Shiftwork, sleep, fatigue and time of day: studies of a change from 8-h to 12-h shifts and single vehicle accidents

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Chapter Eight

Summary and Conclusions
8.1 Introduction

The distribution of shiftwork is moving away from heavy industry and growing in the service industries (see section 1.2). Fuelling this change, are a number of social and economic factors (Gowing et al. 1997; Pierce et al. 1989). Employees are seeking increased work flexibility to provide more time off and at the same time, business is seeking increased deregulation of the labour market (Callus, 1997) to increase competitiveness and respond to market forces (Kogi, 1995). In turn, these factors are placing new challenges for responsible shift design to ensure health and safety.

One approach to increasing flexibility is the compressed workweek (CWW). They are increasingly being established as a vehicle that meets organisational goals (Heiler, 1998) and are popular with shiftworkers (L. Smith, Folkard et al. 1998). These extended shifts are associated with faster rotations in order to minimise cumulative sleep loss and fatigue (Tepas & Mahan, 1989) and to increase time away from work (Duchon & Smith, 1993). However, the overriding concern with the CWW is increased fatigue (Rosa, 1995). The 12-h shift is one example of working the CWW. The irony, is that these shifts were widespread at the turn of this century (Scherrer, 1981). Of course, the number of hours worked are far less today.

The recognition that weekly and slow rotations do not result in circadian adaptation (Akerstedt, 1985; Folkard, 1992) has led to recommendations for shift designs with faster rotations (Knauth, 1997). In particular, shift design needs to balance two main factors; minimising fatigue and maximising time away from work. The ergonomic shift design criteria (Knauth, 1997) specify, a maximum of three consecutive shifts and a minimum of two days off. However, these recommendations were largely based on 8-h shift studies. Therefore, their application to 12-h shifts needs careful examination.
8.2 Main results and discussion

Concern over fatigue as a result of working extended shifts remains high. There is an increasing recognition that fatigue is no longer regarded as being a function of time on task. Fatigue may reflect an interaction between time on task and time of day (Dinges, 1995). An assessment of fatigue may be achieved via a number of indicants (Duchon et al. 1994; Tepas et al. 1997). In these studies, fatigue was operationalised in terms of changes in self reported survey data, total sleep time (TST) and performance. The results in chapters two and three indicated these criteria are far from independent. Indeed, some shiftworkers indicated a willingness to trade-off sleep for more social time. The key findings from each chapter are reviewed below, followed by some recommendations for 12-h shift design and some suggestions for future studies.

8.2.1 Sleep duration

Main effects for mean TST between 8-h and 12-h shifts were not found in either the Coal or Steel studies. However, mean TST was maintained by some redistribution of TST on 12-h shifts in both studies: (a) night shift sleep was significantly reduced; (b) sleep after day shift and days off increased; and (c) the increase in TST on days off was significant for Steel.

The fall in night shift sleep duration is of most concern. The sleep loss was explained by three factors. The first is that the faster rotations result in an increased number of transitions to night shift. Each one of these, is associated with an acute sleep loss.

The second factor is that the longer shift results in less time available between shifts, to fit sleep and social/domestic activity. One outcome was less napping before 12-h night shifts compared to 8-h night shifts.
The third factor was a deliberate strategy to balance sleep loss and fatigue. The shiftworkers in the Steel study, indicated taking less sleep when only two consecutive night shifts were worked. This was because sleep could be recouped on days off. In contrast when three night shifts were worked, they consciously aimed for more sleep because the amount of fatigue increased.

The benefits of a faster rotation in reducing cumulative sleep loss was mixed. In the Coal study, the number of shifts worked and the total number of days when daily sleep was below the mean for the shift cycle decreased. In the Steel study, the number of shifts worked when sleep fell below the mean for the shift cycle increased. However, the total number of days when sleep was below the mean decreased.

These differences may be due to differences between the shift systems and the personal choices made by shiftworkers. For example, it appeared the shiftworkers were choosing to take less sleep during work days and taking longer sleeps on days off. A good shift design is ultimately of potential value only.

The cumulative sleep gain/loss plots are an incomplete representation of changes to sleep. While they provide some useful indicants of where sleep is lost and recouped, they require to be read in conjunction with daily mean sleep deviation from the shift cycle to provide a more complete assessment.

In terms of methodology, sleep diaries provided better sleep estimates and the opportunity to examine cumulative sleep gain/loss across a shift cycle. Sleep diaries provide a context for capturing the daily fluctuation in sleep. Chapter three confirmed that in the absence of a daily context, shiftworkers provide ideal sleep estimates in response to sleep need questions. Nonetheless, chapter three also found that the inflated sleep estimates were in line with sleep diary estimates across a shift cycle.
Self report estimates of sleep duration are all open to bias, if the shiftworkers choose to favour a particular outcome. However, the evidence from these two studies, suggested that sleep diaries were not used to necessarily support 12-h shifts. If this was the case, the loss of night shift sleep on 12-h shifts would not have been found.

Sleep diaries do result in lower compliance rates compared to survey or interview formats and this is a real difficulty, because they provide better quality data. Actigraphs may reduce the recording burden and have been successfully used (Lowden et al. 1998). However, actigraphs are costly for large scale field use and do not always readily distinguish between rest and sleep. Furthermore, they are also open to data loss due to compliance.

Sleep diaries have a long history of use. However, a review of the self report sleep literature does not identify a standard approach for defining sleep time. There are at least two major difficulties: (a) whether to include sleep before and after a shift or whether to only include sleep before a shift; (b) whether to use the main sleep period as the dependent variable or whether to set a standard 24-h period and include all sleep taken in this period. The absence of an agreed scoring protocol limits the ability for cross study comparisons.

8.2.2 Survey and interviews

The survey data in both studies showed general improvement on the SSI measures. The fact that both sites had different 8-h shifts and changed to different 12-h shifts suggested at least two possibilities to explain the support for 12-h shifts. This may suggest a positive bias for any system that provides more time off.

In both studies, the advantages of 12-h shifts outweighed those on 8-h shifts and there was a reduction in shiftworkers willing to transfer to day work. These findings were attributed to the increased number of days off (see chapter three).
Additional self report data and the interview data in chapter three however, indicated that these data are not necessarily biased in favour of 12-h shifts. Rather the shiftworkers are accepting a trade-off between more free time and fatigue. This intention is signalled in giving up the afternoon shift. This shift provides good sleep duration but is poor in terms of a social and family life.

The survey data also identified a number of fatigue indicants in both studies. Self reported need for sleep increased in both studies. This may not be too surprising given the sleep loss on night shift and the rapid rotation. It is important to note that sleep duration is not an ideal indicator of recovery from fatigue (Akerstedt, 1990). Sleep is terminated for circadian and social factors. However, sleep length does provide some indication of tiredness.

The shiftworkers in the Coal study indicated a willingness to modify their 12-h shift to provide a better distribution of work and rest. In achieving a single block of eight days off, the remaining work periods provided too little time off for recovery. They indicated a preference for shortening this long break and to increase the days off between the work periods.

In the Steel study, a non significant increase in chronic fatigue and a significant increase in cardiovascular symptoms were found. This may reflect differences in job tasks. The job tasks in the Steel study required much walking and stair climbing. Also, they needed to respond immediately to furnace difficulties. In contrast, the Coal shiftworkers were more able to control their work pace.

Dissatisfaction with some aspects of 12-h shifts were found in the interview study of the Steel shiftworkers. In general however, these comments appeared to be a desire for even more free time. In particular, three consecutive shifts (especially night shifts) were found to be tiring, as were the following day shifts due to insufficient time off
between these two work periods. However, no shiftworker asked for the balance of work and rest days to be altered.

8.2.3 Absence

The introduction of 12-h shifts in the Steel study was associated with a significant reduction in absence. However, this decrease was not attributed to 12-h shift per se but to the change in remuneration policy that accompanied the change. Whereas, absence on 8-h shift resulted in the payment of overtime, absence on 12-h shifts did not result in overtime payments. The interview study found evidence of a 'social pressure' to ensure absence was taken only when genuinely ill.

A comparison of the absence explanations between 8-h and 12-h shifts also supported that shift length was not responsible for the change. The comparisons identified no differences. This result also supports the position that absence is a poor indicator of health status (Kleiven et al. 1998).

The results from the investigation of absence suggest that when absence is combined with other reasons for absence from work (vacation and other leave), it represents in part, a strategy by shiftworkers to effectively redesign their shift system.

Non-attendance at work, coupled with the opportunity to work overtime enables shift redesign. During 8-h shifts absence and overtime were highly correlated and suggested these were used to compress the workweek. Absence either end of the shift spell, reduced the number of workdays and overtime maintained or increased earnings.

On 12-h shifts, absence, single days of annual leave and small periods of annual leave (non attendance) appeared to be used to provide relief from difficult parts of the shift system. In particular, non attendance increased during periods of three night shifts. While absence avoided the third shift, it also served to increase the span of time
off, from two to three days. This suggested that two days off were insufficient, especially after three consecutive shifts.

8.2.4 Safety and performance

There were no significant differences to the number of recorded accidents by those who worked both 8-h and 12-h shifts (see chapter five) in the Steel study. Nonetheless, there was some indication that the extended shifts were associated with increased accident frequency when the same time of day was compared (see table 5.8).

A number of reasons may explain the lack of impact of 12-h shifts on accidents: (a) job design and reliable automation combine, to ensure a safe working environment despite shift length; (b) shiftworkers are aware of this increased risk posed by longer shifts and therefore, make compensatory efforts (L. Smith, Folkard et al. 1998); (c) overall working hours were less on 12-h shifts due to a reduction in overtime; and (d) accidents are rare events requiring more than a one year review of each shift type.

The low frequency of work place accidents hinders the ability to consider the effect of alternative shift designs on safety. Demonstrating the effect of work on accidents requires a large and longitudinal database that gathers data at a state, national (Hanecke et al. 1998) or international level. Road vehicle accidents are a useful alternative to demonstrate time of day performance variation (see chapter six) but they are not linked to work hours.

The accident database also provided an opportunity to conduct an archival study of police performance errors by time of day (Bjerner et al. 1955; Hildebrandt et al. 1974). This study also found that errors increased markedly on the night shift. A comparison of the error rates between this study, the peak accident timing of the single
vehicle accidents (chapter six) and the error peaks in Bjerner et al. (1955), suggested that the impact of time of day is task related. This is an area for further study.

8.2.5 General limitation of the Coal and Steel Studies

The studies presented from chapter two to chapter five each share a common methodological difficulty stemming from their small sample sizes: statistical power analysis (Cohen, 1988, 1992).

Power analysis indicates the probability of making a Type II error given the sample size, the expected effect size, the alpha level and whether a one way or two tailed test is used. Given the criteria used in each study and the small sample size, each of the studies reported low power estimates.

The results from both longitudinal sleep studies suggested retaining the null hypothesis. The low power estimate associated with these studies would suggest the high probability of a Type II error having been committed. Similarly the absence and safety studies are open to the same difficulty and further compounded by the time period investigated.

The power issue however, should not detract from the other methodological strengths in the Coal and Steel studies. The statistical data analysis were complimented by feedback sessions (Coal) and a combination of interviews and a case study methodology in the Steel study.

Small sample sizes may be associated with power difficulties and an inability to generalise the results to a wider context. However, these issues are not reason enough to not conduct research. The sleep studies nonetheless provided an longitudinal overview of the effect of a new shift schedule on those shiftworkers. In addition the small samples allowed one way to examine the SDM (Tepas & Mahan, 1989). While the SDM is derived from empirical research, this study was the first to whether the
reductions in chronic sleep loss following a slow (weekly) rotating shift schedule are offset by an increase in acute sleep loss associated with a faster rotation.

8.3 Implications for 12-h shift design

A number of recommendations in terms of 12-h shift design are possible based on the results from this set of studies. Some of the recommendations are in agreement with Knauth's (1997) criteria for good ergonomic shift design;

1. the shift cycle should not be overly compressed, in order to provide a large single block of time off.

2. work periods should avoid combining day and night shifts to avoid cumulative fatigue.

3. night shifts should be followed by a minimum of three days before returning to day shift to better facilitate recovery and free time.

4. a maximum of three consecutive shifts.

5. structure the shift cycle to include as many free weekends as possible.

6. avoid placing three consecutive shifts during the weekend.

These recommendations are not meant to be exhaustive and reflect primarily the demands of the shift systems studied. Other factors to consider include the physical and psychological demands of the task, toxic exposure (Knauth, 1996) and the active involvement of the shiftworkers (P. Smith et al. 1998).

It is important to highlight a recommendation for good shift design that appears to have been overlooked in the enthusiasm for faster rotations; to reduce or abolish the night shift (Knauth, 1993).

Twelve hour shifts repackage the same total number of shifts into smaller work blocks but do not reduce the number of shifts or the hours of total exposure to night work. By redistributing the former afternoon shift to extend the day and night shift, they
create more rest days but do not alter the work hours.

Exposure to night and shiftwork can be reduced in total terms by alternative shift design options. Two examples are, reducing the average duration of the workweek and introducing a five crew system. Both options result in more free time and reduced night shift exposure. These alternatives do not necessarily result in increased organizational costs.

The salient point is that shift design needs to consider solutions to reduce total night shift exposure. The issue of reducing chronic exposure from slow rotating shifts appears to have been satisfied, by faster rotations.

8.4 Future studies

The research reported in this thesis and the work of other authors, suggests at least eight key areas for future research:

1. Longitudinal studies need to incorporate repeated measures covering several years. This allows the long term impact of the change to be monitored and may also shed some light on the 'life-span' of new shift systems. There are no reported studies that have tracked the viability of recently introduced systems.

2. Field based performance studies of actual job tasks. These are methodologically difficult but necessary to validate the impact of sleepiness and fatigue.

3. Well planned safety studies. This requires a prospective design across a number of organizations to ensure a sufficiently large database, akin to road accident archives.

4. The use of repeated measures sleep diary data across complete shift cycles. In particular, these studies require the support of a standardised
protocol for defining total sleep time, acute sleep loss and chronic sleep loss.

5. Studies that seek to optimise compliance rates for recording daily sleep data.

6. An increased understanding of the personal and situational factors that impact on sleep behaviour, in addition to shift design parameters.

7. Future studies should examine innovative solutions to reducing total night shift exposure.

8. The effect of increasing the number of episodes of acute sleep loss on performance and well-being.

8.5 Conclusions

Twelve hour shifts provide a useful approach to increasing flexibility in shift design. There is strong evidence that 12-h shifts are popular with shiftworkers for a number of reasons. It also seems to be the case that the faster rotations result in less chronic sleep loss. However, this benefit is at the cost of increasing the episodes of acute sleep loss. Strategies to reduce the number of these episodes are required.

In terms of shift design, it is important to stress that 12-h shifts represent one of a number of alternative approaches to increasing shift design flexibility. Therefore, alternatives to 12-h shifts require continued support towards improving shiftworker well-being. While the survey data supported the popularity of 12-h shifts, the survey and sleep data both recorded concerns regarding fatigue.