evidence DERA put forward to support these proposals and produce a Position Paper on their understanding of current thinking on shiftwork, fatigue and other associated issues.

To reflect recent research, Railway Safety have updated their Position Paper.

1.2 Overview

The purpose of this Position Paper is to explain why the design of shift patterns has an impact on fatigue, and to demonstrate the role fatigue can play in error and accidents. The paper is supported by evidence from a wide range of studies conducted both in the laboratory and in the field.

The Position Paper starts with the premise that fatigue is a potential cause of accidents. Examples of where fatigue has contributed to accidents are provided. The paper then identifies shiftwork to be a major contributory factor to fatigue and explains why shiftwork is a significant cause, namely the failure of our internal body clock to fully adjust to shift working and the cumulative sleep deficit which arises from working shifts. Different types of shifts and shift patterns are reviewed in detail in order to identify the aspects that contribute most to fatigue. Finally, the paper provides details of current thinking on guidance for the design of shift patterns and concludes by detailing Railway Safety's programme of research and evaluation designed to help move the rail industry towards optimum shift working and fatigue management practices.

The paper has been reviewed by Professor Simon Folkard, who is widely recognised as a leading world authority on the various problems associated with shiftwork, especially fatigue and safety, and in 1996 was elected as chairman of the Shiftwork Committee of the International Commission on Occupational Health (ICOH).

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2 How does fatigue contribute to accidents?

Fatigued operators can cause accidents. Simon Folkard provides a good example of this in his paper Transport: Rhythm and Blues (2000) [5]. In July 1996, the Peacock, a Panamanian flagged refrigerated cargo ship, ran aground while she was sailing down the inner channel of the Great Barrier Reef. This incident raised considerable concern since the breaking up of the vessel could have caused substantial damage to the coral reef.

Australia's Marine Incident Investigation Unit found that the Peacock had grounded at full speed (about 16 knots) at about 01:55 only 100 yards from a light beacon (Parker et al 1998) [6]. This was despite the fact that navigation lights are actually far more visible at night than during the day. The inquiry concluded that it seemed probable that the pilot had fallen asleep about 15 minutes before the grounding, and suggested that the formation of competing pilotage services (ie, privatisation) had resulted in a reduction of income for individual pilots. It is understood that the pilots' hourly rate of pay had effectively halved with the result that they had doubled their work hours.

Numerous other accidents have occurred at night, such as Three Mile Island, Bhopal and Chernobyl. It has been estimated that in the US alone, the cost of all sleep-related accidents is between 43 and 56 billion dollars per year, though this does include accidents at work and in the home (Leger, 1994) [7].

Of course it is possible that fatigue might not be the only factor contributing to accidents at night. There could be something different about a task at night that makes it more difficult and therefore more prone to error. To establish whether this might be the case, Folkard [8] examined performance in situations where shiftworkers perform an identical task under constant conditions. He found that performance was poorest at about 3am, which is the same as the trend found in road accidents. This clearly implies that the increased likelihood of a road accident in the early hours of the morning is not because the task of driving is so different, but is because of the state of the individual doing the driving.

This finding was also confirmed by an analysis that looked at the risk of accidents associated with different shifts [9]. This found that where the influence of confounding variables, such as type of task and number of individuals present, was limited, the night shift showed a 30% increase in the risk of accidents compared with the morning shift.

The evidence suggests that fatigue is a significant contributor to accidents and as such, it should be minimised to reduce the risk of their occurrence. However, in order to determine how to minimise fatigue, it is first necessary to understand what causes it.

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3 What causes fatigue?

3.1 Overview

Fatigue is a difficult concept to define. For example, mental fatigue can be associated with both overload and underload from a task that is either overly demanding or monotonous and boring (although the physiological effects are the same, Grandjean, 1988 [10]). However, the result of fatigue is generally accepted to be 'a dimunition in the capacity and/or inclination to work' [11].

There are a number of causes of fatigue and also a number of possible consequences. Figure 1 provides an influence diagram that has been developed to show how various factors influence fatigue and the potential consequences fatigue may have on operations and personnel. The diagram does not necessarily consider all the potential influences nor does it represent the complexity of the relationships between the factors. Its aim is to represent the main issues. However, this position paper is primarily concerned with the relationship between fatigue, shiftwork and safety (*ie* the non-shaded areas of the diagram) and therefore all the potential causes and consequences of fatigue, represented in Figure 1, are not addressed here, but, for information, have been outlined in Annex A.

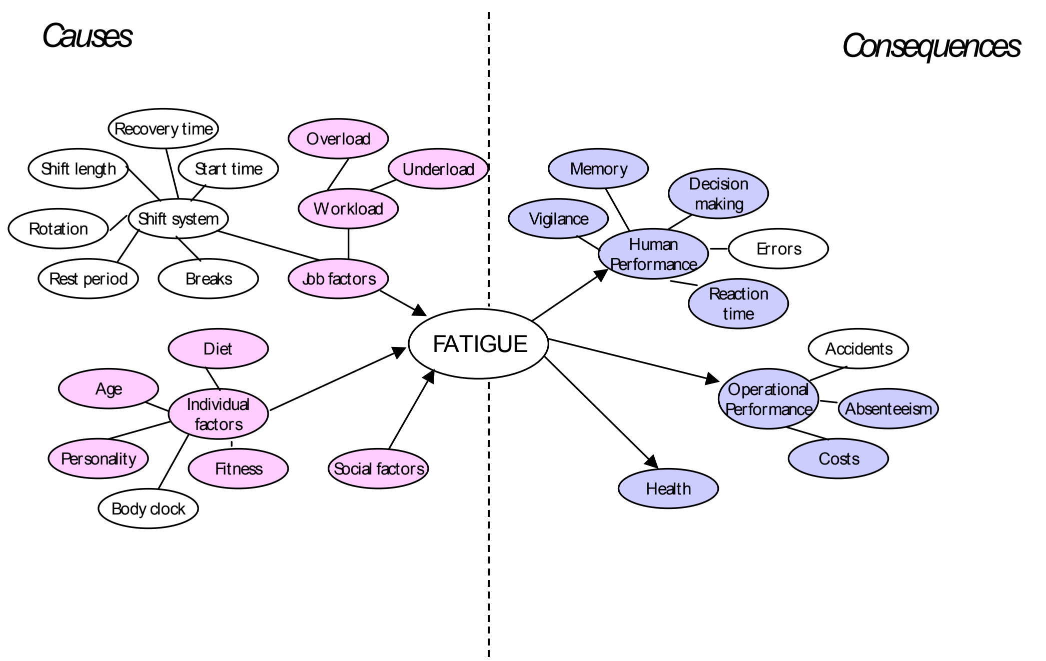

Figure 1: Causes and Consequences of Fatigue: An Influence Diagram

3.2 Shiftwork

Shiftwork contributes to fatigue in train drivers and other operators because it limits the amount of sleep that workers are able to obtain to ensure that they are able to maintain sufficient alertness when at work. For example, human error and poor judgement, related to sleep loss and shiftwork during the early morning hours, were cited as contributing to the Space Shuttle Challenger accident, [12]. Certain key managers had slept for less than two hours the night before and had been on duty since 01:00 that morning. The resulting fatigue was reported to have impeded effective communication and jeopardised job performance.

One of the main reasons why shiftwork limits our ability to obtain sufficient sleep is because of our 'internal body clocks' or circadian (around the clock) rhythm. This is explained in the following two sections of this paper.

3.3 The internal body clock

It is well established that people feel more sleepy in the early hours of the morning. Simon Folkard [5] describes a study conducted on Swedish train drivers which clearly demonstrates this.

Train drivers were studied on day and night drives using an observer who sat beside them and noted any errors they made. In addition electrodes were placed on drivers' heads for the electroencephalographic (EEG) (brain activity) recording of the drivers' sleepiness [13]. The results showed a clear build up of sleepiness during the course of the night drives (indicated by the EEG) but not during daytime drives. They also found that during the night drives, drivers made errors, such as failing to stop at a light or to reduce speed, despite the observer's presence, and that these errors tended to occur when the EEG showed drivers to be most sleepy.

The reason for feeling sleepy at night is very simple. Like all other species, we have evolved in a world subject to pronounced 24-hour changes in light and temperature, due to the movements of the earth relative to the sun. Early life forms probably simply responded to these changes, but at some point during the course of evolution it transpired that there was an advantage to actually anticipate these changes rather than merely respond to them; as the saying goes, 'the early bird catches the worm'. Almost all species, including humans, have evolved an internal 'body clock' that allows them to anticipate the pronounced 24-hour environmental changes. We now know that this clock is situated in the suprachiasmatic nuclei (SCN) of the brain. If the SCN is removed from animals, they lose their normal sleep/wake cycle and other 'circadian' (around a day) rhythms.

The most obvious manifestation of this body clock is our marked propensity to sleep at night rather than during the day. We are not designed to drive a train or pilot a vessel at night, we don't have good night vision and our body clock winds down all our physiological processes in the evening in anticipation of sleep. It's clear we can normally resist this pressure to fall asleep, but it would seem that there is a cost.

3.4 The internal body clock and sleep patterns

The impact that our body clock has on our sleep patterns has been investigated in a number of studies.

Lavie (1986) [14] conducted a rather strange study which involved volunteers being put to bed for seven minutes and got out of bed for 13 minutes over a 24 hour period. He showed that, even if people were sleep deprived, their propensity to sleep was greatest in the early morning and late at night.

Wever, in the 1960s [15], recruited volunteers to live in an underground laboratory for periods of a month or more. The laboratory was shielded from the natural light/dark schedules, outside noise and even the earth's magnetic field! The volunteers were allowed to sleep and wake whenever they wanted and were provided with fresh food and drink through a sound proof 'airlock'.

The results showed very clearly that even in the total absence of time cues (or zeitgebers), people continued to sleep and wake on a fairly regular basis. They also showed that the circadian rhythm in body temperature persisted with the maximum temperature usually occurring during the equivalent of mid-afternoon, and the minimum temperature during sleep.

Following on from this work, Zulley et al (1981) [16], examined the influence on the internal body clock, as reflected in temperature rhythm, on the probability of falling asleep, and having done so, on sleep duration. The results showed that the probability of falling asleep is high when temperature is falling or low, but low when temperature is rising or high.

For example, when a train driver comes off a night duty and tries to go to sleep, his temperature will typically be rising rapidly and so he will have problems falling asleep. Furthermore, if he does fall asleep, he is unlikely to sleep for very long. Although these findings are based upon an experimental study, large scale surveys of shiftworkers have found similar effects. This suggests that the sleep duration of shiftworkers is largely determined by their internal body clocks rather than external factors such as the demands of their families or social pressures, for example.

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4 The impact of shift patterns on fatigue

4.1 Overview

There are a number of aspects of shift patterns, which contribute, to a greater or lesser extent, to fatigue. This section describes how these aspects of shift patterns contribute to fatigue and provides supporting evidence from experimental research. The following aspects of shift patters are considered:

- timing of shifts;
- duration of shifts;
- rotation of shifts;
- rest and recovery periods.

4.2 Timing of Shifts

4.2.1 Night shifts

Incompatibility of the internal body clock and working nights

It is inevitable that fatigue will usually be greater on a night shift than on a day shift. The internal body clock causes levels of alertness and performance to be at their lowest between 02:00 and 06:00 and at their highest approximately 12 hours later in the late afternoon. Hence, during a night shift an individual is trying to work at a time normally reserved for sleep and therefore he is out of phase with his body clock. In addition, the internal body clock adjusts fairly slowly to working at night.

Folkard and Monk (1979) [17] conducted a review of shiftwork and identified a consistent finding that performance is considerably impaired during the night shift. Performance was found to be slower, less accurate and there is some evidence that accidents are likely to be more frequent. Fletcher (1999) [109] comments on recent studies where the risk of accidents involving truck drivers between midnight and 2am is found to be more than double the average during the day.

Other studies that have identified similar performance decrements include:

- 'Performance overnight in shiftworkers operating a day-night schedule' [18]
- 'Workload and fatigue in single seat air operations: a laboratory study' [19]

- ‘Diurnal variation in human performance: a review’ [20]

Loss of sleep associated with night work

Night work is also associated with loss of sleep. As well as often taking very little sleep during the day before the first night shift [21], sleep at home between night shifts can be shortened by up to one third compared to a normal night’s sleep. In a study involving 12 male shift workers, Tilley et al (1982) [22] demonstrated that by the end of a week of night shifts the shift workers had lost the equivalent of at least one night’s sleep.

Additional studies that show the reduction in sleep on night shifts include:

- ‘Sleep of shiftworkers within the arctic circle’ [23]
- ‘Sleep on the night shift: 24 hour EEG monitoring of spontaneous sleep/wake behaviour’ [24]

Other research has demonstrated that the ability to maintain sleep can vary depending on the time of day. Specifically, the longer sleep is postponed from the evening towards noon on the following day, the shorter the length of sleep becomes (Akerstedt et al 1981) [25]. Therefore, going to bed between morning and noon, when most shift-workers go to bed after a night shift, results in shortened sleeps.

The loss of sleep experienced when on night shifts and the effect of the body clock means that shift workers report greater feelings of sleepiness at this time. As previously cited when describing the effect of the internal body clock, Torsvall et al (1987) identified an increase in sleepiness on the night shift in a study of train drivers [13].

Consequence of successive night shifts

Successive night shifts result in a cumulative sleep debt that may get worse as more night shifts are worked. Folkard [5] identifies evidence to support this suggestion. A German study of long-haul pilots found the incidence of micro-sleeps during night flights to increase substantially from the first to the second successive night flight (Samel et al 1997) [27].

In addition, a number of studies done in industry have reported increases in accident risk over at least four successive night shifts (Folkard et al, 2000) [9]. Figure 2 shows an averaged trend of the relative risk over successive night shifts. Relative to the first night shift, the risk is increased by about 15% on the second night shift, by about 30% on the third night shift and 50% on the fourth night shift.

The implications of these findings is that the number of successive night shifts should be kept to a minimum and they should be followed by sufficient rest days to allow people to recover sufficiently from accumulated fatigue. Totterdell et al (1995) [28] showed that alertness in nurses during the first three days back at work was rather higher following two rest days rather than one. It is worth noting that the regulations for the hours of Air Traffic Controllers stipulate a maximum of two successive night shifts must be followed by a minimum of 54 hours off-duty [29]. This is to ensure operators have a full two days rest and that their second night of sleep is not truncated by an early shift.

The consequences of successive night shifts are discussed further when considering the rotation of shifts in Section 4.4.

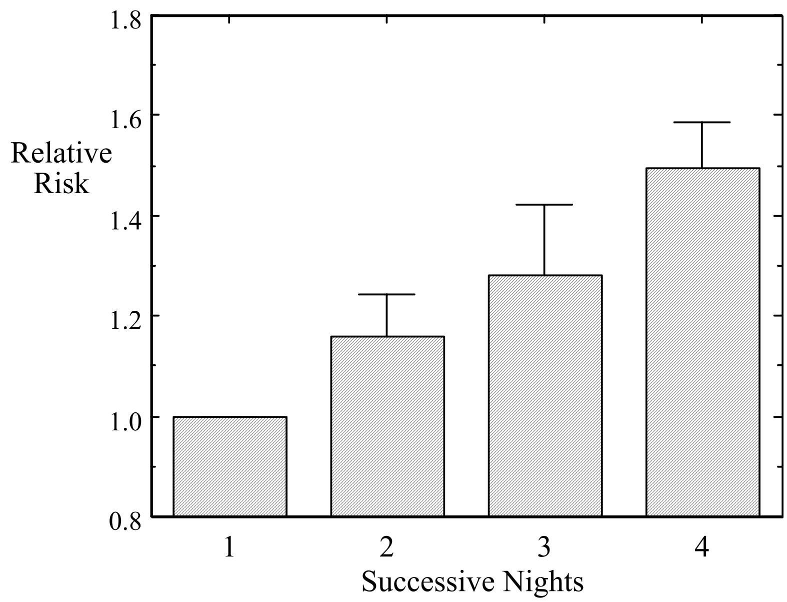

Figure 2: The averaged trend in relative risk over successive night shifts, including standard errors of the means

Benefit of taking naps

Taking a nap has been shown to mitigate fatigue. Studies have shown that a nap of at least one-hour can reduce fatigue during the early morning hours of a night shift [30, 31]. Napping as a coping strategy is discussed further in section 7.1.

Summary

- reduced alertness and performance occur at night due to the internal body clock;

- there is often a lack of sleep during the day before first night shift;
- the reduced amount of sleep whilst working night shifts, is due to the internal body clock and, to a lesser extent, to social pressures;
- successive night shifts result in a cumulative sleep debt which is best mitigated by at least two days rest (avoiding an early shift on the return to work);
- naps have been shown to reduce fatigue on the night shift.

4.2.2 Early starts

Early starts are likely to be associated with a reduction in sleep duration. This has been previously observed in airport security personnel where work commenced as early as 04:30 (Rogers, et al) [39]. Sleep periods prior to an early start (*ie* before 07:30) were found to be, on average, three hours shorter than those obtained on a rest day.

Difficulties in obtaining adequate sleep prior to the start of duty has also been reported in a number of other studies, and even a one to three hour curtailment of sleep has been shown to reduce levels of alertness during the following day. Furthermore, sleep periods of less than six hours contributed to higher levels of sleepiness and impaired driving ability on the journey to work than those of six hours or more.

Studies that have found these results include:

- Time-budget studies of policemen in weekly or swiftly rotating shift systems [40]
- Sleep and mood on a weekly rotating shift system: some preliminary results [41]
- Does the forbidden zone for sleep-onset influence morning-shift-sleep duration? [42]
- Sleep and early morning work [43]
- Sleepiness and shiftwork: Field studies [44]
- A review of the current scheme for the regulation of air traffic controllers hours [45]
- The impact of tiredness as a cause of road accidents for specific groups of 'at risk' drivers: A review [46]

An earlier bedtime to compensate for an early start may not be practical, partly as a result of social pressures, but also because of the influence of the so-called 'forbidden zone' for sleep [14]. This is a period, lasting for about four hours in the evening, when the body's higher level of alertness hinders the onset of sleep. Therefore, even if shift-workers are conscientious and retire to bed early, they may experience difficulties in falling asleep. A further problem is that sleep prior to an early shift may be disturbed by the fear of not being able to wake up sufficiently early [43]. Also, as for night shifts, it would seem likely that working successive early shifts is likely to result in a cumulative sleep deficit. It would therefore seem sensible to restrict the number of consecutive early shifts worked.

Indeed, in a study on the work hours of aircraft maintenance, Folkard [117] comments that there is good objective evidence that an early start to the morning/day shift can result in a substantial truncation of sleep. In light of this and other findings, Folkard recommends that a span of successive morning or day shifts including 32 or more hours of work that start before 07:00 should be limited to four. Immediately following which there should be a minimum of two successive rest days continuous with the 11 hours off between shifts. This limit should not be compromised by overtime.

Levels of fatigue on the early shift can also be increased by long commuting times. In a group of policemen [40], the average duration of a night's sleep before a morning shift was reduced by three hours compared to days off. This shortened sleep was explained by the fact that some of the workforce were getting up at 04:00 to travel long distances between home and work. The fatiguing effect of travelling to work was also apparent at air traffic control centres, and those who commuted for longer than one hour were found to have increased levels of tiredness during the shift [45]. More recently, analysis of data from aircrew operating short-haul flights between the UK and Europe has shown an association between fatigue and length of commuting time (after correcting for other significant factors such as the length of duty and time of day) (unpublished DERA data), (Figure 3). The increase in fatigue that results from one hour of commuting is roughly equivalent to an extra hour of flying. In addition, Folkard [117] reports that for each hour earlier that individuals have to leave home because of earlier shift start times they sleep for 46 minutes less.

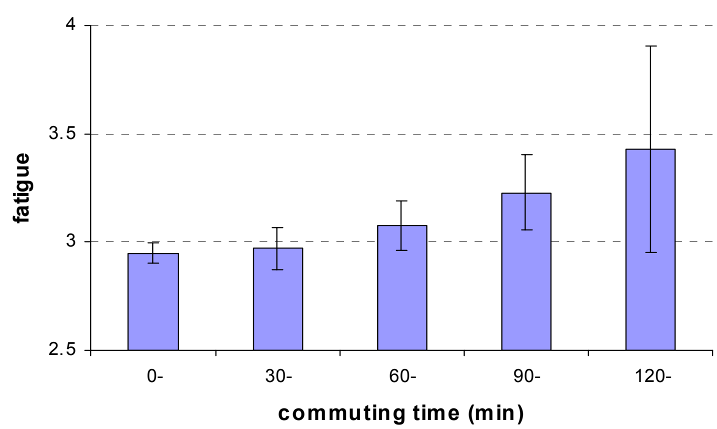

Figure 3: The effect of commuting time on the subjective assessment of fatigue

Overall, the evidence indicates potential problems associated with commuting times of an hour or more.

Summary

Early starts are associated with increased fatigue because of the following:

- reduced sleep duration because early bedtimes are difficult to achieve due to the 'forbidden zone' and social pressures;
- fear of not waking up in time and therefore waking up early, curtailing sleep;
- long commuting times which contribute to fatigue and also mean an operator has to get up even earlier in order to get to work on time.

4.2.3 Afternoon shifts

Although most emphasis has been placed on impairment of performance during night work, there may also be a secondary dip during the early to mid-afternoon.

Folkard (1997) in his paper about 'black times' (as opposed to 'black spots' on roads) describes analyses he carried out on transport data to determine the risk of accidents in relation to both time of day and time on shift. He identified a small increase in the risk of accidents at around 15:00 [8]. Other studies have confirmed this finding. For example, Hilderbrandt (1974) [47] reported an increase in the number of automatically induced emergency braking incidents in locomotives between 13:00 and 15:00.

This so-called 'post-lunch dip' in alertness was originally thought to be related to the digestion of lunch, but has since been shown to occur irrespective of meal times. Studies in a time-free environment have suggested the existence of a two phase (bi-phasic) sleep-wake pattern, since there is a tendency to take a short nap around 15:00-17:00 [48]. This is still seen in siesta cultures, where a nap in the afternoon is commonplace.

Summary

Fatigue on the afternoon shift is affected by the 'post-lunch dip', *ie* reduced alertness in the afternoon, which occurs as a result of the workings of the 'internal body clock' rather than as a result of a meal at lunch-time.

4.2.4 Start times

Within UK industries, most eight-hour shifts include a changeover between:

- 06:00-07:00;
- 14:00-15:00;
- 22:00-23:00 [49].

It has been found that a shift changeover at 07:00 causes considerably fewer problems than one at 06:00 [50].

Shift-workers on the 06:00 changeover reported shorter overnight sleeps and were less alert during the day shift than their counterparts who changed at 07:00.

The key issue with regard to shift start times is that morning shift start times should be balanced carefully with night shift finish times. This means that the morning shift should not start too early in order to avoid short sleep durations and greater fatigue during the shift; on the other hand, night shifts should not finish so late that they reduce subsequent daytime sleep.

Folkard [117] also discusses this point and in his report on work hours of aircraft personnel recommends that a morning shift should not start before 06:00, and where possible should be delayed to start between 07:00 and 08:00.

4.3 Duration of shifts

4.3.1 What is the best shift length?

Over the past two decades there has been an increasing trend for shift durations to be extended. In the UK, 12-hour systems have become increasing popular and are used by a diverse range of industries. Many shift-workers prefer to work long shifts in order to maximise their time off and minimise trips to and from work. Longer shifts are also attractive to management since a popular work schedule is likely to reduce absenteeism and increase morale.

Evidence from research suggests that the comparison between 8 and 12 hour shifts can be complex and contradictory [51]. There is concern that workdays that extend beyond eight hours may promote fatigue and reduced performance. Indeed, Fletcher [109] comments that laboratory research has shown that reaction times increase as time on task increases (Mascord & Heath, 1992; Nagatsuka, 1996) [109] and that research has shown that continuous sustained attention is mentally draining (Hancock & Warm, 1989). For example, a study was carried out in the US [52] that investigated the impact on operators of a new three to four day/12hour rotating shift schedule rather than a five to seven day/eight hour schedule. Shift times under the eight hour schedule were:

- 07:30 – 16:00;
- 15:30 – 24:00;
- 23:00 – 08:00;

and for the 12 hour schedule were:

- 06:30 – 19:00;
- 18:30 – 07:00.

Mental arithmetic and grammatical reasoning tests were used to assess alertness. After seven months, performance on these tests was reduced which may either reflect the extra four hours of work per day or the changed start time of the day/morning shift. There were also reductions in sleep and disruptions of other personal activities during 12 hour workdays. However, the new schedule was popular and although a reduction in alertness was found, it is difficult to establish precisely the impact of reduced alertness on the risk of accidents (though accidents have occurred as a result of fatigue, as described earlier).

Another study did establish a relationship between the risk of accidents and time on shift. In a study of 160,000 work injuries [53], the effect of length of time at work was obtained by computing the time elapsed between the time of the accident and the start of the shift. Results showed that the accident risk remains fairly level for the first 8-9 hours of work (including meal breaks), but beyond nine hours the risk rises steeply. At 16 hours the risk is three times greater.

If accident risk is used to determine an appropriate length of shift, it is also important to consider any peaks in accident risk which occur early on in a shift. Simon Folkard [8] reports that the greatest risk of accidents occurs during the second to fourth hour of a 12 hour shift and the risk of accidents only becomes greater than between two to four hours when 12 hours of work is exceeded. This conclusion was partially based on a study of lorry drivers that showed that the risk of an accident was worst in the first four hours of a shift unless the driver worked for longer than 12 hours (Hamelin, 1987) [54].

Similar peaks in accidents, which are difficult to account for in terms of the internal body clock, have been found in UK rail operations. A substantial increase in signals passed at danger (SPADs) per million driver hours, from the first hour to the second and fourth hour, followed by a decrease up to the 12th hour, was established by Hilary Wharf in 1993 [55]. This trend in safety risk was also consistent across different depots.

This two to four hour peak in risk is difficult to explain but one theory is that in the first few hours of a shift, operators have to consciously think about their various tasks. As the shift progresses, they are able to carry them out more automatically, potentially reducing the likelihood for error. Alternatively, the increased risk between two to four hours could be related to the pattern of driving activity and breaks within a shift. However, there is a clear need for further research to investigate the underlying reason for this increased risk and to develop potential countermeasures.

It seems that there is no clear answer to the optimum length of shifts. On the one hand, fatigue and accidents have been shown to increase after eight hours, on the other, there is some evidence that there is an increase in risk between two and four hours into a shift although it is not clear that this is a fatigue related phenomena. These two issues are equally important when considering optimum shift lengths. If an eight hour shift is selected, more shifts are required than if 12 hour shifts are selected, and therefore the number of times the two to four hour period occurs is increased. Hence, it is clear that further research is necessary to establish the optimum length for the railway industry.

Summary

- shift workers and managers prefer 12 hour shifts;
- shifts extending beyond eight hours may cause fatigue and degrade performance;
- some studies find that the risk of accidents becomes greater after nine hours on a shift;
- other studies suggest that the risk of accidents is greater between the second and fourth hour of a shift rather than between the 8th and 12th hour;
- optimum length for shifts is not clear.

4.4 Rotation of shifts

4.4.1 How frequently should shifts be rotated?

In the design of shift patterns, a key issue is how many consecutive shifts of the same type should be worked before an operator changes to a different shift type (*eg*, how many early shifts should be worked before changing to a late shift). Since night shifts tend to be the most disruptive, the argument tends to focus on the maximum number of consecutive night shifts that should be worked.

The problems associated with lack of sleep before a single night shift are likely to escalate over successive nights if the internal body clock does not adjust. Levels of alertness will be low on the night shift, when the operator normally sleeps, and sleep quality will be poor during the day when the body is normally active. If train drivers were scheduled to work seven consecutive night shifts, it has been estimated that by the end of this period a worker may have lost the equivalent of a least one night's sleep (Tilley, et al, 1982) [22]. This is supported by evidence of an increased accident risk over at least the first four shifts in a sequence of night shifts [56].

There is some evidence to suggest that, as night work continues, individuals may adapt to the new pattern of rest and activity. Barton et al. in their study on the optimum number of night shifts [111] found that sleep duration was shown to increase with more consecutive nights worked.

This has led some experts to advocate permanent night shifts or very slowly rotating shift patterns [57]. However, a major difficulty with long runs of night shifts is that operators will need days off, during which time they are likely to revert to their normal sleep-wake pattern since all the environmental and social cues around them are encouraging it. Therefore, all the benefits of adaptation to night-work may be lost.

Even in environments where operators are surrounded by others on the same shift pattern, for example on oil rigs, most individuals cannot adjust to night-work within one week [58]. Indeed, there is very little evidence to suggest that complete adaptation is ever achieved; a study by Knauth et al (1978) showed that even in ideal circumstances, the core temperature of students did not completely adjust to night-work, despite working 21 consecutive night shifts in a laboratory [59]. However, more recently, Barnes et al [119] reported that oilrig workers did adapt to consecutive night shifts in the first week. They postulated that the specific environment and social factors together with the shift schedule may have facilitated the adaptation observed.

In a study of air-traffic controllers, daytime sleep following consecutive night shifts was much shorter and of much poorer quality than that obtained on rest days, and individuals felt less well-rested on waking [45]. Thus, for safety-critical operations, such as public transport, it may be preferable to limit the number of consecutive night shifts worked by rotating shiftworkers to no more than two or three in order to restrict the accumulation of a sleep deficit associated with successive daytime sleeps.

Folkard [117] in his study of aircraft maintenance personnel has attempted to link the number of consecutive shifts with the duration of the shifts. He recommended that a span of successive night shifts should be limited to 6 for shifts up to 8 hours long, 4 shifts of 8.1 to 10 hours long and 2 for shift of 10.1 hours or longer. Where these limits should not be exceeded by overtime.

As described in Section 4.2.2, there is evidence to suggests that there is a continued disruption of sleep associated with consecutive early starts, although this is not always as great as that associated with the night shift [45]. Indeed the magnitude of the disruption of sleep on the early shift depends very largely on the time that the individual has to leave home in order to report for work on time. In industries where there is a need for early shifts, it may be advisable to place a limit on the number of consecutive early shifts worked. However, further research needs to be carried out to determine the optimum way in which early starts should be managed.

Recently, a questionnaire study has been conducted within British industry, including a train operating company, to investigate the effect of three or more consecutive shifts on subjective levels of alertness [49]. An increase in subjective fatigue over seven days was found for all shift types (early, afternoon and night). The effect of consecutive early starts was consistent with other studies. A more detailed analysis indicated that afternoon shifts finishing after midnight were associated with higher levels of fatigue than shifts that finished before midnight, and this effect was significant from the fifth afternoon shift. These late shifts are likely to involve some sleep loss, since individuals are unable to retire to bed until the early hours of the morning. Indeed, the sleep of security screeners, who operated consecutive late shifts, was found to be around two hours shorter prior to the second and subsequent late shifts compared with that obtained on a rest day [39].

The data from seven consecutive night shifts were less conclusive, since there were large individual differences. Around half the respondents reported decreased levels of fatigue in response to night work over a seven-day period, whereas the remainder showed a progressive increase in levels of fatigue. Indeed there may be a small percentage of the working population who would prefer to work nights, and may be better able to adapt their lifestyle to cope with long sequences of night shifts. This would suggest that until further research is carried out to determine which individuals are most suitable for night-work, the majority of schedules should be designed to avoid long sequences of consecutive shifts and minimise fatigue. However, permanent nights need not be ruled out, since they may be suitable for a small percentage of the population. Under these circumstances it would be necessary to carefully monitor such individuals to ensure that they are able to cope with this pattern of work.

Rapidly rotating schedules, involving no more than two or possibly three night shifts are generally the most favoured [60]. Slowly rotating shift systems, including those that involve weekly rotation are generally regarded as the most fatiguing since any benefit accruing from the partial adaptation to a new shift will be immediately lost by the switch to another shift. Indeed such systems may be viewed as maximising the disruption of the individuals' body clocks and, perhaps because of this, these systems have been associated with sleep disturbance, problems of circadian adaptation and performance decrements [61].

Summary

- it is not clear that complete adjustment to night shifts ever really occurs, since the internal body clock does not appear to fully adjust;
- there appears to be a small percentage of the working population who would prefer to work nights, and may be better able to adapt their lifestyle to cope with long sequences of night shifts;
- rapidly rotating schedules are favoured by most experts over slowly rotating shifts.

4.4.2 In what direction should shifts be rotated?

Shifts can rotate in clockwise (early, late, night) or anti-clockwise directions (night, late, early). In the past, it has been considered that the clockwise direction (delaying system) has less ill-effects on shiftworkers than the anti-clockwise direction (advancing system).

In a study of policemen, Orth-Gomer (1983) [61] found that a change from anti-clockwise to clockwise rotation had a favourable effect (at least in the short-term)on both subjective well-being and coronary factors. A study that involved more than 300 industrial shift-workers on a range of advancing and delaying continuous systems, found better physical and psychological health, less chronic fatigue, less social disruption, fewer sleep difficulties and more job satisfaction among workers on delaying systems [63].

More recently, a difference between the two directions of rotation has been established in eight-hour continuous systems [49]. Levels of alertness during the morning and afternoon shifts were found to be worse on the advancing system. However, other recent studies have identified that advancing shifts may not be as harmful as research has previously suggested [64]. This result is qualified though by saying that it is possible that shift systems self-select those workers most able to cope with their adverse effects. It is considered that the 'quick returns' often associated with advancing systems may have been responsible for the previous findings that sleep duration was reduced under these shift systems and the associated adverse health consequences.

4.5 Rest and recovery periods

4.5.1 How often should breaks be taken and how long should they be?

The DERA Visual and Mental Acuity Study [4] demonstrated the benefits of breaks on alertness levels. In this study the time taken to cancel the AWS was shown to increase with time into shift but was reset following a break. However, the optimum frequency and duration of breaks to minimise the risk of accidents has not yet been established. Although there is now evidence that regular rest breaks are an effective means of controlling the accumulation of risk during prolonged task performance.

A study by Tucker et al. [118] sought to identify whether there were consistent temporal trends in industrial risk associated with the timing of intra-shift rest breaks.

The study examined records from a database of all on-duty accidents occurring over a three-year period at a car assembly plant in the UK. The database contained detailed records of all injurious accidents, each compiled in the immediate aftermath of the incident. A shift comprised of two hours continuous work, followed by a 15 minute rest break; another two hours of work, followed by a 45 minute meal break; another two hours of work followed by a 10 minute rest break; and finally 83 minutes of work.

Examination of the accident records showed that there was a significant increase in risk across the four half-hour segments that made up a two hour period of continuous work, with the relative risk of an accident in the last half hour being 2.08 (95% Confidence Interval 1.73 – 2.43) higher than in the first half hour. It can therefore be concluded that rest breaks successfully counteracted the accumulation of risk that was observed over two hours of continuous, repetitive and largely machine-paced work.

The original research on deterioration in performance for tasks requiring sustained attention were the vigilance studies carried out by Mackworth in the 1940s. These studies were instigated by radar operators' failing to spot infrequent 'targets' on displays during the 2nd World War. Mackworth devised a 'clock test' to assess the level of vigilance over two hours under a variety of different conditions. He concluded that after 30 minutes there was a significant decline in performance but that a short rest of 30 minutes was enough to restore performance [65].

The practice of incorporating breaks and rest pauses into a work period is well established, and has been shown to reduce fatigue [66,67]. The regulations for air traffic controllers' working hours stipulate a 30-minute break after continuous periods of two hours operational duty, and a recent review recommended that these limits should be retained [45]. However, where levels of workload were low and the activity was spasmodic, it was considered that the two-hour limit could safely be increased up to four hours, provided there was an opportunity to take a short 'physical needs' break within that time.

The requirement to take frequent short rest breaks may be of particular importance when driving in an unstimulating environment. This type of environment is likely to induce sleepiness, since studies in a sensory deprivation chamber have shown that individuals habitually fall asleep within 45 minutes despite being well-rested [68].

In general, the benefits of breaks at work are positively related to their length. Longer breaks have a greater and more sustained effect, and it has been suggested with respect to driving performance that the length of breaks should be considered with respect to the duration of work [69]. However, it is necessary to balance carefully the duration of breaks so as to minimise fatigue associated with the demands of the job, whilst ensuring that the duty period is not unduly lengthened.

Furthermore, the re-emergence of sleepiness can occur rapidly when individuals are tired [70], and so the frequency of breaks is an important factor. McClumpha [71] indicated that self-paced rest periods might be better than pre-programmed rest periods, but that the optimum frequency and timing of breaks are strongly dependent upon the specific work demands.

A recent laboratory study [19] concerned with the interaction of workload and fatigue, highlighted the problems of sustaining performance during a duty period. The inclusion of a 15 minute break at the end of each 75 minute of continuous work had a considerable beneficial effect, overcoming some of the performance deficits associated with time on task (Figure 4). The recuperative value of these breaks was evident throughout a 12-hour duty period, both during the day and overnight.

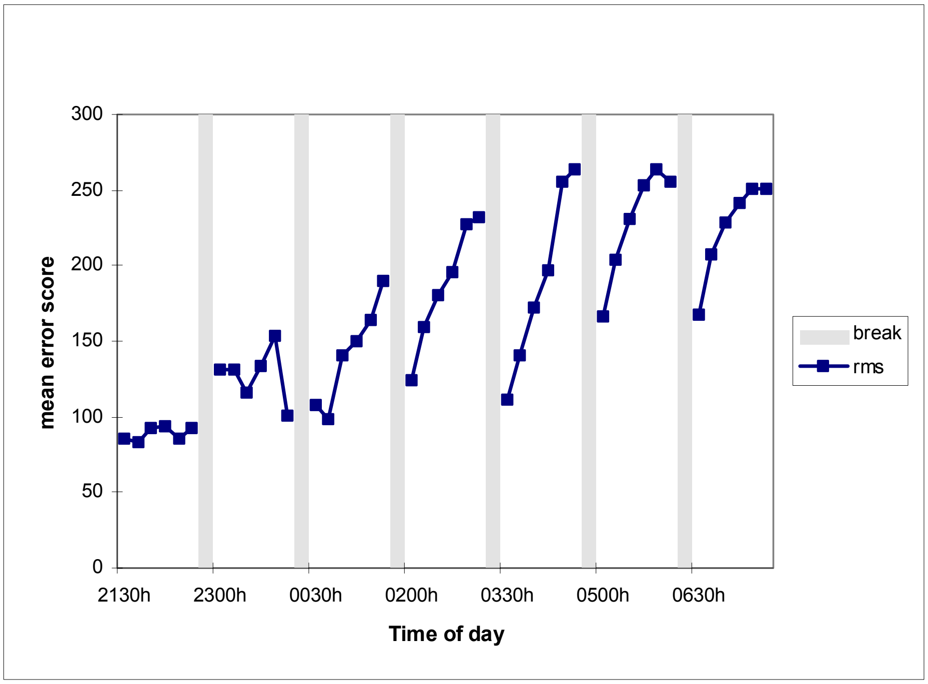

Figure 4: The effect of 15 minute breaks on tracking ability during an overnight work period

In 1991, as part of the Drivers Restructuring Initiative, Folkard made the following proposals for the structuring of breaks [72]:

- the length of any break should not be less than four minutes for each 30 minutes, or part thereof, since the last break or start of duty. However,
- all turns of duty in excess of five hours should include at least one break of 30 minutes, while no scheduled break should be less than 20 minutes long, and;
- all breaks must be increased by a minimum of five minutes walking time, each way, to allow the driver to walk to and from the available facilities. This figure must be increased appropriately when local conditions require it, and;
- no period of continuous duty should exceed five hours before either the provision of a break or the start of a period of off-duty.

And in his study of the working hours of aircraft maintenance personnel [117] he recommends that;

- A maximum of four hours is worked before a break.
- A minimum break period be ten minutes plus five minutes for each hour worked since the start of the work period or the last break.

However, as stated above, the relationship between breaks and accident risk has not yet been clearly established. In addition, the timing and duration of breaks in current operations has not been identified. Therefore, it is considered that further research is required to clarify the link in order to enable appropriate and up to date recommendations for the scheduling of breaks to be made.

4.5.2 How long should operators rest between shifts?

The rest period between the end of one shift and the start of the next should be long enough for a normal full sleep, having accounted for other factors such as commuting time and family responsibilities. However, for social reasons, workers may prefer to concentrate their working hours into a shorter period, so that time off can be accumulated into longer breaks.

Short rest periods can arise as a result of overtime working or they may be a feature of the scheduled shift pattern. They are common in some advancing systems (night, late, early) that include 'quick returns'. These are rest periods, normally of eight hours, that enable a rapid switch from one eight-hour shift to another. Despite their popularity, quick returns may severely restrict sleep duration and exacerbate the shift-worker's problems [58,60].

Coplen and Sussman [105] comment on a recent simulator study where Thomas Raslear and Huehn (1997), found measurable decrements in train handling performance in work/rest cycles (the time between the start of a shift and the start of the next consecutive shift) of less than 24-hours. In addition, they also found that these performance decrements were worse when the work/rest cycle was about 20 hours in length as opposed to 22 hours in length.

Lack of sleep is most likely to occur when an evening shift follows a night shift. Sleep after a night shift is usually no longer than five or six hours, and this may be reduced even further when the next shift is scheduled for the evening, as workers may interrupt their daytime sleep to give priority to social activities [73]. However, quick returns at any time of the day are inadvisable and should be avoided.

There are occasions when a 12 hour rest period may be insufficient to obtain adequate sleep. Kurumatani and his colleagues have studied the effects of rapidly rotating shifts on the sleep patterns of nurses [74]. They found that the longer the time between two consecutive shifts, the longer the total sleep time. The available sleep time depended on commuting time, timing of sleep and many other factors, including family responsibilities. They concluded that an interval of at least 16 hours is required prior to a night shift to achieve around seven hours sleep.

In addition, Clissod et al. [110] studied female nurses working a continuous 3-shift roster and found that the average sleep duration per 24 hours across the roster is almost one hour less for nurses who combine shiftwork, partner and parent roles. In particular they are not free to use the later starting afternoon shift as an opportunity to repay the sleep debt incurred on night shift.

Studies of military operations [49] have also shown that the amount of sleep obtained during rest periods is dependent on time of day and length of the rest period. Duration of the rest period was found to be less important if the duty period started in the morning, when the main consideration was duty start time. However, prior to afternoon and evening starts, the length of the rest period was crucial. To achieve an average of eight hours sleep, a 12-hour rest period was required prior to a 14:00 start, almost 14 hours prior to a 16:00 start and 16 hours prior to a 19:00 start.

Folkard [117] recommended that aircraft maintenance personnel have a minimum rest period of 11 hours between the end of the shift and the beginning of the next and that it should not be compromised by overtime.

However, a variation in recommended duration of rest periods, which is dependent upon the time at which the next shift would start, seems impractical. Therefore, it is considered that 14 hours rest is desirable between shifts in order to ensure complete recovery.

Summary

- the rest period between the end of one shift and the start of the next should be long enough to enable enough sleep. Some research shows that to achieve 8-hours sleep, 12 hours rest is required before a 14:00 start, 14 hours before a 16:00 start and 16 hours before a 19:00 start.
- quick returns may severely restrict sleep duration and exacerbate the shift-worker's problems.

4.5.3 How long should the recovery period be?

In addition to adequate rest between successive shifts, it is important to consider the length of a recovery period after several consecutive periods of duty. Ideally a recovery period should provide sufficient time to recover completely from any accumulation of fatigue or sleep problems arising from the previous schedule of work.

There is very little evidence in the scientific literature concerning recovery from work. Those studies that have investigated the recovery period have been concerned primarily with the recovery from a period of consecutive night shifts. According to Kecklund [75], most shiftworkers reported that they needed at least three days, including three normal sleep episodes, to recover from seven consecutive night shifts, and at least two days to recover from three night shifts.

This is in close agreement with a study of shift-workers in the UK [49] which suggested that at least two days off are required to recover from two consecutive night shifts, three days off after four to five night shifts, and three to four days off after seven night shifts. When the shifts involved early start times, individuals reported that they needed one day off to recover from working three consecutive shifts and two days off to recover from five consecutive shifts. It was also reported that individuals needed two days to recover from seven consecutive afternoon shifts that finished around 23:00 to 23:30. In a review of the working hours of air traffic controllers [45], it was recommended that the recovery period following two consecutive night shifts should be at least 51 hours.

Similarly, Folkard [117] recommended that aircraft maintenance personnel have a minimum of two consecutive rest days continuous with the 11 hours off between shifts when completing a span of night shifts. If the span of night shifts exceeds three or 36 hours of work then they should be followed by a minimum of three consecutive rest days continuous with the 11 hours off between shifts. These limits should not be exceeded by overtime

Work has been shown to have adaptive costs for the shift-worker, and these costs are most evident on the first rest day following the shift cycle [28]. Cognitive (mental) performance and self-ratings of alertness were poorer on rest days that followed a night shift compared with a day shift. Also alertness on the first three days back at work was higher following two rest days than following a single rest day.

However, difficulties can also arise if drivers return to work following a long period away. Indeed, it has been reported that safety risks were higher for the first shift back after time off, although it was unknown whether these were related to the length of time absent [55]. Within the nuclear industry, following a block of seven or eight consecutive days off, shift-workers have shown greater impairments at shift handover, compared with a block of four consecutive rest days. This suggests that they have become ‘out of touch’ with the status of the plant [76]. Thus any beneficial effect of extended time off, in terms of recuperation, may be counteracted by the need to re-orientate to work upon return. Ways of achieving this re-orientation might include the use of simulators or attending safety briefings on a first day back rather than driving, for example. Further research is necessary to investigate appropriate and effective means of achieving re-orientation.

To conclude, a single rest day is normally insufficient to recover completely from the fatigue that builds up over a series of shifts, particularly a series of night shifts. An extended recovery period is required after a succession of night shifts, the length of this period depending on the number of consecutive shifts worked.

Summary

- the recovery period between periods of work should provide sufficient time to recover completely from any accumulation of fatigue or sleep problems;
- returning to work following a long period away appears to have associated safety risks.

5 Current Shift Working Practices in the Rail Industry

As part of the Visual and Mental Acuity study carried out by DERA [4], a survey of rosters used by Train Operating Companies (TOCs) was evaluated to establish the current working practices. This review establishes the current position within the railway industry although it is considered that there are gaps in our knowledge and further research is required.

The findings of this review of shift working within the railway industry were as follows:

- it was identified that shifts as early as 04:15 are scheduled;
- breaks from the driving task have been reported by railway companies to occur usually between the end of the third and seventh hour of duty;
- no evidence was found of quick returns, and the rest period between consecutive shifts was usually 12 hours or longer;
- rest periods between consecutive shifts of the same type were at least 16 hours, provided that the shifts were no longer than eight hours;
- train crew only normally return to duty following a rest period of less than 12 hours when they take part in non-operational duties, such as classroom training or a meeting;
- there are occasions during a schedule when train drivers are given insufficient time to recover from their preceding schedule of work, for example, an early shift was scheduled 46 hours after two consecutive night shifts (as oppose to the established best practice of 51 hours or more).

However, one of the main concerns arising from discussions with train operating companies during the DERA study is that the rosters do not always provide an accurate representation of the actual hours worked. In fact, there are reported instances of work periods extending beyond 12 hours when trains are delayed due to incidents on the line. Swapping shifts is also permissible, providing drivers are able to cover each other's shift in full. In these circumstances, the rest period between consecutive shifts may be curtailed. Hence, it is important that, if shift swapping or overtime is allowed, there is a control procedure in place to ensure compliance with good practice.

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6 Guidance for Shiftworking

6.1 Established Guidance

The following guidance has been concluded from the preceding sections.

6.1.1 Night shifts

- It is considered good practice to restrict the number of consecutive night shifts to two or three to minimise the build up of fatigue. This does not apply to staff on permanent shifts, when up to six successive night shifts are considered acceptable.

- A short nap during the night shift can alleviate fatigue.

- Having worked two or three consecutive night shifts it is important that staff are able to have sufficient sleep to fully recover. This requires two full nights' sleep after the consecutive night shifts, without an early start after the second night. In order to ensure this is achieved (and commuting time does not leave too short a period for rest), it is considered optimum that 54 hours or more should elapse between the end of the consecutive night shifts and the next shift.

6.1.2 Early starts

- Due to the cumulative sleep deficit of working early shifts, it is considered best if the number of consecutive early shifts is restricted to three or four to minimise the build up of fatigue. This does not apply to staff on permanent early shifts, although it is believed no research has been carried out to identify what might be an acceptable limit for the number of successive early shifts, but as for night shifts, six would seem a sensible limit.

- The commuting time of the shiftworker should be considered when scheduling early shifts.

- Having worked three or four consecutive early shifts, it should be immediately followed by two full nights off, without an early start after the second night.

6.1.3 Afternoon Shifts

- As fatigue on the afternoon shift is affected by the post lunch dip (as a result of the internal body clock rather than a meal), special care should be taken when carrying out safety critical tasks.

6.1.4 Start times

- It is recommended that where possible early shifts should start no earlier than 07:00, although it is appreciated that morning shift starts should be balanced carefully with night shift finish times.

6.1.5 Rotation of shifts

- The literature review suggests that the majority of schedules should be designed to avoid long sequences of consecutive shifts and minimise fatigue. However, under careful monitoring, permanent nights might be suitable for a small percentage of shiftworkers.

- In general, the previous sections suggest that clockwise rotation of shifts is more favourable than anti-clockwise rotation in terms of ill-effects on shiftworkers.

6.1.6 Rest periods

- It is considered that ideally the minimum rest period between shifts should be 14 hours. This should not include the time taken by a driver, after shift handover, to return as a passenger, to his depot.

6.2 Further research required to establish guidance

Further research should be carried out to establish more precisely what would be best guidance for the following:

6.2.1 Length of shift

It is apparent that there should be some restriction on the length of shift which staff are required to work. However, there is no reason why staff should not work 10 hours rather than eight hours based on the literature on the consequence for accidents. Whether this limit could be extended to 12 hours without an increase in accident risk is subject to debate. A proposal for a maximum shift length raises the question as to whether a minimum shift length should also be proposed. This is due to the peak in accident rate that is typically shown to occur between the two to four hour period. If shifts are not sufficiently long (*ie*, not much greater than four hours) then no use is made of the reduced risk period between approximately the 4^{th} to the 10^{th} hour.

6.2.2 Breaks

There is no established guidance for the frequency and length of breaks, particularly with regard to safety. In general, it is considered that they should be a function of how long a person has been working but a typical minimum for a break would seem to be between 10 to 15 minutes. However, it is proposed that further work should be carried out to investigate the optimum timings and duration of breaks with respect to performance and safety.

6.2.3 Commuting times

There is no established maximum for the duration of commuting that ensures that performance and safety are not compromised, although it is accepted that long commuting times are likely to be detrimental. DERA suggest that commuting time should be limited to an hour's duration but their data suggests that the risk increases exponentially with time so it is difficult to determine exactly where the best cut-off point might be. It is recognised that it may be difficult to restrict commuting time but consideration could be given to attempting to ensure staff with long commuting times are not required to work the very early shifts.

6.2.4 Annual leave

Very few studies have examined how annual leave might impact on levels of fatigue. Folkard [108] comments that some residual fatigue might accumulate over weeks and months despite the provision of rest days, therefore annual leave is important. There is, however, little evidence to indicate what might be considered an ideal number of days annual leave.

It is noted though that a minimum of 4 weeks leave, that cannot be compromised by paid overtime, is a requirement of the EU's "Working Time Directive" and may apply to the Rail Industry soon.

6.2.5 Length of recovery time

It is important to allow sufficient recovery time after working successive shifts to completely recover from any accumulation of fatigue. However, there is very little evidence concerning the length of recovery time, any studies that have investigated this area have primarily been concerned with recovery time after a span of night shifts (see section 6.1.1.)

7 Coping Strategies

It is not possible to eliminate by design the risk associated with shift patterns, the risk can only be minimised. It is worthwhile exploring the possible ways in which any residual risk might be reduced by means of coping strategies. The next section addresses coping strategies under four categories

- Napping
- Pharmacological
- Education
- Eating and Exercise

Whilst this section attempts to summarise the findings from research into coping strategies, it is acknowledged that the means by which they can be best implemented, if at all, into the UK Rail Industry requires further research.

7.1 Napping

A recent laboratory study [32] investigated the effect of a nap, which varied in length (30 or 50 minutes) and timing (01:00 or 04:00), on performance during the night. Although the 50 minute nap taken at 01:00 was the most effective, all the naps decreased lapses in a reaction time test during the early morning hours compared with the no-nap condition. Taking a nap on the night shift is a widely adopted practice in Japan and has been shown to reduce fatigue [33].

Taking naps at work should allow for a period of impaired alertness on waking known as 'sleep inertia'. Duration of sleep inertia between a few minutes and three hours [34], has been associated with deterioration in both mental and physical performance, such as reaction time [35]. Although most of the sleep inertia effect has dissipated within the first hour of awakening, it can be greater if the arousal from sleep occurs in the early morning hours [36].

Sleep inertia is also driven by the severity of the pre-nap sleep debt. Sherry [106] reported on a Dinges study (1989) that found sleep inertia can be severe if the nap is taken by someone with a severe pre-nap sleep debt. The degree of sleep inertia reported appears to be correlated with the time of day that the nap is taken and the length of time since the last major sleep period.

Robertson and Stone [115], in a study to investigate the effectiveness of naps of different duration to airline pilots, concluded that major long-term benefits from in flight napping cannot be achieved without a significant amount of sleep inertia lasting for a period of about 30 minutes immediately after waking and that it may be sleep inertia is a price that has to be paid for the benefits, in terms of improved levels of alertness, which may accrue later in the shift.

As a compromise, they suggested rest periods of 60 minutes would provide some benefit with respect to alertness. This would allow time for the individual to achieve 20-30 minutes of restful sleep, together with a period of 20 minutes after waking to return to full effectiveness.

A nap taken in advance of an overnight period of work - known as a 'prophylactic nap' - is commonly used as a coping strategy in shift-work. A four-hour sleep taken prior to an overnight duty has been shown to mitigate against the usual decline in performance [37]. Similarly, a two-hour nap in the afternoon was shown to have a beneficial effect on a sustained attention task performed 10 hours later [38] and even a short 20 minute nap in the mid-afternoon has positive effects upon the maintenance of the daytime vigilance level. (Hayashi, Watanabe, and Hori) (1999)

Mason [107] comments on a recent study where it was shown that traffic accidents amongst police drivers on the night shift were significantly reduced by the simple expedient of encouraging them to nap before coming on duty.

However, it should be noted that the beneficial effects of these naps was probably due to them having dissipated some of the sleep need that had already built up prior to the nap. There is no evidence that we can "bank" sleep and build up a "sleep credit" in anticipation, for example, of a particularly onerous work schedule.

Indeed, Sherry [106] commented on a study that showed off-duty napping may interfere with a permanent night worker's ability to sleep normally. Rosa et al., (1990) hypothesised that napping may hinder adaptation to shift work by "providing an excuse for sacrificing regular sleep, by making a person too drowsy upon awakening, or by slowing the inversion of the circadian rhythm". The latter concern may be less important for rotating shift workers or permanent shift workers who often do not maintain sleep schedule on days off as on workdays.

When a shift-worker is attempting to nap, every attempt should be made to make the environment as conducive to sleep as possible. A dark quiet environment with a mild ambient temperature is ideal. Ear-plugs will help to reduce environmental disturbances.

Summary

- Naps have been shown to reduce fatigue

- When taking naps at work, a period of 'sleep inertia' should be allowed for, where impaired alertness will be experienced upon waking.
- A nap taken in advance of an overnight period of work - known as a 'prophylactic nap' - has been shown to mitigate against the usual decline in performance.

7.2 Pharmacological

The use of caffeine to prolong levels of alertness is long practiced and common amongst industry. Recent research though has found that combining caffeine with napping has beneficial effects.

ASLEF's report on Shiftwork, Lifestyle and Health [104] highlighted a DTLR Road Safety Research Report on (road) driver sleepiness which found that caffeine (150mg) is an effective countermeasure to sleepiness, as is a short (less than 15 minutes) nap or doze. The two combined together (caffeine in the form of a caffeinated drink, then nap) are particularly effective.

Likewise, Sherry [106] commented on a recent study by Reyner & Horne (1997) that found a short nap of less than 15 minutes combined with a cup of coffee containing 200 mg of caffeine reduced the number of traffic "incidents" in a driving simulator "3-4 fold". In addition there was no evidence of "sleep inertia" reported, but this should be qualified as it may have been due to the lack of an accumulated sleep debt.

It should be noted that the timing of caffeine use is important, as taking caffeine too late in a shift might impact on a person's ability to sleep when that shift has finished.

The combination of light and caffeine has also been investigated as a means to counter fatigue. Babkoff et al. [113] hypothesised that light and caffeine exposures were expected to improve nocturnal fatigue degradation. They found that although 1 hour exposure to bright light at 0130 hours combined with a 200-mg dose of caffeine maintains performance throughout the remainder of the night/early morning, whereas a 1 hour exposure to bright light without the caffeine may actually degrade performance.

Research has not only been confined to the use of caffeine. Folkard et al. [114] examined the effects of the hormone melatonin on sleep, mood and behaviour in a double-blind, placebo-controlled study of a small group of police officers working spans of successive night shifts. Compared to placebo, and no treatment, melatonin (5mg) taken at the desired bedtime improved problems related to sleep and increased alertness during working hours, especially during the early morning. This preliminary study suggest that melatonin has beneficial effects on sleep and alertness, but that its effects on performance need careful evaluation.

Summary

- Caffeine (150mg) has been shown to be an effective countermeasure to sleepiness
- The timing of caffeine use is important, as it might affect a person's ability to sleep when off shift.

7.3 Education

Education is another means by which fatigue can be countered. It does not only apply to the shift workers but to management as well. It is also arguable that the families of shift workers should be subject to training, so that they understand how they can assist the shift worker in dealing with shift-related fatigue.

Any education must enable employees to understand how counter measures will work and how specific actions when off-duty can ease shift work. Folkard [117] highlights that it is important to draw their attention to the objective trends in risk with a view to increasing their vigilance at points when risk may be high despite that fatigue might not be. Folkard [117] also suggests that aircraft maintenance personnel should be dissuaded or prevented from working for other organisations on their rest days and that they should be required to report for duty adequately rested.

Such a step would put the responsibility of managing sleep debt and related fatigue outside the hours of work squarely on the employee, so that it does not impact on performance whilst at work.

Sherry [106] comments that seminars, videos and plenty of readily available brochures are the most common and the most effective means of conveying information to railroad employees. He also raises the fact that educational activities may need to be directed to specific employees.

Management training in the causes of fatigue and fatigue management will assist in the development and subsequent management of fatigue friendly rosters. Whether this is implemented in the UK has yet to be determined but in Australia it has been decided to train all those engaged in a management role in all sectors of the transport industry, whether they be a private company or a government entity which is responsible for contracting transport related services [108].

It has also been suggested in Australia [108] that a cross modal working group be established to develop and coordinate fatigue awareness education material and programs. Thus enabling industries to learn from each other.

Summary

- Educating shift workers and their families can assist the shift worker in dealing with shift-related fatigue in enabling them to understand how counter measures will work and how specific actions when off-duty can ease shift work.
- Management training in the causes of fatigue and fatigue management will assist in the development and subsequent management of fatigue friendly rosters.

7.4 Fitness and Diet

Whilst fitness and diet are not officially coping strategies, they influence negative health effects and as such can impact on the likelihood of errors and degradation of performance of shiftworkers.

Annex A highlights fitness and diet as potential causes of fatigue. Physical training has been shown to reduce subjective levels of fatigue, whilst an adequate supply of blood sugar (glucose) is essential for the function of certain parts of the brain. Further information on the role of fitness and diet can be found in the Annex.

Summary

- Studies have suggested that there are beneficial effects of physical training, but that these may be limited to subjective assessments of fatigue. Further research is required to examine the exact amount of required activity and its timing in relation to the work-rest schedule.
- Although studies have showed that the intake of certain foods can alleviate tiredness, specific food intake cannot be recommended to counteract fatigue, since scientific evidence is inconclusive and speculative.

8 Monitoring the risk associated with Shiftwork

Monitoring the risk associated with shift patterns is dependent on two factors, firstly systems that collect reliable and complete data on fatigue in relation to shifts and wherever appropriate the link to incidents. Secondly, a means by which the risk associated with shift patterns and fatigue can be quantified.

Having this information available will be of great benefit informing future research and enabling management to make sound decisions regarding shiftwork.

8.1 Data collection

It is generally accepted that sufficient data on accidents and incidents is not available to investigate the impact of fatigue. Coplen and Sussman [105] quoted from a report on Switching Operations Fatalities Analysis where findings indicated that fatigue could not be investigated as a contributory factor to fatalities because the relevant data was missing, incomplete, or lacked good exposure measures for establishing appropriate rate information. In general they found that fatigue related incidents are generally considered to be much more prevalent than the data suggests (Sussman & Coplen, 2000)

8.2 Models

Few companies currently manage shift-related fatigue in a quantitative manner. That is not to say the need to do so has not been acknowledged.

The Australian House of Representatives [108] has stated the Australian Transport Safety Bureau should establish guidelines for the use of computer based fatigue modelling packages in all models of transport and that computer based fatigue modelling systems should be implemented for testing the fatigue effect of work schedules and rosters.

The U.S Department of Transportation [116] has initiated a groundbreaking effort to develop tools that commercial aviation, marine, rail, transit and trucking industries can use to prevent fatigue related incidents in their operations. Specific tools are being developed to

1. Aid managers and schedulers in evaluating and designing work schedules that promote on-duty alertness
2. Predict employee's alertness and performance based on their work schedules.
   (This model is known as FAST – Fatigue Avoidance Scheduling Tool). This tool is not however accepted by the scientific community for a number of reasons. In particular, it assumes a linear function in performance decay with zero performance being reached after continuous sleep deprivation.
3. Provide guidance by means of a handbook of best practices for managers and schedulers in identifying, implementing, and evaluating fatigue management approaches.
4. Synthesise key policy issues, research gaps and evaluation methods into a framework that provides a blueprint for future research and systematic long-term data collection and monitoring on fatigue and its effects

Within the U.K. Rail Industry there is a requirement to identify a model (and any customisation requirements) that can be used to assess the risk associated with shift patterns.

9 Way Forward

It is considered that a long-term objective of the railway industry should be to achieve patterns of shift work for all staff which are optimum for the safe running of the railway and for the health of all employees, whilst achieving a high operational performance.

In order to achieve this objective, a programme of work has been developed and Qinetiq have been commissioned to undertake this work..

This study (outlined in Figure 5) has been partly prompted by DERA's evaluation of driver rosters. This showed that drivers sometimes work unscheduled overtime and often swap their shifts. This gap in our knowledge regarding shift working practices within the railway industry will be addressed by the development an application of an instrument to collect data on shiftwork patterns (refer to [1], Figure 5). This instrument will consist of a questionnaire and diary study to establish precisely the current shiftworking practices within the rail industry.

In addition, a number of interviews with roster clerks will take place to understand the culture behind rostering and the factors that influence it [2]. This will allow data to be collected on the planned rosters.

In parallel with [1] and [2], there will be a review of the current tools and techniques available for estimating the risks associated with shift patterns [3]. From this review, a tool/technique will be identified that is suitable for application to the Rail Industry, along with any customisation requirements.

Once all data has been collected, it is planned to measure the baseline risk associated with current shift work [4]. The tool/technique selected in [3] will be applied to the data collected in [1] and [2], so that an estimate can be made of the risk associated with basic shift patterns and the additional risk that may be associated with modifications to duty times and working hours that may occur in practice.

The risk estimates from [4] will then be compared with accident / incident data to obtain an initial estimate of the contribution of fatigue to the accident / incident rates [5]. It is acknowledged that this data will have to be analysed with some caution, as there are many difficulties associated with drawing inferences about fatigue from accident data.

Potential risk reduction strategies will then be proposed [6]. This will be on the basis of the work carried out so far and the guidance already put forward in this paper. There will be a review of principal tools and techniques for optimum shiftwork design along with a summary of coping strategies that are applicable to the UK rail industry.

A workshop, involving delegates from all sections of the industry, will be held to debate pertinent issues relevant to the suggested risk reduction strategies, such as costs and benefits, risks and potential barriers and critical success factors.

The output from the workshop will be agreed shift design and coping strategies to use in the pilot study [7].

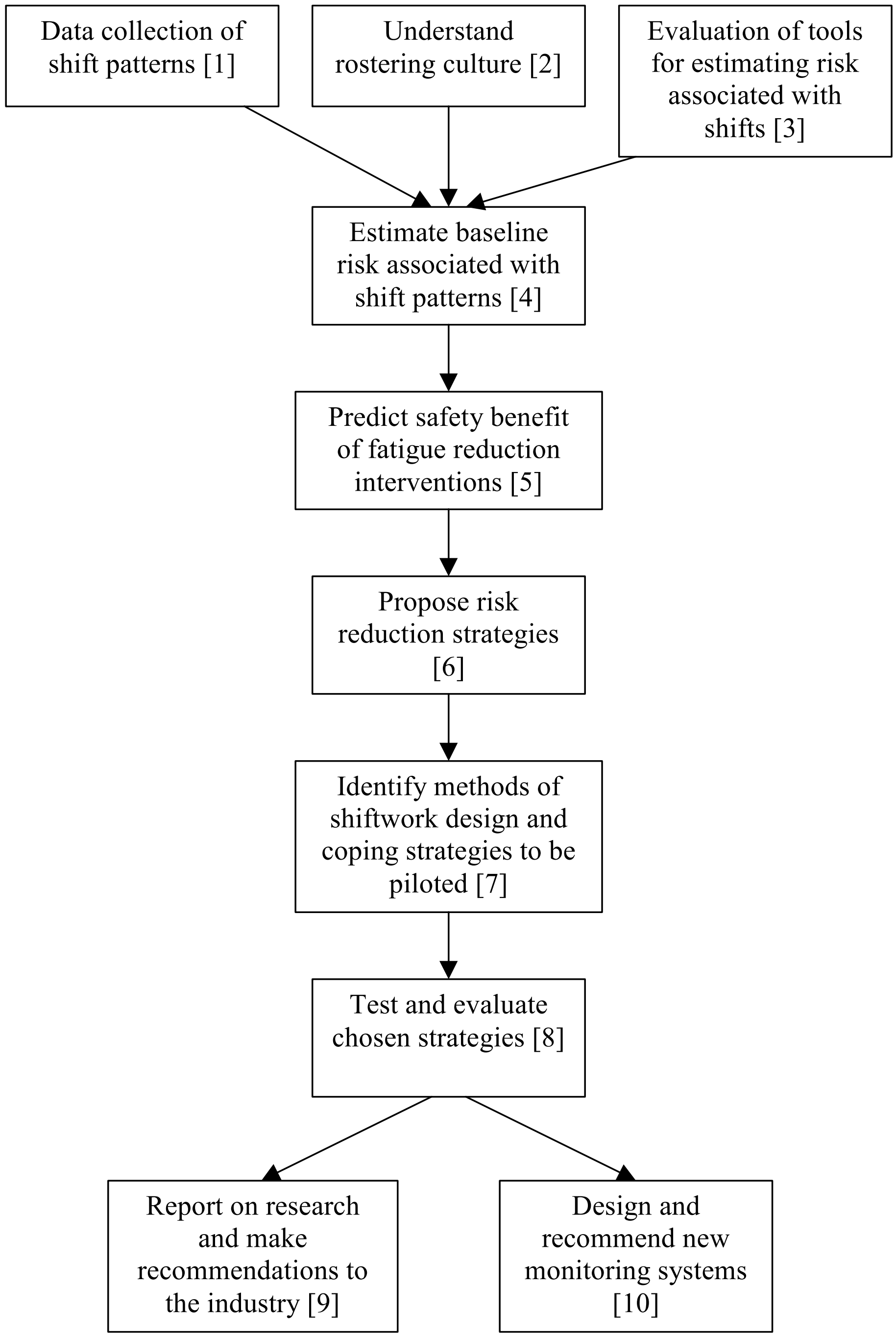

Figure 5: Proposed Programme for Optimisation of Rosters within the Railway Industry

Once principles for the design of rosters have been established, trials of the new shift patterns along with any feasible coping strategies, will be conducted within the Rail Industry [8]. It is expected that any trials will last for at least 5 months.
Upon completion of the trials, the implications of the research will be reported to the industry. Recommendations on shiftwork design and coping strategies will be made to the industry, based on objective evidence of safety improvements that might be achieved if changes in shift patterns were implemented [9].

In addition, recommendations will be made on:

- Defining the minimum criteria that monitoring systems should be capable of monitoring,
- Monitoring levels of fatigue throughout the safety critical elements of the rail industry,
- Monitoring the contribution of fatigue to accidents [10]

In addition to this program of work, The Federal Railroad Administration's (FRA) Office of Research and Development (OR&D) has embarked upon a Fatigue Research Program [105]. This program will systematically assess the many underlying factors that result in fatigue and reduced alertness, and develop appropriate tools that will assist the industry in developing its own effective management solutions. Wherever possible the program of work being sponsored by Railway Safety will seek to share information with the FRA's study.

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10 Acknowledgements

In recognition of the work required to compile and manage the production of this paper on behalf of Railway Safety, thanks are due to Laura Sutton of ERM Risk.

This position paper quotes extensively from the work of two parties and their permission to draw upon their work is gratefully acknowledged. The papers quoted are as follows:

(1) The 10th Westminster Lecture on Transport Safety', Parliamentary Advisory Council for Transport Safety, 'Transport Rhythm and Blues', by Simon Folkard DSc, Body Rhythms and Shiftwork Centre, University of Swansea, 1999; and

(2) Defence Evaluation and Research Agency (DERA) 'Visual and Mental Acuity Study', 2000.

In addition, it is a pleasure to acknowledge Simon Folkard in his capacity as reviewer of this paper and for the time he generously gave to discussing its content and writing the foreword.

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Annex A: Causes and Consequences of Fatigue

Figure 1 provided in the main body of this position paper shows an influence diagram that represents the main factors that cause fatigue and the main consequences arising from fatigue. The shaded areas in the diagram were not discussed in the main report but their contribution to fatigue or the impact fatigue has on them is described in this annex. It should be noted that it is not considered that all the factors are necessarily shown in Figure 1 but that the diagram is merely meant to represent the main issues. Furthermore, the inter-relationships between the factors are likely to be much more complex than represented in the diagram but it has been kept simple for clarity.

Potential ***causes*** of fatigue are as follows:

A1 Job factors

A1.1 Shift system

Factors associated with the shift system that may contribute to fatigue are described in detail in the main body of this position paper.

A1.2 Workload

Fatigue has been shown to be consequence of both underload and overload. Drivers of Japanese high-speed trains showed more signs of drowsiness as their workload decreased [77]. These signs included increased yawning and change of the sitting position, as well as poorer performance on a secondary auditory task.

Under conditions of relatively high workloads [78] performance was measured over a two-hour period on either a simple or complex air traffic control task. The time to detect aircraft under the complex task condition was found to increase significantly over the two hours whereas detection time for the simpler task showed no evidence of impairment. It was, therefore, concluded that performance may be related to the amount of information processing required for event detection.

A2 Individual factors

A2.1 Age

Studies consistently show that adjustment to shift-work tends to become more difficult with increasing age. Evidence suggest that at

40-50 years and above shift-work may impose severe strains, where coping with shifts deteriorates and health problems are more likely to occur [79,80].

At around 45 years of age, difficulties associated with night shifts start to increase with increased exposure to shift-work, implying that an individual does not 'learn' to adjust to shift-work [79]. Older shift-workers have reported poorer sleep and greater use of sleeping pills than their younger colleagues [81], suggesting that they may suffer more from fatigue and need more time off to recuperate. However, there is contradictory data which suggests that the ability to cope with early starts may improve with age (unpublished DERA data).

A2.2 Personality

Individuals differ in their preferred time of day for mental and physical activity. Those who experience peak alertness and activity early in the day are called 'morning types', whereas others, who perform better later in the day, are called 'evening types'. Although morningness tendency has been associated with poor adjustment and decreased tolerance to shift-work [82], a recent study found that evening types on a permanent night shift actually reported greater physical health complaints than morning types [83]. It is possible, therefore, that individuals may choose to work the type of shift that is in fact the most detrimental to them.

Rather more, though limited, success in predicting individuals' ability to working at unusual times and long-term adjustment to shift-work has been achieved using measures of flexibility of sleeping habits [84,85]. Individuals classed as 'flexible types', find it relatively easy to sleep at unusual times and have no preference for regular sleeping or meal times. In contrast, 'rigid types' have difficulty in getting to sleep early, or sleeping in late, even when tired. They also prefer to sleep and eat at regular times and maintain their normal sleeping habits even on holiday.

A2.3 Body clock

The impact of the internal body clock on fatigue has been discussed in detail in the main body of this Position Paper.

A2.4 Fitness

Moderate physical exercise may be a useful measure to counteract fatigue. Physical fitness and the effects of a training program have been studied in nurses working irregular shifts. Fit individuals felt less fatigued during a shift cycle, and they rated the quality of their sleep after the night shift as being better [86].

A physical training programme, which involved two to six training sessions over a four-month period, reduced subjective fatigue over a three-week cycle and during night shifts [87]. Fatigue during evening shifts was reduced and subjective sleep length increased, due to the exercise taken immediately prior to the shift.

These studies suggest that there are beneficial effects of physical training, but these may be limited to subjective assessments. Physical activity does not seem to increase adjustment to shift-work, although the exact amount of training and its timing in relation to the work-rest schedule need further examination.

A2.5 Diet

An adequate supply of blood sugar (glucose) is essential for the function of certain parts of the brain (the cerebrum). As blood sugar levels fall, the brain tries to shut down muscle activity to conserve the remaining sugar for maintenance of cerebral function. If blood sugar levels fall below a certain level, the following symptoms are likely: disorientation, lack of co-ordination and a progressive waning of consciousness.

Hubert's study on driver performance showed that the risk of falling asleep was reduced by an increased intake of sugar [88]. Also, certain foods that are high in protein (*eg* meat, eggs and cheese) have since been reported to alleviate tiredness if foods high in carbohydrates (*eg* bread and potatoes) are avoided [89]. However, at present, specific food intake cannot be recommended to counteract fatigue, since the scientific evidence is inconclusive and speculative.

Caffeine, although present in coca cola and chocolate is mainly consumed in the form of coffee and strong tea. It can also be found in many over-the-counter medications, such as pills for headache and cold relief. Caffeine can have beneficial effects on the performance of shift-workers, particularly overnight, [90], but heavy caffeine users, such as those who consume five or more cups of coffee per day, may have developed a tolerance and larger quantities will be needed to produce a beneficial effect. Caffeinated drinks taken within four hours before bedtime can delay sleep onset and disturb the subsequent sleep period.

Alcohol is sometimes used to promote sleep. However, it is best avoided prior to a working day, since even a small amount tends to disrupt sleep. Sleep onset may be shorter, but individuals may wake more frequently.

A3 Social factors

A shiftworker's social circumstances, such as marital status, number of children and leisure interests, for example, will influence likely well-being, including levels of fatigue. The extent to which he or she is able to acquire sufficient sleep will depend to an extent on the amount that his family depends upon him to integrate into family life at 'normal' times and to keep social engagements that may be difficult for him.

The neighbourhood may affect the ease with which a shiftworker can recover after night work – traffic noise may make it difficult to get to sleep and frequent interruptions, from telephone calls and visitors may also disrupt the sleep period. A shiftworker will rely upon the efforts made by his family to maintain a quiet environment during the day, when he may be sleeping, in order to ensure that he gets enough sleep [91].

Shiftworkers are well renowned for taking jobs additional to their main employment, potentially made more likely if suffering from financial pressures at home. Andlauer (1988) asserts that 'unofficial and more or less clandestine statistics show that 33% of shiftworkers have another job 'on the side' [92]. This is highly likely to increase fatigue levels.

Potential ***consequences*** of fatigue are as follows:

A4 Human Performance

A4.1 Vigilance

Vigilance tasks are particularly sensitive to fatigue since they are usually simple and monotonous. Fatigue results in short lapses in attention, or in some cases 'microsleeps', where for short periods, typically of only a few seconds, the individual lapses into a state of drowsiness. The resulting 'vigilance decrement' is characterised by a decrease in the number of stimuli correctly detected or by an increase in response times. Performance has been shown to deteriorate rapidly on tasks requiring continuous monitoring for two hours or more, and decrements can be expected as early as 20-35 minutes after the start of a vigil [93].

A4.2 Memory

Memory tasks require an individual to acquire and retain information and to recall it when needed. Short-term memory, such as remembering a new telephone number, can be maintained for a few seconds, or longer if the number is rehearsed. As an individual becomes tired the ability to retain and recollect new information decreases. Long term memory is more complex, and there is no practical limit on the capacity of the brain to store information permanently. Most laboratory studies have, therefore, investigated the effects of fatigue on short-term memory, as these tasks are easier to quantify.

Studies have shown that for a low memory load task, peak performance occurs in the late afternoon, whereas for medium and high memory load tasks, performance is best in the early hours of the morning [94]. This would suggest that performance on tasks involving a high memory load might actually be better on the night shift.

A4.3 Decision making

Simple tasks such as those involving responses to simple stimuli are easy to evaluate in the laboratory. However in real life, many tasks are more complicated and require complex decisions. Due to the difficulty of reproducing such complex tasks in the laboratory, few studies have investigated the effect of fatigue on decision-making.

Early studies suggested that problem solving and complex decision making appeared to be more resistant to fatigue, since they failed to show any significant effects of sleep deprivation [95]. It was thought that, as such tasks are interesting to the subject, they encourage sufficient motivation to counteract the expected decline in performance. However, more recent investigations have shown that complex tasks that require innovative, flexible thinking and planning are also sensitive to fatigue [96].

Fatigue is associated with rigid thinking, and difficulty in responding to changing circumstances. Individuals may revert to poorer practised strategies rather than develop novel or creative ideas that would improve their performance. Banderet and co-workers [97], using a simulation scenario, showed that tired subjects were unable to cope with unforeseen rapid changes in tasks and to update and revise information in the light of new events.

A4.5 Reaction time

Reaction time is the delay between the occurrence of an event and the response to it. As a person becomes more fatigued, their performance becomes more and more uneven, with periods of efficiency being interspersed with performance lapses [98]. Visual reaction time performance is more susceptible to fatigue than auditory reaction time [99].

A4.6 Errors

The impact of fatigue upon human error has largely been discussed in the main body of this Position Paper, particularly with respect to human errors that cause accidents. However, degradations in the above mentioned aspects of human performance, such as vigilance and decision making, are also likely to cause human errors.

A5 Operational Performance

The impact of fatigue on accidents, and to some extent costs, is discussed in the main body of this Position Paper. Simon Folkard discusses the costs of fatigue further in the foreword to this paper.

Absenteeism and a higher staff turnover are inevitable consequences of a workforce suffering from levels of fatigue which they find intolerable or which potentially put them and/or others at risk of injury. Akerstedt and Torsvall (1978) showed a clear decrease in sickness absence in a group of steelworkers transferred from shiftwork to daywork because of a change in production requirements [100].

A6 Health

Monk and Folkard (1992) [101] quote 'Shift work is probably bad for the heart, almost certainly bad for the head and definitely bad for the gut'.

In a 15 year follow-up study of shiftworkers in a paper mill, Knutsson et al (1989) [102] found that 11- 15 years of shiftwork gave a relative risk of coronary heart disease of 2.2 and that 16-20 years gave a relative risk of 2.78 (compared with day workers). The relative risk fell sharply after 20 years, potentially due to a 'healthy worker effect', essentially those shiftworkers who suffer most transferring to the day working population.

Bohle and Tilley (1989) have shown a clear and significant increase in self-reported psychological symptoms (such as depression, loss of self-esteem, difficulty in concentrating, etc.) in a group of nurses, 15 months after commencing shiftwork [103]. Shiftwork and fatigue can also have a negative influence on an individual's relationships with family and friends. Strain in such relationships may affect an individual's well-being and potentially their performance at work (Monk and Folkard, 1992) [101].

As long ago as 1921, Vernon noticed an excess of gastric problems in shift workers in the armaments industry [11]. As well as reduced sickness absence in the group of steelworkers who were transferred from shiftwork to daywork, Akerstedt and Torsvall (1978) found a clear decrease in gastrointestinal complaints. There were also reductions in sleep disturbance and mood disorders [100].