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 One

Shiftwork, shift design and sleep
1.1 Introduction

Shiftwork involving nightwork is not necessarily a major problem for all employees (E. Taylor, Folkard & Shapiro, 1997). Nonetheless, there is a body of evidence to link shiftwork to a range of physical, psychological and social impairments (Waterhouse, Folkard & Minors, 1992). In particular, achieving sufficient sleep is a major pre-occupation among shiftworkers (Akerstedt, 1991). Estimates vary but some 60-70% also complain of sleep disruption (Rutenfranz, Haider & Koller, 1985). Furthermore, shiftwork is implicated with an increased accident risk (L. Smith, Poole & Folkard, 1994) and impaired performance (Rosa & Bonnet, 1993).

One shift design strategy that can ameliorate shiftworker health is shift rotation speed. The evidence suggests faster rotations contribute to improving shiftworker well-being (Knauth, 1997; Tepas, Paley & Popkin, 1997; Wedderburn, 1992a). Nonetheless, the question of rotation speed is a topical debate (Wilkinson, 1992). This debate has been refuelled by a shift to the compressed workweek (CWW) and 12-h shifts in particular (Duchon & Smith, 1993). The CWW allows shiftworkers to work fewer but extended shifts that result in a faster rotation. There is far less agreement regarding the impact of the CWW. Some studies have found clear support for the CWW (Williamson, Gower & Clarke, 1994; Lowden, Kecklund, Axelsson & Akerstedt, 1998), while others have found increased fatigue (Rosa, 1995; Tepas, 1994). At present, acceptance of the CWW is subject to a number of qualifications (see Knauth, 1997).

The present chapter begins by defining shiftwork and presenting shiftwork estimates, including recently available Australian data. This is followed by a discussion of shiftwork and health, and an overview of two general models which illustrate this relationship. These general shiftwork models are considered to best serve as heuristic aids, rather than the prediction of unequivocal outcomes (E. Taylor, Briner & Folkard,
An alternative approach is offered by the sleep deprivation model (SDM) (Tepas & Mahan, 1989). The narrower focus of the SDM addresses specific aspects of shift design outcomes and it is empirically based. The chapter then discusses key issues in shift design. Finally, an argument is presented for the use of sleep duration as a marker of shift design adequacy, due to the relationship between sleep duration and a number of dependent variables.

Chapter one serves primarily as the literature review for chapter two. The focus in chapter two is on changes to total sleep time and selected measures from the Standard Shiftwork Index (SSI) (Barton et al. 1995a), in response to a change from 8-h to 12-h shifts. Chapter three seeks a more comprehensive understanding of this change by interviewing shiftworkers (Tepas, Walsh & Armstrong, 1981; Wedderburn, 1987). Chapters four to seven are mostly self contained. Chapters four and five examine the effect of the shift change on absence and safety respectively. The difficulties inherent in clearly linking shiftwork and safety (Folkard, 1996) has led some researchers to use alternative data sets. Chapter six has followed this approach by exploring single vehicle accidents by time of day. The use of this archive data also allowed an analysis of police reporting errors which are presented in chapter seven. Finally in chapter eight, an overall discussion is presented to draw together the findings from the various chapters.

1.2 Shiftwork: definition and estimates

Shiftwork refers to the regular replacement of workers at an agreed time and includes work during unsocial hours. This interpretation is underpinned by the definitions offered by Akerstedt (1991) in which shiftwork involved the use of 'two or more teams (shifts) to cover the time needed for production' (p.129), and Kogi (1985) who described shiftwork as a work strategy whereby, 'one team of workers regularly
replaces another team of workers on the same job and in the same workplace' (p. 166).

It is important to note that these definitions do not specify some important characteristics of shiftwork systems. For example, shift change times, shift length or rotation speed and direction. The many possible shiftwork configurations has led some bodies to broadly consider shiftwork, as work carried out outside the hours of 07.00 to 18.00 (OTA, 1991).

A framework to assist in the classification of shiftwork systems has been developed (Knauth, 1996). In essence, shift systems are described as being either permanent or rotating. Rotating systems may be further categorised as involving continuous or discontinuous operation. This basic framework is complicated however, by the many possible permutations when combined with the additional shiftwork features listed in table 1.1.

Insert table 1.1

The use of Knauth's (1996) classification system assists in interpreting the results from various studies. However, there is still ambiguity surrounding some features such as rotation speed (Tepas et al. 1997). A fast rotating shift in Europe refers to shifts which rotate every two to four days, whereas in the USA a weekly rotating system may be classified as fast rotating.

Precise shiftwork estimates are difficult to obtain. National data are not available in all countries and comparisons are limited by definitional differences. Furthermore, shiftwork estimates are masked by downsizing and a shift from traditional shiftwork industries to the service sector.

Maurice (1975) indicated some 20% of workers were shiftworkers and similar estimates are still being reported (Colquhuon, Costa, Folkard & Knauth, 1996). The
### Table 1.1  
**Additional Features of Shift Systems (Knauth, 1996)**

- Number of consecutive morning, evening and night shifts  
- Number of consecutive working days  
- Length of each shift  
- Times at which shifts start and finish  
- Distribution of leisure time  
  - the duration of time off between two shifts  
  - the time of day at which leisure time is available  
  - the time of week at which leisure time is available  
- Direction of rotation  
- Regularity of shift system  
- Flexibility of shift system

OTA (1991) concluded 20% of non-agricultural employees in the USA were shiftworkers in their primary jobs. More recently, Dekker et al. (1996) reported some 18% of employees in the USA worked outside the daytime hours and Wedderburn (1996a) reported that in the UK, shiftwork accounted for 18.1% of all occupations.

Australian shiftwork data were first produced by the Australian Bureau of Statistics (ABS) in 1993 and are published bi-annually. Shiftwork is defined as "a system of working whereby the daily hours of operation at the place of employment are split into at least two set work periods (shifts), for different groups of workers (ABS,
1997, p. 46)."

The data in table 1.2 shows a small overall increase in Australian shiftworkers from 14.20% (1993) to 14.47% (1997). The table also suggests an increase in part-time shiftworking and decrease in full-time shiftworking. The number of shiftworkers engaged in manufacturing industries decreased to 19.1% in 1997. A detailed breakdown of Australian shiftwork data by occupation, industry and gender can be found in appendix one.

Table 1.2

The Total Number and Percentage of Shiftworkers by Employment Type, Industry and Trade Union Affiliation.

<table>
<thead>
<tr>
<th></th>
<th>1993</th>
<th>1995</th>
<th>1997</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of shiftworkers:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall (%)</td>
<td>14.20</td>
<td>14.61</td>
<td>14.47</td>
</tr>
<tr>
<td>Part time (%)</td>
<td>27.30</td>
<td>27.18</td>
<td>29.26</td>
</tr>
<tr>
<td>Full time (%)</td>
<td>72.70</td>
<td>72.82</td>
<td>70.74</td>
</tr>
<tr>
<td>Industry:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mining (%)</td>
<td>4.32</td>
<td>3.89</td>
<td>3.34</td>
</tr>
<tr>
<td>Manufacturing (%)</td>
<td>19.50</td>
<td>19.23</td>
<td>19.09</td>
</tr>
<tr>
<td>Labouring (%)</td>
<td>20.98</td>
<td>19.93</td>
<td>12.80</td>
</tr>
<tr>
<td>Trade Union:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes (%)</td>
<td>58.43</td>
<td>54.00</td>
<td>53.10</td>
</tr>
<tr>
<td>No (%)</td>
<td>41.57</td>
<td>46.00</td>
<td>46.90</td>
</tr>
</tbody>
</table>

¹ The percentage of the total number of shiftworkers.
General shiftwork estimates in Europe and USA have remained largely unchanged over the last two to three decades, despite the global 'downsizing' trend (Gowing, Kraft & Quick, 1997; Littler, Dunford, Bramble & Hede, 1997). Downsizing is apparent in traditional shiftwork areas in Australia. Falls in the mining and manufacturing industries, and most notably for labouring occupations can be seen in table 1.2. Similar changes in the UK have been noted by Wedderburn (1998, p. 16).

The size of the decrease in traditional shiftwork areas may however, be over estimated. Wooden (cited in Trinca, 1999) has suggested that while declines in mining and manufacturing have occurred, these data are masked by changes in employment patterns. For example, some organisations are terminating employees who are subsequently re-employed by an outsourcing company or under direct contract. In terms of the ABS criteria, outsourced employees are counted in the service categories. This change may lead to under estimates of shiftwork in manufacturing.

Shiftwork estimates are also influenced by a redistribution of work from blue, to white collar and service occupations. Table 1.3a (see appendix one) shows shiftwork increased in transport and storage, business services, hospitality and other services. Similar increases in the UK service industry have also been reported (Wedderburn, 1998, p. 16). The shift to non-traditional shiftwork operations can also seen in table 1.2. Australian shiftworker membership of trade unions is falling with an increase for shiftworkers not belonging to a trade union. This trend may also be explained by a shift in Australian industrial relations practices from trade unionism to 'enterprise agreements' (Callus, 1997).

A number of economic and social factors may explain the growth of shiftwork in the service sector. Information technology has linked the 'global village' (Brewster & Tyson, 1991) with a concomitant need for 24-h operation to allow round-the-clock
trading. Organizational concerns for increased efficiencies has led to pressure to increase total working hours (Gowing et al. 1997).

From a social perspective employees are seeking alternatives to established work patterns. Tele-working (Chapman et al. 1995) is one vehicle for allowing employees to balance the competing needs for work and leisure. Changing work patterns, combined with changes in the family structure (eg. dual career couples) and in the workforce have led to increased consumer demand for round-the-clock availability of services (eg. supermarkets and banking). Detailed reviews of the economic and social drivers can be found in Cohen and Gadon (1978) and Pierce, Newstrom, Dunham and Barber (1989).

1.3 Shiftwork and health

Human biology is predominantly diurnal with the daily oscillation of endogenous body rhythms entrained to strong exogenous environmental time cues (Wever, 1985). The disruption of these circadian and social rhythms by shiftwork is well documented (Waterhouse et al. 1992) and is considered to be stressful (Costa, 1996). These effects can be seen in terms of impaired physical health, performance and safety, sleep and psychological well-being.

Shiftwork has been linked to a number of physical difficulties. Knutsson (1989) and his colleagues (Knutsson, Akerstedt, Jonsson & Orth-Gomer, 1986) have reported a direct and indirect (eg. diet, smoking and alcohol) link between shiftwork and increased cardiovascular disorders. Gastrointestinal disorders (Angersbach et al. 1980; Verner, Szabo & Moore, 1989) are often reported to be higher in shiftworkers. While there are some methodological difficulties with most of these studies, Costa (1996) nonetheless concluded that on the balance of the evidence, shiftwork is a definite risk factor. Preliminary evidence from Nurminen (1998) suggests the
detrimental effect of shiftwork on female pregnancy. Furthermore, there is some evidence which suggests the accumulation of health deficits (Kundi, 1989) and increased health complaints with increased shiftwork exposure (Nachreiner, Lubeck-Ploger & Grzech-Sukalo, 1995).

Shiftworkers also face difficulties at work. Both field studies (Liou & Wang, 1991) and interpolated studies (Tepas, Walsh & Armstrong, 1981; Tilley et al. 1982; Rosa & Bonnet, 1993) have demonstrated performance impairment at night. This night time impairment is further supported by an increased safety risk during the night shift (Mitler et al. 1988; L. Smith et al. 1994). Other studies have reported difficulties in staying awake during the night shift (M. Smith, Colligan & Tasto, 1982), and decreased alertness (Rosa, 1991; Tucker, Barton & Folkard, 1996). However, not all studies report night shift impairments (P. Taylor 1967; Taylor, Pocock & Sergean, 1972).

There are sound biological and theoretical grounds to expect health and performance impairments in shiftworkers. However, there is little direct evidence linking shiftwork to specific physical illness (Scott & LaDou, 1990) or significantly impaired performance and safety (Folkard, 1996) in field studies. Interpreting causality from most studies is problematic due to methodological limitations. These include; a reliance on cross sectional studies (Akerstedt & Torsvall, 1978), the inability to find matched control groups (Knauth, 1995), and healthy worker effects in the data (Frese & Semmer, 1986). Furthermore, demonstrating performance impairment requires a large data set and an environment in which the effect of working at night can be clearly established. This is seldom available in industrial settings. These conditions are more closely achieved in studies of single vehicle road accidents (see chapter six).

The effect of shiftwork is clearer on sleep and psychological health. The most robust finding in shiftwork studies is the reduced sleep quantity and quality following
night shift (Tepas & Carvalhais, 1990; Wilkinson, 1992). Sleep is especially reduced following the night shift due to primarily circadian factors (Akerstedt & Gillberg, 1981a) and exacerbated by environmental and social factors. Reduced sleep is associated with feelings of tiredness and irritability (Bennet, Smith & Wedderburn, 1982). These feelings of malaise carry over into disturbed social and family lives (Colligan & Rosa, 1990; Staines & Pleck, 1984; Wedderburn, 1981; Walker, 1985) including partners' social lives and well-being (L. Smith & Folkard, 1993).

Psychological health has often been reported to be affected by shiftwork (Bohle & Tilley, 1989; Wyatt & Marriott, 1953). Meers, Maasen and Verhaegen (1978) demonstrated the effect in a longitudinal study with new and experienced shiftworkers. Base line results showed new shiftworkers reported increased well-being compared to experienced shiftworkers. After six months, well-being decreased significantly in both groups and further deterioration was observed after four years. After four years, Meers et al. collected data from 31 original shiftworkers who had either left the plant or returned to daywork. One-third of the fifty reasons cited for leaving shiftwork were centred on lowered 'subjective well-being and/or disruption of social relations' (p. 858). Other studies have concluded impaired psychological health is attributable to fatigue and tiredness resulting from sleep loss (Naitoh, Kelly & Englund, 1990; Rutenfranz et al. 1985). Rotating shiftworkers are in a continual state of flux (P. Smith, 1979) either adjusting to a spell of night shift or re-adjusting to diurnal activity.

A good deal of impaired psychological well-being is attributed to shift rotation speed (see section 1.6.1). In particular, most of the studies reviewed above involved a seven day or longer rotation. In contrast, studies with a faster rotation speed report fewer difficulties. These studies typically report increased ratings regarding social satisfaction and psychological well-being (Knauth & Hornberger, 1998; Knauth &

These findings indicate that researchers and shiftworkers have different criteria for assessing the impact of a shift system. While psychosocial impairments are reported by shiftworkers (Costa, 1996), they continue to be attracted to shiftwork. In particular, additional income and (paradoxically) more time with family and friends (E. Taylor, Folkard & Shapiro, 1997) are cited as major benefits of shiftwork. These benefits are often achieved at the expense of criteria which researchers hold critical; health (including sleep duration), fatigue, safety and performance. Faster rotations appear to allow a better integration of the work and non-work demands. However, the cost of these increased social benefits may be at the expense of sleep and fatigue.

The theoretical expectations between shiftwork and health are not easily found in field studies but this does not necessarily suggest poor theory. Methodological difficulties hinder the interpretation of results. Despite these difficulties, the practice of shiftwork must generally be regarded as a strong risk factor in the aetiology of health and psychosocial problems (Costa, 1996).

1.4 Shiftwork health models

There are two types of shiftwork models that describe the relationship between shiftwork and health; general and specific. Implicit in all shiftwork models, is that shiftwork is a stressor and requires the shiftworker to make an adaptive response.

General shiftwork models have paralleled the changes in the occupational stress literature (E. Taylor, Briner & Folkard, 1997). This can be seen in the shift from stimulus-response models (Rutenfranz 1976, cited in Rutenfranz, Knauth & Angersbach, 1981) to transactional models (Folkard, 1996; Monk 1988). This shift has also introduced variables such as hardiness (Wedderburn, 1995), locus of control (Hill,
Welch & Godfrey, 1996; L. Smith, Spelten & Norman, 1995) and active coping (Spelten et al. 1993) as mediators of the shiftwork-health relationship.

General shiftwork models have recently been criticised for being largely based on untested interpretations from the literature (E. Taylor, Briner & Folkard, 1997). In particular, the models were developed to fit a set of findings and not, from an *a-priori* argument. While the specific linkages between shiftwork and health may be debated, a strength of shiftwork models is they provide a basis for intervention. From this perspective, two general models of shiftwork are briefly reviewed.

### 1.4.1 General shiftwork models

Rutenfranz's stress-strain model (1976, cited in Rutenfranz et al. 1981) suggested two pathways to impaired health (see figure 1.1). Stress is generated from the phase shifting of working and sleeping hours. Desynchronised circadian rhythms generate shiftworker 'strain'. The strain is manifested in lowered well-being or the development of disease. The indirect pathway, suggests a number of *intervening* variables (e.g. personality, physiological adaptability) that may moderate the link.

Insert figure 1.1

One main limitation of this model is that it over-emphasises the physiological aspect of circadian disruption at the expense of social (Alward & Monk, 1990) and/or behavioural factors (Knutsson & Akerstedt, 1990). The stress-strain model suggests the most beneficial intervention is to redesign the shift schedule, as a means for reducing or eliminating the phase shifting of work and sleep hours.

The process model (Folkard, 1996) represents an ambitious attempt to explain the shiftwork-health relationship. At the heart of this model, are the elements considered by Monk (1988) to be central to shiftworker well-being. These are balancing the needs from competing biological, sleep and family/social demands.
Figure 1.1. Stress and strain model of shiftwork and health (Rutenfranz, 1976, cited in Rutenfranz, Knauth & Angersbach, 1981, p. 166).

Folkard's (1996) model (see figure 1.2) begins by noting that shift systems per se may have a differential effect, moderated by a range of individual and situational differences. The inter-play between the shift system and the individual/situational differences, determines the level of biological, sleep and family/social disruption. In turn, the level of imbalance between these factors has a direct and acute impact on mood and performance and on safety and efficiency.

The process model has received some empirical support (Barton et al. 1995a; C. Smith, Robie et al. 1997). It suggests shiftworker well-being may be improved by addressing both shift design and individual shiftworker coping strategies. Furthermore, the model recognises the importance of social factors as stressors in their own right,
Figure 1.2. Folkard's process model of shiftwork, health and safety (1996, p. 83).
whereas in Rutenfranz's model, social factors were mediators in the shiftwork-health relationship.

This brief discussion of general shiftwork models highlights their increasing sophistication. They also underline a shift from a focus on circadian rhythm adjustment, to a consideration of wider well-being. However, whilst elaborated models have allowed a better conceptual understanding of the shiftwork-health relationship (Knutsson, 1989), they have not led to clearer predictions of causality. E. Taylor, Briner and Folkard (1997) have usefully recommended that 'narrower theories specific to shiftwork findings' (p. 79) may prove more useful to predicting shiftwork effects.

There is already some evidence for narrower theories linking shiftwork with depression (Scott, Monk & Brink, 1997) and a quantitative model which seeks to predict alertness based on circadian influences, wakefulness and sleep inertia (Akerstedt & Folkard, 1995). Tepas and Mahan's (1989) SDM seeks to explain the effect of sleep loss on shiftworker well-being. The SDM is of particular relevance to the central research in this thesis and therefore, is briefly reviewed below.

1.4.2 Sleep Deprivation Model (SDM)

The importance of sleep to shiftworker health is central to most shiftwork models. The SDM is an empirically based model focusing specifically on the impact of sleep loss (see figure 1.3) and is consistent with calls for shiftwork theory with a narrower focus.

The SDM should not be interpreted as suggesting circadian and social/domestic factors are not important to sleep behaviour. Rather the model presupposes that for whatever reason, sleep is disrupted. The goal of the SDM is to attach meaning to the effects of sleep reduction.
The focus of the SDM is the relationship between sleep loss and fatigue. It notes that sleep deprivation, in particular, chronic sleep loss (CSL), is associated with microsleeps, lapses in performance (Pilcher & Huffcutt, 1996) and feelings of tiredness and fatigue (Naitoh et al. 1990). The model effectively presents sleep loss as building from acute sleep loss (ASL, i.e. little or no sleep in a 24-h period) to CSL (i.e. acute sleep loss occurring over successive days). The model assumes that both ASL and CSL are discharged by adequate recovery sleep. The SDM suggests that shift design should seek to eliminate CSL and to minimise ASL.

CSL reflects a cumulative sleep deficit acquired and maintained over several days. For example, the first night shift is typically associated with ASL because it is
worked following an extended period of wakefulness with little (Akerstedt, 1991; P. Smith, 1979) or no additional sleep (Glenville & Wilkinson, 1979). The shorter subsequent day sleeps means that as the spell of night shift increases, so does the cumulative sleep loss.

The SDM suggests a shift schedule with a faster rotation would limit cumulative sleep loss and provide an opportunity for sleep recovery. However, assuming the total number of night shifts remains the same, faster rotation will also increase the number of transitions to night shift. According to the SDM, this will increase the amount of ASL. Therefore, whilst faster rotation reduces CSL it is at the cost of more episodes of ASL. The following example illustrates this possibility.

A weekly three-shift rotating cycle of seven consecutive shifts requires 13 first night shift transitions per year (excluding annual leave). In contrast, a faster rotating shift may require many more first night transitions dependent on the rotation speed. The example in table 1.3, is based on actual sleep data and by necessity, some assumptions have been made:

- Mean sleep = 7.5-h.
- Sleep duration before first night shift = 2.1-h (Knauth & Rutenfranz, 1981).
- Mean day sleep = 5.7-h (Akerstedt & Torsvall, 1981).
- Slow rotation involves seven consecutive shifts involving 13 night shift transitions.
- Fast rotation involved three consecutive shifts involving 30 night shift transitions.
- There is no change to sleep duration from a change in shift pattern.
- Day sleep after the last shift is equal to previous shifts.
Table 1.3
A Comparison of Sleep Loss Between a Slow and Fast Rotating Shift Schedule.

- Sleep loss on slow rotation across one year:-
  - Sleep loss for first night (7.5-h - 2.1-h) = 5.4-h.
  - Sleep loss on subsequent 6 nights (6 x (7.5-5.7) = 10.8-h
  - Sleep loss across 13 transitions (13 x (5.4 + 10.8) = 210.6-h

- Sleep loss on fast rotation across one year:-
  - Sleep loss for first night (7.5-h - 2.1-h) = 5.4-h.
  - Sleep loss on subsequent 2 nights (2 x (7.5-5.7) = 3.6-h
  - Sleep loss across 30 transitions (30 x (5.4 + 3.6) = 270-h

In this example, the faster rotation would result in a sleep loss of 60-h across a year, assuming there are no other changes in sleep behaviour. Thus it is possible that savings in accumulated sleep debt, may be diminished by the greater ASL.

Extended shifts are typically attributed to explain increased subjective fatigue, sleepiness and impaired performance (Duchon et al. 1994; Paley et al. 1998; Rosa, 1991). However, it may also be that the increased transitions and associated ASL are compounding this situation. Suggestions to decrease the amount of night shift (Knauth, 1993) should not be confused with repackaging the same number of nights into smaller blocks, as often occurs on faster rotation.

Increased transitions to night shift on faster rotations may also increase mood disturbances (Bohle & Tilley, 1993), but this may be offset by the increased free time on extended shifts. Knauth and Schonfelder (1990) reported increased satisfaction for a
fast rotating 8-h shift, but nonetheless, 42% disliked the increased number of shift changes.

The SDM does not extend its focus to include an understanding of sleep as a behaviour over which the individual exerts a measure of voluntary control. This is of particular importance to understanding shiftworker behaviour in planning work, sleep, family and social activities. Sleep patterns and durations underpin ASL and CSL. For example, afternoon shift for male shiftworkers is often associated with extended sleep durations (P. Smith, 1979), as a result of individual time budget choices. Understanding the rationale which underlie such choices is therefore, important in supporting the use of the SDM as an aid in shift design.

1.5 Intervention strategies

To reduce or eliminate the development of shiftworker problems, there are three broad intervention strategies: education and selection, on-shift strategies and shift design (see section 1.6). Each of these strategies has limitations and in practice, a systems approach that brings them together is preferable (Tepas, 1993).

1.5.1 Education and selection strategies

Educational interventions aim to provide shiftworkers with some form of advice regarding the possible effects of shiftwork and ways of coping (Monk & Folkard, 1992). Active coping strategies have been shown to improve psychological well-being (Spelten et al. 1993). The least effective technique, is to remain passive and suffer in silence (Wedderburn, 1991).

Educational advice must demonstrably improve shiftworker well-being.

Wedderburn and Scholarios (1993) assessed the usefulness of 24 guidelines presumed to assist shiftwork adjustment. Examples of items rejected by the majority included; the use of ear plugs, disconnecting the phone/door bell and asking others to
remain quiet in order to facilitate sleep; interrupting sleep to share meals with others; avoiding fatty foods on night shift and eliminating caffeine intake within 2-h of bed time. Furthermore, males believed that sleep onset was facilitated by taking alcohol. In contrast, Greenwood, Rich and James (1995) reported shiftworkers generally behaved in accordance with sleep hygiene practices.

The finding that some shiftworker practices are not congruent with ‘expert’ guidelines, raises the question: who knows best (Wedderburn & Scholarios, 1993)? The provision of shiftworker advice offers good face validity but its efficacy has not been established. Tepas (1993) has argued that most shiftworker education amounts to information overload. Accordingly, Tepas has suggested programs be underpinned by educational psychology.

Nonetheless, the results of a tailored educational program (Popkin, 1994; cited in Tepas et al. 1997) indicated while 90% would recommend the program, the shiftworkers made little use of the content. This resistance of established behaviour may suggest that educational interventions should be aimed at new shiftworkers, prior to habit acquisition.

Attempts at selecting shiftworkers on the basis of self report circadian instruments have not proved particularly successful. Some of these tools have reported inadequate psychometric properties (P. Smith, Brown, Di Milia & Wragg, 1993). The difficulty in designing good chronometric tools may not be too surprising, since the constructs they measure are poorly defined (see Nachreiner, 1998). However, it is possible to screen future and current shiftworkers for known factors which are associated with shiftwork coping problems (Costa, 1996; Tepas et al. 1997). Some examples are: age, moonlighting, sleep and gastrointestinal disorders, chronic medical conditions and extreme scores on some psychological characteristics (eg.
1.5.2 On-shift strategies

On-shift strategies attempt to reduce the effect of fatigue and sleepiness whilst at work. This literature has been reviewed by Akerstedt and Landstrom (1998) and Penn and Bootzin (1990). They offer a wide variety of techniques for maintaining alertness. These include: the timing and length of rest and nap breaks; the use of stimulants (Walsh, Muehlbach & Schwetzer, 1995) and the use of melatonin (Arendt, Deacon, English, Hampton & Morgan, 1995). The timing of food, the use of environmental/sensory stimulation such as sound, work scheduling, light intensity (Czeisler & Dijk, 1995) and ventilation have also been investigated.

The use of on-shift strategies may prove useful. However, their efficacy has not been extensively validated in shiftwork populations. This is an area requiring further research.

1.6 Shift design

Table 1.1 listed a number of structural shift design features that can be manipulated to minimise circadian and social disruption.

The placement of work in a temporal structure has a large influence on shiftworker behaviour. Shift parameters have both direct and indirect effects, by fixing the time available for sleep, work and social/domestic contact. Shift design has been extensively researched for its impact on well-being. For example, rotation speed (Wilkinson, 1992), shift timing (Kecklund & Akerstedt, 1995), direction of shift rotation (Barton & Folkard, 1993; Czeisler et al. 1982), time off between shifts (Dahlgren, 1981a; Kecklund, 1995; Kurumatani et al. 1994) and shift length (Wallace & Greenwood, 1995).

The development of new shift designs, has historically been driven as much by shiftworkers and employers, as it has by research. Indeed, fast rotating shifts were
popular well before they were supported by research (Wedderburn, 1992a). In Australia, as elsewhere, there is an increasing employee demand for innovative shift design. This is matched by employer demands for shift systems that reduce turnover, improve occupational health and safety, and increase labour productivity (Wallace & Greenwood, 1995).

The impact of rotation speed has been the subject of intense research as a way of ameliorating shiftworker well-being. Two alternatives have been proposed. One position is that shifts should be permanent or rotate slowly (Wilkinson, 1992). The alternative position is for a faster rotation (Folkard, 1992; Wedderburn, 1992a). This debate has a long history (Teleky, 1943; Wyatt & Marriott, 1953; Kleitman, 1963).

Proponents of slow/fixed rotations (Czeisler, Moore-Ede & Coleman, 1982; Kleitman, 1963; Winget, Hughes & LaDou, 1978; Wyatt & Marriott, 1953) consider inappropriate circadian phasing to be most problematic. The argument suggests that once circadian disruption has occurred, some realignment of rhythms will take place over a long spell of night shifts. The additional advantage of the slower rotation is that it also reduces the number of times when inappropriate circadian phasing is encountered.

There are at least two criticisms of slow/fixed rotations. The first is that circadian adjustment to night shift is not possible (Akerstedt, 1985; Knauth & Rutenfranz, 1976) because shiftworkers revert to diurnal activity on days off (Van Loon, 1963) and because night work is undertaken with little or no change in external zeitgebers (P. Smith, 1972). The second difficulty is that slow rotations severely restrict the opportunity to participate in social and family activities. Slow rotation ignores the salience of social factors.

Supporters of rapid rotation propose that since circadian adjustment is not practicable, the goal should be to prevent the uncoupling of circadian rhythms (Monk,
The added benefit of faster rotation is that they allow shiftworkers to retain more of a diurnal lifestyle than slow rotation. Therefore, faster rotations allow improved social and family opportunities, and reduce circadian disruption. The disadvantage of faster rotations is that they are associated with reduced day sleep and impaired night time performance due to unaligned circadian rhythms (Rosa, 1995).

The current shift design criteria favour faster rotations (Knauth, 1997). This signals a shift from an over emphasis on biological adjustment to a consideration of total well-being, ie. the need to balance the competing biological and social demands.

Rotation speed has a differential effect on fatigue (including sleep), social satisfaction and psychological well-being. Therefore, the resolution of this debate centres on deciding which criteria best reflect shiftworker well-being. A recent discussion of these factors is provided below. There is a strong possibility that shiftworkers and researchers have different criteria for defining a 'good' shift system.

1.6.1 The rotation debate

Wilkinson (1992) used sleep duration, performance, health, absenteeism, and personal satisfaction as dependent variables for comparing rotating and permanent night shifts. His review of 8-h shift studies to the late 1980's, concluded that with the exception of personal satisfaction, permanent or weekly rotating shifts were superior to faster rotating shifts. In particular, Wilkinson found increased self reported day sleep and better work performance (on perceptual-motor tasks) in permanent night shift workers followed by those on weekly rotation and then, faster rotating shifts.

These conclusions were made with the following caveats: (a) too few direct comparisons of permanent and rapidly rotating shifts; (b) tasks requiring higher cognitive loads show better performance on rapidly rotating shifts; (c) the presence of individual differences in biological and environmental characteristics would limit the
applicability of permanent shifts to all workers; and (d) the possibility of creating an ‘us
and them’ attitude between permanent night and other workers.

Wedderburn (1992a) considered Wilkinson’s conclusions were achieved by
being selective in sources and narrow in the outcome variables considered. For
example, Wedderburn argued that some dependent variables in the performance
studies were of little consequence. Furthermore, findings from experimental and
interpolated studies are equally dubious in industrial settings because they cannot
replicate the realism and consequences of actual work.

Implementing a permanent night shift is considered problematic. Wedderburn
(1992a) indicated management are reluctant to accept a permanent night shift in
continuous operations to prevent the formation of an ‘us and them’ culture. Finding
volunteers for a permanent night shift is also not without difficulty. L. Smith and Folkard
(1993) reported only 13.7% of shiftworkers in their sample, preferred to work
permanent nights and this was insufficient to meet operational demands.

Whereas Wilkinson considered some circadian adjustment an advantage,
Wedderburn disagrees with partial adjustment. Wedderburn clearly considers social
satisfaction to be a high priority in shift design. In particular, he noted the consistency
with which rapid rotation is associated with improved social benefits.

Folkard (1992) also concluded permanent night shifts are a solution. In
contrast to Wilkinson’s more general recommendation, Folkard considers permanent
shifts are appropriate for a few individuals in situations where safety is critical.
Elsewhere, Folkard (1990) has argued the case for a constant ‘nocturnal sub-society’.

In particular, Folkard had three criticisms of Wilkinson’s conclusion that a
mean sleep of 6.72-h was acceptable on permanent night shifts. He pointed out that
6.72-h is below both the sleep ‘norm’ and is reliably shorter than sleep obtained by
permanent day workers (Tepas & Carvalhais, 1990). Secondly, while sleep length may be lower on rapid rotation, it prevents a cumulative sleep loss across several night shifts. Third, Wilkinson did not consider the sleep durations achieved by rotating shiftworkers on other shifts. There is some evidence indicating mean sleep duration over completed shift cycles is higher in rotating shiftworkers compared to permanent night workers (Totterdell & Folkard, 1990; Tepas & Carvalhais, 1990). Escriba, Perez-Hoyos and Bolumor (1992) reported mean sleep durations between 5.0-h and 5.4-h in rotating shiftworking, compared to between 4.9-h to 5.1-h for permanent night shift nurses.

The commonly held belief that shiftwork adjustment may be seen in inverted circadian rhythms was also questioned by Folkard (1992). Furthermore, Folkard has argued that Wilkinson has over estimated the adjustment of the body clock to a permanent shift. The effects of masking (Folkard, 1989) are a particular problem in interpreting the extent of phase shifting of endogenous rhythms.

Folkard (1992) concluded that for most shiftworkers, rapid rotation is the best compromise. The key factors being; (a) a reduction in sleep debt; (b) minimised circadian disruption; and (c) social advantages.

To summarise, the key to the rotation debate is underpinned by the salience of the outcome measures. With some qualifications, Wilkinson (1992) has argued for slow/fixed rotation due to acceptable sleep levels and performance. Folkard (1992) also used sleep to support faster rotations. A faster rotation has the advantages of reducing the cumulative sleep debt, less circadian disruption and more social satisfaction. Wedderburn also concluded faster rotations to be ideal since they best provided social and family benefits.
1.6.2 The effect of consecutive night shifts

Night shift has been the focus of considerable research because they are associated with the most difficulties. In this section, the effect of consecutive night shifts on some key dependent variables are briefly reviewed.

A number of sleep studies since Wilkinson’s (1992) review, have provided further support for his position of longer sleep duration on slower rotation. Dirkx (1993) matched two groups of permanent night shift female nurses for shift experience, workload, age and number of children. The groups differed on the number of consecutive nights worked; few (1-4) and many (5-8). There were no differences in subjective health or job satisfaction. Sleep duration between the two groups were also not significant but the group working many nights recorded longer sleep durations over the same number of night shifts. Sleep duration also showed a small increase from the first (426-min) to the fifth night shift (442-min). The many nights group were found to use significantly more cognitive coping strategies. Overall, working more nights was not associated with negative findings.

In a study of part-time and full-time permanent night shift nurses, Barton, Spelten, Totterdell, Smith and Folkard (1995b) reported full-time nurses slept longer than part-time nurses but there were no sleep differences on days off. More importantly, longer sleep was associated with better sleep quality which in turn, predicted better health and well-being. These findings were replicated with a sample of nurses working non-standard rotating shifts but these results were less impressive. If adaptation is considered in terms of increased sleep length, these results lend support to Wilkinson's suggestion of permanent shifts.

There is some evidence that increasing sleep across consecutive night shifts is a function of rotating or fixed shifts. Dahlgren (1981b) found an increase in EEG sleep
after the first night shift (271-min) to 325-min between the sixth and seventh night shift for rotating shiftworkers. However, Dahlgren also found a decrease from 352-min after the first night shift to 338-min between the fifth and sixth night shift in permanent night workers. Totterdell, Spelten, Barton, Smith and Folkard (1995) reported rotating nurses had longer day sleep (7.61-h) compared to permanent night shift nurses (6.99-h) but these differences were eliminated after controlling for age and shift experience. Furthermore, rotating nurses reported lower sleep quality and mood ratings compared to permanent night nurses after working night shifts.

A number of other studies have also reported the advantages (or not being worse off) for working permanent night shift on a number of self report physical and psychological well-being variables (Alward & Monk, 1990; Barton & Folkard, 1991; Barton, Smith, Totterdell, Spelten & Folkard, 1993; Folkard, Monk & Lobban, 1979; Verhaegen et al. 1987).

It is important to note that these studies were conducted with (mostly) female nurses. Thus the ability to generalise from these findings may be limited. One factor that may best explain these findings, is that 'choosing' (Barton, 1994) to work a particular shift results in greater commitment to the work schedule. A typical finding is that permanent night shifts suit female nurses because it enables regular child care to be established (Barton, 1994; Verhaegen et al. 1987). Alternative explanations may include, differences in work load by shift type, or an increased level of 'esprit de corps' among night workers (L. Smith & Folkard, 1992).

Bohle and Tilley (1993) reported mood scores on vigour and activity improved from the third to the fifth night shift but fatigue-inertia scores were low and showed no improvement. Others have found alertness declined across a spell of rapid rotation night shifts (Dahlgren, 1981a). Permanent night security guards reported 2-3 times
more fatigue (sleep disturbances) than in a day working population (Alfredsson, Akerstedt, Matsson & Wilborg (1991). In general, weekly rotations are associated with poorer psychological well-being.

Less clear effects for consecutive night shifts are found in safety and performance. L. Smith et al. (1994) demonstrated that accident frequency increased across four consecutive night shifts, indicating no circadian adjustment. Monk and Wagner (1989) showed accidents peaked on the fourth night of a seven night spell and this was attributed to sleep loss resulting from social factors. However, accident frequency between the first and second half of the work spell were about the same and also indicated no circadian adjustment.

Meers (1975) reported production quality was similar across the first four night shifts but the fifth night showed a large increase. The improvement was attributed to some adaptation of the temperature rhythm. Vidacek, Kaliterna, Radosovic-Vidacek and Folkard (1986) showed productivity increased up to the third night and then decreased. However, productivity was higher for the last two nights compared to the first two shifts. Liou and Wang (1991) reported productivity on rotating 8-h shifts increased to peak on the fourth day despite the shift type. Performance on the final (sixth) shift was similar to performance on the second/third shift. Overall, productivity was best on day shift, followed by the afternoon shift.

These studies provide mixed results. Sleep clearly increases with a slow rotation and seems to be critical for subsequent well-being. The results for mood, productivity and safety are less clear to interpret. Nonetheless, performance and safety studies clearly do not show overwhelming impairments during slow rotations.
1.7 The compressed workweek

The compressed workweek (CWW) reflects an alternative shift design approach for improving shiftworker well-being. Long (12-h) shifts were common prior to, and early this century (Alluisi & Morgan, 1982; Scherrer, 1981). Shift durations subsequently decreased under the combined effect of social reform and findings which suggested shorter working hours resulted in greater productivity (Goldmark & Hopkins, 1920; Mather 1894, cited in Mclvor, 1987; Vernon, 1918).

It is important to point out however, that these studies involved a simultaneous reduction in both daily and weekly working hours. This is not presently the case with the CWW. Total working hours are being maintained but the length of the working day is being extended to accommodate additional free time. Therefore, a major concern of extended workdays is increased fatigue (Rosa, 1995; Tepas, 1990). This may result from the extended shift length per se and further exacerbated by shift designs that do not allow sufficient recovery from work days.

1.7.1 Definition

The CWW describes a work system where the shift length is extended beyond 8-h but the number of consecutive shifts is reduced to less than five (Tepas, 1985). In effect, workers are trading off a longer work day for more free time. Some examples include working, four 10-h shifts (Volle, Brisson, Perusse, Tanaka & Doyon, 1979), three to four 12-h shifts (Rosa, 1991; Williamson et al. 1994) and the 10/14-h system used in the fire service (Knauth, Keller, Schindle & Totterdell, 1995; Paley et al. 1998).

1.7.2 Estimates

Some indication of the extent of 12-h shifts in Australia can be found in data published by the Australian Centre for Industrial Relations Research and Training (ACIRRT), at the University of Sydney and unpublished data from the ABS.
Australia is not a signatory to ILO conventions regarding night work, shiftwork, overtime or maximum working hours. Furthermore, there is no statutory legislation concerning working hours (Heiler, 1998). However, most states have restricted transport drivers to 12-h work spells.

Australian working hours were primarily regulated by the industrial award system. This system has been weakened by the deregulation of the labour market during this decade. Of increasing prominence is the role of enterprise agreements, whereby working conditions are determined by direct negotiation between employers and employees at the work site level.

ACIRRT (1996) reported that of over 2000 agreements registered in their database (1992-96), 63% were concerned with hours of work. During 1992-93, some 7% were concerned with 12-h shifts and this increased to 17% in 1996-97 (ACIRRT, 1997). These agreements were most common in manufacturing, utilities and food/beverage industries. In particular, these agreements aimed to eliminate the allowances and penalties associated with working beyond 8-h. In effect, employers are seeking to replace the financial compensation for shiftwork inconvenience with the restructuring of working hours. Whilst the total standard working hours remain the same, the extended shift schedules provide for longer periods of time away from work.

The increase in working hours appears to be more dramatic in the service sectors that tend not to be unionised. ACIRRT (1997) recorded an increase from 20% (1992-93) to 30% (1996-97) for agreements specifying more than 12-h of work per day.

Callus (1997) has cautioned that working arrangements are largely designed to meet employers' productivity needs rather than employee needs. In support, he cited data from a 1995 Department of Industrial Relations employee survey. While 57% were satisfied with work and leisure, only 13% recorded an improvement and the balance
reported less satisfaction than in the previous year. Heiler (1998) has also suggested that working hours flexibility, is sometimes 'of' and not 'for' employees.

The ACIRRT database monitors companies that are actively transforming their industrial relations practices and therefore cannot be considered representative. Far less specific data concerning 12-h shifts comes from unpublished ABS data. They recorded an increase in males working 12-h shifts from 10.8% (1993) to 14.6% (1995). More recent data are not available since this item was deleted from the 1997 survey.

1.7.3 Drivers for the CWW

A number of social and economic drivers have fuelled the interest in extended shifts from both employees and employers. Rising living standards and changes in educational levels have resulted in employees seeking an improved quality of life. This has led to a demand for alternative work patterns (Cohen & Gadon, 1978) to provide greater flexibility in managing the interface between work and home (Breaugh, 1985). A detailed discussion of social factors can be found in Pierce et al. (1989).

Concomitant with employee interest for flexible working, is a similar shift in industry seeking to provide an efficient response to changing market forces (Kogi, 1995). Wallace and Greenwood (1995) suggested that changes to shiftwork systems are often the outcome of a business 'strategy' aimed at raising productivity. These strategies appear to focus on the abolition of penalty rates for extended hours and weekend work (Callus, 1997) in exchange for time off. Other employer benefits are discussed in section 1.7.5.

1.7.4 CWW and shift design

The current shift design criteria (SDC) (Knauth, 1997) identify a number of features for improving shift systems. In particular, these criteria have evolved to a stage where a maximum of three consecutive shifts are recommended.
Relative to the SDC (Knauth, 1997), the possibility exists that a well designed CWW is able to satisfy the following criteria:

- fewer consecutive shifts.
- a forward rotating roster.
- adequate resting time between shifts (>11-h).
- two or more days off after a spell of night shift.
- more time away from work.

One issue however, is that the SDC were primarily based on 8-h shift studies. Recommendations regarding extended workdays have remained cautious and general (Knauth, 1997).

The SDC provides some indicators to guide policy-makers in assessing extended shifts but the lack of specificity may be problematic. The scientific data is sufficiently complex and it is reasonable to suggest that policy-makers, may bow to significant pressure from a workforce seeking the CWW.

While the focus has been on rotation speed, there has been far less attention to the placement of days off within the shift schedule. Dahlgren (1981b) compared two forms of rapid rotation shifts that differed in the structure of rest days. She concluded rotation speed per se, was an insufficient criterion for judging shift systems, without a consideration of the arrangement of free days between work spells. A number of other studies have also concluded that more than two days off after night shift are desirable (Kecklund, 1995; Kurumatani et al. 1994; Totterdell et al. 1995).

It may be the case that in order to provide large blocks of days off in the CWW, there are fewer days available for rest between the work shifts (P. Smith et al. 1998). As an illustration, Axelsson et al. (1998) reported a shift system in which workers completed in succession; three 12-h day shifts, four 8-h night shifts, followed by ten
days off. The concern is that the CWW may be overly compressed in order to increase the duration of time off as a single block. Over compressed shift systems provide little time for recovery between work spells.

1.7.5 Advantages and disadvantages of the CWW.

Advantages

Faster rotations are considered to provide at least three main benefits (Knauth, 1993). These include: (a) reduced circadian disruption, (b) increased social opportunities, and (c) decreased sleep debt by working fewer consecutive night shifts. Tepas (1985, p. 158) has listed a number of indicative benefits arising from the CWW (see table 1.4).

The most consistent finding for the CWW, from both the scientific (Axelsson et al. 1998; Duchon et al. 1994, Frese & Semmer, 1986; Kaliterna & Prizmic, 1998; Lowden et al. 1998; Paley et al. 1998; Rosa & Bonnet, 1993; Tucker et al. 1996; P. Smith et al. 1998; Williamson, Gower & Clarke, 1994) and management literature (Cunningham, 1989; Northrup, Wilson & Rose, 1979; Northrup, 1989) is the self reported improvement to social and family life.

Employer benefits are more difficult to assess. Hard productivity data are seldom available and the evidence is often, anecdotal (Northrup et al. 1979; Northrup, 1989). It is salient to note that positive qualitative assessments are made by managers within the context of a workforce, that initiated the drive for the CWW and are satisfied with its benefits.

Qualitative reviews have reported the CWW does not raise productivity (Colligan & Tepas, 1986). Kopelman (1986) concluded, 'perceived changes in productivity often reflect attitudes about the intervention, rather than actual changes
Table 1.4

Potential Advantages of the Compressed Workweek.

**Employees**

- Increased possibility for leisure and care activity.
- A reduction in commuting problems and costs.
- Fewer workdays with no loss of pay.
- A regular steady workweek.
- Ease in covering all jobs at the required times.
- More time for scheduled meetings or training sessions.
- Increased opportunity for communication within the organization.

**Employers**

- Increased opportunity for communication with other organizations.
- Decreases in start-up expenses.
- Fewer supervisory personnel may be needed.
- More efficient stock flow for assembly line operations.
- Less night work.
- Increased production rates.
- Improvement in the quantity and quality of services to the public.
- Better opportunities to hire skilled workers in tight labour markets.

(p. 152). In contrast, a meta-analytic review (Moores, 1990) of empirical studies reported decreased absenteeism and small increases in productivity.
The momentum for 12-h shifts among employees may provide management with a powerful bargaining tool to increase efficiencies. For example, savings in overtime and penalty rates are possible by trading these for increased time off (Heiler, 1998).

Indirectly, the CWW offers a number of savings. Flexible working practices are considered to increase or strengthen 'employee commitment' via a better alignment between work and social demands (Cohen & Gadon, 1978). This may lead to decreased absenteeism (Moores, 1990). Cooperating with employee wishes serves to increase industrial peace and in keeping the organisation union free (Northrup, 1989). Employers have also recognised that extended shifts may contribute to increased employee morale (Northrup et al. 1979), motivation and reduced turnover (Rosa, 1991). Retaining a skilled workforce reduces training costs and may provide a safer workplace.

**Disadvantages**

The potential advantages of the CWW need to be carefully considered in terms of specific shift design, job demands, employee characteristics and geographic location (Duchon et al. 1994; Parkes, 1994). As a result, some indicative disadvantages of the CWW (see table 1.5, Tepas, 1985, p. 158) are direct contradictions of the advantages shown in table 1.4.

Insert table 1.5

It is worthwhile highlighting three factors that may be problematic for the CWW; workplace communications, social opportunities and fatigue. Concerns regarding absenteeism and safety are discussed in chapters four and five respectively.

Difficulties with workplace communications between management and workers are increasingly being reported (L. Smith, Hammond, Macdonald & Folkard, 1998;
Table 1.5

Potential Disadvantages of the Compressed Workweek.

- Decrements in job performance due to 'moonlighting'.
- Increased commuting costs.
- Overtime pay required by law.
- More fatigued workers.
- Little recognition of employee's individual differences.
- Increases in tardiness rates.
- Increases in absenteeism rates.
- Increases in employee turnover.
- Increases in on-the-job and off-the-job accidents.
- Decreases in production rates.
- Fewer supervisory personnel may be needed.
- Increased exposure to toxic substances and/or physical hazards.
- Scheduling problems if the organization operations are longer than the workweek.
- Difficulty in scheduling child care and family life during the workweek.
- Contrary to traditional objectives of labour unions.
- Increased energy and physical maintenance costs.

P. Smith et al. 1998) due to the reduced daily attendance (Northrup, 1989) and the difference in working hours (P. Smith, Brown & Di Milia, 1992). Communications
between work crews are also restricted because handover occurs between fewer crews (Lowden et al. 1998).

The social and family advantages of extended shifts are well documented (Cunningham, 1989; Northrup, 1989; Rosa et al. 1989). However, cross sectional (Kogi, Ong & Cabantog, 1989; Northrup, 1989) and longitudinal (Rosa, 1991) studies have each noted that social life is more restricted when working 12-h shifts. Two recent studies have also suggested the extra free time from 12-h shifts is diminished after additional time is taken for recovery (Iskra-Golec, Folkard, Marek & Noworol, 1996; Kundi et al. 1995). Indeed, Kundi et al. (1995) found 8-h shifts were associated with less work strain and less disrupted health, family and social life.

L. Smith, Hammond et al. (1998) have warned that shiftworkers may accept extended shifts for social gain. Similarly, Rosa et al. (1989) described a ‘trade off’ between more time off and increased fatigue. These warnings reinforce Dahlgren’s (1981b) emphasis on the need to consider the distribution of days off within a rapid rotation schedule to minimise fatigue.

From a health and safety perspective, fatigue may be the single most important issue (Rosa, 1995; Tepas, 1994). The 4/40 week was rejected by the American Management Association on the grounds that fatigue would lead to inefficiencies (Wheeler, Gurman & Tarnowieski, 1972). Hodge and Tellier’s (1975) survey of the 4/40 week reported increased fatigue as well as increased job satisfaction.

A number of health and social reasons were cited for the abandonment of 12-h shifts in some Singaporean companies (Kogi et al. 1989). Indicators of fatigue on 12-h shifts included: sleep loss and disruption, significant falls in productivity, increased labour turnover and increased moonlighting. Some 64% of employees at one site
reported spending less time with families due to the clash with work demands. The hot and humid climate combined with low living standards were also considered to impede adequate rest.

Ramaciotti et al. (1990, cited in Wedderburn, 1996b) cited tiredness as the factor that led to the abandonment of 12-h shifts on weekends. Northrup (1989) reported four chemical companies had abandoned 12-h shifts since an earlier review (Northrup et al. 1979).

Duchon and Smith (1993) reviewed 32 studies of extended workdays and related studies (e.g., overtime). These studies represented a mix of laboratory and field studies using subjective and objective measures. Of the 50 dependent variables across these studies, only eight showed improvement, 15 were neutral and 27 were impaired.

Harrington (1994) concluded working 'in excess of perhaps 48-56-h is harmful' (p. 703) after considering the effect of extended hours on a range of physical and psychological variables. This qualitative conclusion was recently supported by a meta-analytic review of 21 studies and a qualitative review of 12 other studies (Sparks, Cooper, Fried & Shirom, 1997). These authors found a small (0.13) but significant correlation between physiological and psychological health with longer hours of work on a range of outcome measures. However, only two of the 33 studies involved shiftwork (Barton & Folkard, 1993; Totterdell et al. 1995). Recent guidelines concerning work and rest concluded that fatigue, is probably 'related to long daily work hours, perhaps combined with shiftwork (Konz, 1998, p. 67).

It would seem that in spite of fatigue concerns, workers are willing to tolerate greater fatigue and sleep loss, in exchange for improved social and family life. The cost of such trade-offs is not immediately apparent (Rosa et al. 1989). Longitudinal studies are required to support the only long term cross sectional study of health and safety by
Laundry and Lees (1991). Nonetheless, a number of studies support the conclusion that shift system satisfaction has more to do with social and family factors than with health factors (Frese & Semmer, 1986; Kaliterna & Prizmic, 1998; Rosa et al. 1989).

The potential for increased fatigue on extended shifts and particularly at night has resulted in some attempts to restrict working time. The European Council directive (93/104/EC) contains three key criteria: (a) limit weekly working hours to 48-h, (b) a minimum rest period of 11-h every 24-h and (c) a maximum mean of 8-h night shifts in a 24-h period for work considered hazardous, physically or mentally straining.

1.7.6 Fatigue on the CWW

Investigations of fatigue are not supported by a clear and agreed operational definition of fatigue. Vernon (1921) considered fatigue to be an outcome of task duration, type of work and the surrounding conditions. One difficulty with this position, is that fatigue does not show a linear increase with time on task. A second difficulty, is that there is no differentiation between psychological and physiological fatigue.

It is reasonable to suggest extended shifts will increase fatigue and particularly at night, given the shift length, working during a circadian trough, poor prior sleep and extended wakefulness (Akerstedt, 1995b). Contemporary conceptualisations of fatigue have recognised the importance of both time on task and time of day factors (Dinges, 1995). Furthermore, fatigue is exacerbated by a number of on-shift factors (eg. noise, heat) and non shift factors (eg. commuting time, social lifestyles and domestic workload).

An assessment of fatigue is not straightforward. Fatigue is a multifaceted construct and is typically inferred from both physiological and psychological indicants. These indicants include, self ratings of health and well-being, ratings of sleepiness and alertness, and sleep loss (Duchon et al. 1994, 1997; Tepas et al. 1997).
The difficulty of working with such measures is illustrated by the impact of faster shift rotations on night shift alertness and on day sleep durations. Both are poorer with faster rotation (Rosa, 1990). However, these negative features are offset by reductions in cumulative effects across several night shifts.

Prior to reviewing some studies that changed from 8-h to extended shifts, it is important to note that the shiftwork literature is far from perfect. This makes it difficult to find studies that are directly relevant. Space limitations also limit the ability to critique the methodological weaknesses of each study. As a general comment, many studies that are considered longitudinal in design, are perhaps more accurately described as before and after studies. These are less powerful than repeated measures studies.

**Physiological measures**

Duchon et al. (1994) reported a longitudinal study of a change from 8-h to 12-h shifts using physiological and self report measures. Main effects for objective measures were not found, but heart rate data indicated better recovery at the end of an 8-h shift but this was not significant. Furthermore, mood and sleepiness were significantly impaired between the start and end of a 12-h night shift. This pattern was not found on 8-h night shifts. This suggested shift length and not circadian variation was the most likely explanation.

The increased subjective fatigue on 12-h shifts, led Duchon et al. (1997) to examine the continuous heart rate data for six shiftworkers in a later analysis. No main effects were found but 12-h shifts showed a modest decrease in work effort. Results also indicated that work effort during both 8-h and 12-h night shifts was reduced. The authors concluded that 12-h shifts are not necessarily fatiguing because the workers slowed their work pace to meet the demands of a longer shift.
Rosa, Bonnet and Cole (1998) reported a laboratory study, that compared ‘upper extremity’ fatigue in 8-h (5 days) and 12-h (4 days) shiftwork. Rosa et al. concluded workers reduced work effort in response to increases in load level and repetition rate to keep discomfort within acceptable limits. Other findings suggested fatigue was lowest on 8-h day shifts and highest on 12-h night shifts. Fatigue levels at the end of 12-h day shifts levels, were comparable to those at the end of 8-h night shifts.

Peacock, Glube, Miller and Clune (1983) reported the effect of a change from a fast rotating 8-h to 12-h shifts. The results from ergometric exercise, blood pressure, urinary cathecolamines, critical flicker fusion (CFF), logical reasoning and subjective responses, supported the benefits of 12-h shifts. The extended shifts were associated with increased ergometric exercise with a lowered physiological effort and blood pressure. However, physiological measurement only occurred once per shift during a one week period. Furthermore, the superiority of the 12-h shift results may be dependent on the design of the former 8-h shift system. It required the completion of three night, afternoon and day shifts, before taking four days off.

Volle et al. (1979) compared 8-h and 10-h shifts by collecting physiological indicants of fatigue at the start and end of the first and last day of a work spell. Significant deteriorations for CFF and hand strength were obtained for 10-h shifts. Nonetheless, the authors’ concluded fatigue was ‘within acceptable limits’ (p. 1008). Production was not reported to be affected by the extended shift. This study however, has a number of limitations; (a) night shift was not worked in either plant, (b) a simple before and after design was used, (c) measures were taken at the start and end of the first and last shifts for one cycle of day and afternoon shift, and (d) measures were not taken on days off.
The ergonomic and physical work requirements are important variables in a consideration of extended hours. Seibt et al. (1990) conducted a cross sectional field study of 12-h shifts at two sites. They concluded 12-h shifts were acceptable in a supervisory environment but not for 32 drilling workers engaged in hard physical work.

A review by Bonnet (1990) concluded night shift results in a 5-10% reduction in work capacity. Bonnet, cites data from Mital (1984, 1986) showing a progressive decline in the ability to lift weights with increasing work duration. The average male was reported to lift 19.64 kg for 25-minutes but this was reduced to 12.99 kg and 11.62 kg, by the end of 8-h and 12-h shifts respectively. These represent reductions of 33% and 40% respectively. These data were generated during the day and it would be expected night time values would be lower.

Rodgers et al. (1995) examined the effect of 48-h of sleep deprivation on working capacity in a laboratory study. Physical performance was significantly lower in the second 24-h period compared to the first. However, the non significant reduction in muscle contraction properties, and the maintenance of blood glucose and lactate levels at baseline values, indicated that performance decrement may reflect psychological factors as much as physiological factors.

**Non-physiological indicants of fatigue**

Indicants of fatigue may also be seen in decreased performance capability, lowered outcomes for subjective health and well-being, increased sleepiness and sleep loss (Duchon et al. 1994; Tepas et al. 1997). Table 1.6 lists a selection of longitudinal studies and table 1.7 lists some cross sectional studies that have compared 8-h with extended shifts.

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<th>Study</th>
<th>Performance¹</th>
<th>Social²</th>
<th>Ψ Health³</th>
<th>Fatigue⁴</th>
<th>Sleepy/Alert⁵</th>
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<td>Rosa 1991; 8 → 12</td>
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<td>Rosa &amp; Bonnet, 1993; 8 → 12</td>
<td>-</td>
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<tr>
<td>Duchon et al. 1994; 8 → 12</td>
<td>0</td>
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<td>Williamson et al. 1994; 8 → 12</td>
<td>+</td>
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<td>Knauth et al. 1995; 8 → 10/14</td>
<td>-</td>
<td>+</td>
<td>-</td>
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<td></td>
<td>Only 10/14 sleep reported.</td>
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<tr>
<td>Lowden et al. 1998; 8 → 12</td>
<td>0</td>
<td>+</td>
<td>+</td>
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<td>↑</td>
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<td>Paley et al. 1998; 8 → 10/14</td>
<td>0</td>
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<tr>
<td>L. Smith et al. 1998; 8 → 12</td>
<td>+, -</td>
<td>+, -</td>
<td>+, -</td>
<td>+, -</td>
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<td>↑</td>
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<tr>
<td>P. Smith et al. 1998; 8 → 12</td>
<td>+</td>
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<td>Study</td>
<td>Performance</td>
<td>Social</td>
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<td>Day off</td>
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<tr>
<td>Iskra-Golec et al. 1996; 8 &amp; 12</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td></td>
<td>Mean sleep increased.</td>
<td></td>
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<tr>
<td>Tucker et al. 1996; 8 &amp; 12</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>↑</td>
<td>↑</td>
<td>0</td>
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<tr>
<td>Axelsson et al. 1998; 8 &amp; 12</td>
<td>0</td>
<td>+</td>
<td>-</td>
<td>↑*</td>
<td>↓</td>
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<tr>
<td>Kaliterna &amp; Prizmic, 1998; 8 &amp; 12</td>
<td>+</td>
<td>0</td>
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<tr>
<td>Tucker et al. 1998; 8 &amp; 12</td>
<td>+</td>
<td>0</td>
<td>↑*</td>
<td>↑*</td>
<td>0</td>
<td></td>
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</tbody>
</table>

0 = extended hours had a neutral effect; + = extended hours had a positive effect; - = extended hours had a negative effect; ↑ = increased sleep duration; ↓ = decreased sleep duration.

* significant

1 Performance measures included work based measures, interpolated tasks and ergonomic measures; 2 Social satisfaction includes measures concerned with shift satisfaction; 3 Includes GHQ and other self report scales; 4 any self report scale; 5 The authors reported mean sleep changes only.

**L Smith et al. two types of 12-h shifts.
The tables show some interesting findings. The most striking feature is the consistency with which faster rotations and extended shifts are reported to improve social and family life. These improvements are concomitant with increased psychological health. These findings are typically attributable to the increased number of days off. This underlines the salient criteria by which shiftworkers assess a good shift system. Only L. Smith, Hammond et al. (1998) reported some dissatisfaction with extended shifts. The dissatisfaction was attributed to an early day shift start (06.00), with no flexibility to swap shifts.

Attitudes to shift system changes appear to be reflections of the change process (L. Smith, Folkard, Tucker & Macdonald, 1998; P. Smith et al. 1998) and the nature of the previous shift system (Lowden et al. 1998). While the majority of changes from 8-h to 12-h shifts are well supported by attitudinal data, these data have typically been reported within a one year period. A one year time period may still be considered to be a feature of the honeymoon stage. With the exception of Rosa (1991), there are no empirical studies that have tracked the longer term impact of 12-h shifts or identified changes to the original design of the 12-h shift.

In terms of performance, the studies in table 1.6 have used a wide number of measures including work errors (Williamson et al. 1994) interpolated tasks (Knauth, 1995; Rosa and colleagues) and a combination of interpolated and heart rate measures (Duchon et al. 1994; Peacock et al. 1983). The use of different dependent variables, differences in job tasks and differences between the form of the extended shifts combine to produce mixed results.

The design by Rosa and his colleagues provided for post change data to be collected after seven months (1989) and after 3.5 years (1991). At the seven month comparison, 12-h shifts were associated with slower reaction times, decreased
performance on grammatical reasoning and increased subjective fatigue. Sleep duration showed small increases for both day and night shifts but the night shift showed a sleep debt of 1-h across the 12-h work spell. Performance across the extended shifts did not seem to deteriorate leading to the conclusion that the additional time off compensated for the longer shift. The evaluation at 3.5 years showed no improvement in the dependent variables, with some evidence of deterioration across the workweek. Furthermore, sleep loss after night shift was reported to have increased by 2.5-h.

Similar results were obtained by Rosa and Bonnet (1993) in a gas processing facility. Reaction time and alertness were impaired on 12-h shifts and particularly at night. Repeated measures sleep data found increased sleep following day shift but significantly less sleep on night shift.

Duchon et al. (1994) found no change in performance or sleepiness relative to 8-h shifts and a small increase in mean sleep duration on 12-h shifts. The increase in sleep was attributed to workers sleeping on site following the change. Parkes (1994) also found longer sleep durations in shiftworkers that lived on site. However, in a follow up study (1997) they concluded that workers on 12-h shifts were not worse off because they had moderated their work effort to deal with the longer shift.

Axelsson et al. (1998) reported no between shift differences for the same workers on 8-h weekdays and 12-h weekends. However, work at the weekends seemed to be more passive and subjects only worked two spells of three consecutive 12-h shifts every six weeks.

Williamson et al. (1994) reported fewer work errors and improvements across all subjective ratings during 12-h shifts. Sleep increased following day shift and days off but decreased on night shift. This finding suggests that 12-h shifts result in a redistribution of sleep duration.
The Williamson et al. (1994) study has some limitations. The positive findings may have more to do with the former shift schedule. The 8-h shift was highly irregular and combined spells of 8-h and 12-h shifts. In contrast, the 12-h shift was a regular four on, four off schedule. Sleep diary data was obtained for two days of each shift type only. Furthermore, the comparison of sleep duration between 8-h and 12-h shifts were not based on the same shiftworkers.

Knauth et al. (1995) concluded that extended shifts were not appropriate based on decreased performance and alertness. Sleep durations on the 10/14 were approximately 5.5-h but the former sleep data were not reported. Nonetheless, the shiftworkers voted to keep the extended shifts. The preference for the new shift may be explained by its regularity and increased time off. In comparison, the former schedule combined 8-h and 12-h shifts, with fewer days off.

Lowden et al. (1998) reported that all measures favoured 12-h shifts. The strongest support came from questionnaire data showing improved attitude to work, increased time for family and friends and self reported improvements to sleep. They concluded these results may be explained by ‘a rather poor 8-h shift system rather than to a very good 12-h shift’ (p. 74). The 8-h shift contained quick returns from afternoon to day shift and night to afternoon shift which reduced sleep. In comparison, the 12-h shift involved a maximum of three day or night shifts and the night shifts were followed by four and five days off.

Tables 1.6 and 1.7 show the effect of the CWW on TST seems to vary by shift. Sleep after day shift seems to generally increase while sleep after night shift tends to decrease on balance. This suggests a redistribution of sleep on 12-h shifts. There are a number of shift design features that may explain the differences in sleep duration between the studies.
The number of consecutive shifts is one factor. Rosa et al. (1989) and Duchon et al. (1994) both found small mean increases in sleep duration on 12-h shifts comprising of three or four consecutive night shifts. Williamson et al. (1994) in contrast reported a decrease in night shift sleep when two consecutive shifts were worked. One possible explanation is that fewer consecutive shifts may tempt shiftworkers to 'short-cut' sleep in order to maximise leisure time. More consecutive shifts means that such behaviour is unlikely to deal with fatigue. A second difference between these studies is that whereas the work spells in Rosa et al. and Duchon et al. were of the same type, Williamson et al. combined a spell of two days followed by two night shifts.

Shift timing also impacts upon sleep duration (Folkard & Barton, 1993; Kecklund, Akerstedt & Lowden, 1997). L. Smith, Hammond et al. (1998) were able to compare a group of policemen changing to two identical versions of 12-h shifts except that start times differed. Sleep after day shift increased for both 12-h systems but sleep after night shift was reduced on the system with a 07.15 finish time, compared with an increase in sleep for the shift completing at 06.00. The earlier finish time may contribute to a longer sleep (Akerstedt & Gillberg, 1981b).

The reliability of some of the sleep data reported in tables 1.6 and 1.7 is suspect. Williamson et al.'s. (1994) study was earlier critiqued for sampling limited sleep data from the shifts and for not presenting repeated measures sleep data. As a general comment, the remaining studies report too little information to enable the strength of their findings to be clearly assessed. It is certainly the case, that none of the studies in table 1.6 have taken repeated sleep measures across the entire shift cycle.

In general however, it seems likely that faster rotations are associated with reduced sleep on night shift. The most likely explanation is that shiftworkers seek to maximise social time by short changing their sleep. This loss is recouped on days off.
A final feature of tables 1.6 and 1.7, is the absence of studies seeking to measure changes in physical health, with the exception of P. Smith et al. (1998). This is in part, a reflection that insufficient time has elapsed between the measurement periods for health variables to show significant changes. However, this also highlights a change in shiftwork research. The prior emphasis for documenting circadian stress on human biology, is less applicable in an era where rapid rotation is recommended. The former concern with circadian adjustment has given way to an interest in fatigue and alertness on extended shifts.

In conclusion, faster rotating shifts are considered to have three main advantages (Knauth, 1997). From the studies reviewed in tables 1.6 and 1.7 it is not possible to comment on circadian changes but theoretically, minimal disruption would be expected. In terms of sleep, there appears to be a redistribution of sleep. Insufficient data is available to conclude whether faster rotating extended shifts reduce sleep debt on night shift. However, reductions in chronic sleep loss may be offset by the increased acute sleep loss. Finally, all the studies reviewed reported increased social benefits. While these benefits are not in question, it is also clearly the case that in most instances, the former 8-h shifts were particularly poor (Lowden et al. 1998; Peacock et al. 1983). Some former shift systems combined 8-h and 12-h shifts (Knauth et al. 1995; Williamson et al. 1994) and others were slow fortnightly rotations (Paley et al. 1998). It is not too surprising that a change to a regular 12-h shift system with ample free time is regarded so favourably.
1.8 Sleep duration as a marker for the adequacy of a shift schedule

1.8.1 Introduction

The precise function of sleep is not clear (Pivik, 1991; Webb, 1992). However, sleep is considered critical to the maintenance of performance and alertness (Carskadon & Roth, 1991). Extended sleep loss has been associated with sleepiness (Akerstedt, 1995b) and tiredness (Naitoh et al. 1990), performance decrements (Dinges & Kribbs, 1991) and mood changes (Totterdell et al. 1994). For these reasons, sleep duration is considered a good marker to reflect the adequacy of a shift system (Barton et al. 1995b; Wedderburn, 1975; Tepas, Duchon & Gersten, 1993).

There is much debate over ideal sleep duration (Bonnet & Arand, 1995; Harrison & Horne, 1995). Horne (1992) has consistently argued that core sleep (approximately 5-h) is sufficient for cognitive functioning. While this may be correct, there is no denying a drive for sleep in excess of 5-h to 6-h (Dinges & Kribbs, 1991).

The most robust finding in the sleep literature is that the longest sleep durations occur on days off (Tune, 1969), followed by afternoon, day and night shift in both permanent (Tepas & Carvalhais, 1990) and weekly/rapidly rotating shift arrangements (Totterdell & Folkard, 1990). Day sleep is characterised by difficulties in maintaining sleep and not feeling rested after waking. Feelings of tiredness and fatigue are often attributed to sleep loss (Lavie et al. 1989; Naitoh et al. 1990).

Decreased day sleep has been found in studies using survey, diaries and EEG methodologies. Surveys have reported day sleep durations ranging from 4.3-h (Akerstedt, 1984) to 6.1-h (Knauth & Rutenfranz, 1981). Akerstedt and Torsvall (1981) found a mean of 5.7-h using sleep diaries with 390 steelworkers. Escriba et al. (1992) obtained sleep durations of 4.9 to 5.1-h sleep from permanent night shift workers. In contrast, Mahan, Carvalhais and Queen (1991), found sleep durations of 6.3 - 6.5-h.
EEG day sleep recorded in shiftworkers’ homes have reported durations of
4.3-h (Torsvall, Akerstedt & Gillander, 1981) and 5.14-h (Tilley et al. 1982). In a two
year follow up, Akerstedt and Kecklund (1991) obtained a non significant increase from
5.2-h to 5.8-h of sleep in the home following night shift.

Further compounding these shorter sleep durations, is the preceding acute
sleep loss associated with working the first night shift. Pre shift sleep durations of 61-
min (Dirks, 1993) and 3.28-h (Alward & Monk, 1990) have been found in permanent
night nurses. Shiftworkers on rotating shifts have reported a preparatory sleep of 2.1-h
(Knauth & Rutenfranz, 1981) and 2.48-h (Alward & Monk, 1990) before the first night
shift. Indeed, there are also reports of no sleep being taken before the first night shift
(Glenville & Wilkinson, 1979).

In the context of the present research, sleep and fatigue require operational
definitions. Sleep may be defined using objective (Monk, 1991) and subjective
measures. In chapters two and three, sleep refers to a subjective self estimate of actual
sleep time that is recorded daily by shiftworkers into a standard sleep diary.

Assessing fatigue is not a simple task (see section 1.7.6). In keeping with the
literature (Duchon et al. 1997; Tepas et al. 1997) a range of subjective and objective
indicants will be used to assess fatigue. In chapters two and three, fatigue is
operationally defined in terms of self reported survey data and changes in mean TST. The
survey data assesses fatigue via related concepts such as tiredness and the chronic
fatigue scale (see SSI). A decrease in mean TST is considered to also indicate fatigue.

The remaining chapters make use of objective fatigue indicators. The impact of
the introduction of extended shifts with a faster rotation may be seen in changes to
absence (chapter four) and safety (chapter five) behaviour. Chapter six and seven are
concerned with changes in performance by time of day as indicators of fatigue.
1.8.2 Impact of Sleep Loss

Sleepiness and fatigue

A clear effect of sleep loss is sleepiness. Sleepiness is considered a physiological drive for sleep (Dement & Carskadon, 1982). Akerstedt (1996) has described sleepiness 'as a special kind of tiredness in the central nervous system' (p. 37). Sleepiness has been found to increase across the night and to have a lesser effect during the day (Duchon et al. 1994; Rosa, 1991; Paley et al. 1998). Sleepiness peaks in night workers during the early morning due to the combined influences of; (a) working during the circadian nadir, (b) working after an extended period of wakefulness, and (c) a reduced day sleep (Akerstedt, 1995a). Other factors that may impact on sleepiness include the task demands (eg. monotonous activity), the length of the work shift and rotation speed (Kecklund & Akerstedt, 1995).

A number of survey (Akerstedt, Torsvall & Froberg, 1983) and EEG/EOG (Torsvall & Akerstedt, 1987) studies have identified that sleepiness during night shift may lead to involuntary sleep. In one study (Torsvall, Akerstedt, Gillander & Knutsson, 1989), up to 25% of night workers were recorded to have slept on three separate occasions. Subsequent interviewing indicated the workers were unaware of having slept. Similar findings were obtained from night time truck drivers (Kecklund & Akerstedt, 1993). In all cases, alpha and theta activity increased towards the end of the drive. While the focus has been on objective sleep measures, it is important to note that subjective estimates of sleepiness are in good agreement with physiological indices (Gillberg, Kecklund & Akerstedt, 1994).

Akerstedt (1984) noted that fatigue is most associated with sleep disturbances and particularly on the night shift. Subjective fatigue has been widely reported on the night shift (Akerstedt & Torsvall, 1978; Akerstedt, 1988; Paley & Tepas, 1994).
Dawson & Reid (1997) 'simulated' fatigue via wakefulness in one group and compared their performance with a group that ingested 10-15g of alcohol every 30-min. Performance on a tracking task showed a decrement for each hour of wakefulness between 10 and 26-h, was equivalent to a rise of 0.004% in blood alcohol concentration (BAC). After 17-h of wakefulness (at 03.00) performance was similar to the group with a 0.05% BAC. After 24-h of wakefulness, performance was similar to 0.10% BAC.

**Performance and safety**

Sleep loss and sleepiness are clearly implicated in performance and this decline has been observed in both laboratory and field studies. A thorough review of the effects of sleep loss in a laboratory setting can be found elsewhere (Dinges & Kribbs, 1991; Carskadon and Roth, 1991) but the evidence suggests that sleep loss of 2-h can be associated with performance impairments.

Pilcher and Huffcutt (1996) recently reported a meta-analysis of 19 laboratory studies of sleep deprivation. The studies were categorised into short (≤45-h), long (≥45-h) and partial (<5-h) sleep deprivation. The overall mean effect size (-1.37) across the three conditions indicated that sleep deprived subjects performed 1.37 standard deviations below the level of non sleep deprived subjects. Simple cognitive tasks were more impaired by partial sleep loss, than the more complex tasks. Partial sleep loss may best describe the condition of night shiftworkers.

The effect of a cumulative sleep debt on performance was recently simulated in a laboratory experiment (Dinges et al. 1997). Subjects had their sleep restricted by 2.43-h per night for seven nights. Performance on a 10-min visual psychomotor task was worst at 10.00, and best at 22.00.

On day one, performance showed slight deterioration compared to baseline results. Day two however, showed a marked deterioration in performance that was
maintained until day five. Subsequent performance further declined in a linear manner over the final two days. These results suggested sleep loss may have a step-like function on performance.

This study offers some support for a faster rotation. Although performance was impaired, it was not significantly affected until the final two days. That is, after approximately 17-h of cumulative sleep loss. It is salient to point out that these results were found when night sleep was restricted.

Field studies of work based performance have also demonstrated the role of sleepiness in performance impairments at night. In general, these studies show poorest performance on night shift (Liou & Wang, 1991) and particularly, about 03.00 (Bjerner, Holm & Swensson, 1955; Browne, 1949). Shiftworkers' safety (see chapter 5) is also considered to be more at risk during the night shift (Levin, Oler & Whiteside, 1985). In particular, L. Smith et al. (1994) have suggested that this risk is markedly greater in self paced work roles during the night shift.

It is important to note that the full effect of sleep loss on productivity and safety is masked by the use of automated processes (Mitler et al. 1988; Wyatt & Marriott, 1953) and work differences across the shifts (C. Smith, Silverman et al. 1997). Stronger evidence for the effect of sleepiness can be found in the timing of single vehicle accidents (see chapter 6). These accidents have reported a consistent accident peak between 02.00 and 03.00 across a number of countries.

More recently, Folkard (1997) statistically linked the timing of transport accident peaks and decrements in job performance. This suggests environmental factors are less important in performance impairment than is time of day.

Folkard (1997) used three transport studies to develop a model of accident risk. The model estimates accident risk is high during the first two to four hours of a
shift and then declines to approximately the ninth hour. Subsequently, the model predicts an exponential increase in risk. Hanecke, Tiedmann, Nachreiner and Grzech-Sukalo (1998) have reported similar findings based on their examination of 1.2 million accidents in Germany. They also found an exponential accident risk after 9-h of work. Furthermore, their data indicated this effect was more likely in shifts with later start times.

**Mood**

The following section will briefly review the effect of sleep reduction on mood. Social and family disruptions are also considered to affect mood and these are discussed elsewhere (Colligan & Rosa, 1990; Walker, 1985).

Pilcher and Huffcutt’s (1996) meta-analysis also considered the effect of sleep deprivation on mood. Importantly, the effect of sleep deprivation was largest for mood (effect size = -3.16), followed by cognitive (-1.55) and motor (-0.87) performance. Partial sleep deprivation (< 5-h) had a greater negative impact on mood, than long term sleep deprivation.

In a laboratory study, Dinges et al. (1997) demonstrated the cumulative effect of 2.43-h sleep restriction per day (mean sleep 5-h) over seven days. Reliable decrements in sleepiness and mood were observed across the week, relative to baseline scores. The significant decrement in sleepiness was paralleled by the pattern of decrement in psychomotor performance. Sleepiness was significantly impaired on the first day of sleep restriction relative to baseline. Across the next five days, scores were similar to day one. Further significant deterioration in sleepiness was found on the seventh day. Mood impairment was also recorded on the overall POMS measure and on the following subscales: fatigue-inertia, confusion-bewilderment, and tension-anxiety.
These two studies highlight some interesting features. The first is that they examined sleep means consistent with the concept of core sleep (Horne, 1992). Dinges et al. demonstrated that such sleep durations are associated with significant increases in sleepiness, which reflects a drive for more sleep. Secondly, performance after sleep deprivation was impaired in both studies. Dinges et al.'s. (1997) finding that mood decrements preceded impaired psychomotor performance, support the conclusions of Naitoh et al. (1990). They surmised that tiredness and sleepiness following sleep deprivation reliably lowered quality of life. In turn, such feelings 'constitute an early warning that serious deterioration in job performance will follow unless more sleep is obtained' (p. 222).

Totterdell et al. (1994) found that early sleep onset (in a non shiftwork population) was strongly related to subsequent cheerfulness. Late sleep onset predicted lower cheerfulness, alertness and sleep length. Cheerfulness was best predicted by short sleep latency, early sleep onset, fewer awakenings and higher quality sleep. Sleep was not associated with prior mood states.

Mood and sleepiness appear to be more affected by the night shift. Duchon et al. (1994) reported significant negative outcomes for mood and sleepiness between the start and end of 12-h shifts. Paley and Tepas (1994) and Paley et al. (1998) both demonstrated deterioration in mood and sleepiness on night shift on slow rotating 8-h shifts and fast rotating 10/14 shifts respectively.

Verhaegen et al. (1978) and Healy, Minors and Waterhouse (1993) both reported psychosocial health impairments in first time shiftworkers. Healy et al. found decreased neuro-vegetative functioning and increased psychosomatic complaints in workers before and after night shift experience. The authors also suggested that shiftworkers complaints had much overlap with depression and helplessness.
There is little doubt that insufficient sleep is a problem to shiftworkers. Its effect can be seen in increased sleepiness and fatigue, performance and safety and decrements in mood. This conclusion is consistent with the outcomes of acute and chronic sleep loss predicted by the SDM (Tepas & Mahan, 1989).

1.8.3 Approaches to assessing shift system adequacy

A large number of dependent variables have been used to reflect the adequacy of a shift schedule. These include inversion of circadian rhythms, self report and sleep duration.

Body temperature was long considered the marker (Monk & Folkard, 1992) for shift adjustment. Its use has waned in recent years. The current interest in rapid rotation is underpinned by the argument that for most occupations, circadian adjustment is not necessarily desirable (Folkard, 1992).

Self reported data can be validly collected on a range of variables (Barton et al. 1995a) including circadian variation in alertness (Folkard, Spelten, Totterdell, Barton & Smith, 1995; Tucker et al. 1996). However, the effectiveness of this approach depends much on the actual measures. For example, Kaliterna and Prizmic (1998) concluded the SOS was not suited for an in-depth analysis of individual differences.

A major limitation with survey approaches is the potential for a response bias in the sample (Barton et al. 1995b). Detecting bias is especially salient in evaluative studies when the former shift system is particularly demanding (Lowden et al. 1998; Wallace & Greenwood, 1995). Employee health and safety is not guaranteed, simply because a new shift system is approved by the majority (Tepas, 1990).

A number of authors have stressed the importance of sleep in assessing shift systems. An early review by Wedderburn (1975) noted that 'sleep is the key to the problems of night shift'.
Shiftworkers encounter two immediate effects from sleep loss (Tepas et al. 1997). The first is the acute sleep loss from working the first night shift. This sleep loss is compounded across several night shifts and results in chronic sleep loss. The sleep loss generated by these two effects is considered to explain the presence of night time sleepiness (Akerstedt, 1991) and tiredness (Akerstedt, 1984; Naitoh et al. 1990).

Sleep reductions are associated with lower well-being. Barton et al. (1995b) reported longer day sleeps were associated with increased sleep quality. Improved sleep quality in turn, predicted less chronic fatigue and better psychological and physical well-being. The longer day sleeps were associated with working more consecutive nights and this led the authors to suggest that longer day sleeps may indicate better circadian adjustment.

Sleep disturbances are also common in shiftworkers, especially during day sleep (Rutenfranz et al. 1985). Circadian, social and environmental factors combine to interrupt day sleep. Lavie et al. (1989) has argued that sleep disturbances can be used as markers for shift system adequacy.

The use of sleep duration as an indicator of shift system adequacy is not without difficulty. Sleep duration is not a clear indicator of sleep recovery need (Akerstedt, 1990) because it is terminated by circadian and social demands. Nonetheless, there is sufficient evidence that excess sleep loss is associated with: sleepiness (Akerstedt, 1995b), fatigue (Paley & Tepas, 1994; Paley et al. 1998), impaired performance (Dawson & Reid, 1997), increased accidents (Dinges, 1995) and mood disturbances (Totterdell et al. 1994).

1.9 Measuring sleep duration

Sleep duration can be assessed via physiological recording or by a number of self report tools. Each method has some advantages and disadvantages which need
Physiological measures leave little doubt regarding consciousness (Akerstedt, 1996). Advances in recording technology has seen sleep monitoring progress from the laboratory (Tepas, Walsh, Moss & Armstrong, 1981), into shiftworkers' homes (Tilley et al. 1982; Torsvall, Akerstedt & Gillberg, 1981) and now into the field (Torsvall et al. 1989; Akerstedt & Kecklund, 1991).

A limitation of these devices is that they are not suitable for large scale field use and require the selection of sub samples (Lowden et al. 1998). The reliability of recorders in the field does have some difficulty. Kecklund and Akerstedt (1993) excluded some 15% of subjects due to technical difficulties and there is also the possibility of subjects tampering with the recorders. Nonetheless, these devices record and score meaningful sleep information as activity logs.

Self report measures of sleep take two basic forms. A common technique is to ask shiftworkers, how much sleep they need irrespective of the shift worked. A second technique is to ask how much sleep is typically taken between shifts. A more recent variation on these techniques, is to express sleep need as a proportion of sleep need relative to each shift type (Barton et al. 1995b; L. Smith, Hammond et al. 1998).

These are a number of sources of bias with these approaches. Principally, they do not take into account sleep variability across a shift cycle (Dahlgren, 1981a; Dirks, 1993). In the absence of a broader context, shiftworkers present what Paley et al. (1998) described as a 'best case scenario'; the sleep they would like to achieve. Frese and Harwich (1984) reported a moderate correlation (r=0.54) between reporting 'typical' sleep duration and sleep duration obtained the previous night. However, Tepas, Walsh, Moss and Armstrong (1981) reported a high correlation (r=0.83) between usual sleep/wake times and polysomnographic sleep.
The variability in sleep duration means that more accurate estimates of mean sleep can be achieved, by taking repeated measures across complete shift types and across time. Repeated measures take into consideration the effect of daily events and should therefore, provide a better estimate of sleep compared to global estimates.

A second difficulty is that studies reporting between night shift sleep durations are overestimating the mean sleep across night shift. This occurs because they disregard the effect of the first night shift, which is associated with maximum wakefulness. An improved estimate of mean sleep for night shift requires using sleep durations obtained across all night shifts.

In contrast to asking shiftworkers to indicate sleep need, sleep diaries have a number of advantages. These include:

- non intrusive.
- paper based diaries are cost effective in large scale repeated measures designs.
- able to record the daily fluctuations in sleep.
- allows pre and post shift sleep to be calculated and therefore, provide a more comprehensive account of sleep.
- actively engages the shiftworker in the study.

Paley et al. (1998) recently argued the advantage of sleep diaries over surveys, is that they provide a more complete picture of sleep. This suggestion stems from an earlier study (Paley & Tepas, 1994) of a slow rotating shift system, that found sleep recorded by survey, increased across the night shifts. In contrast, Paley et al. (1998) found a decrease in night shift across the cycle, when sleep was recorded using a diary. Paley et al. concluded that because the diary data were more consistent with the literature, that sleep diaries represent a better method for collecting sleep data.
The conclusion that sleep diaries are more accurate than survey questions is appropriate. However, their argument may be flawed. Slow rotating night shifts have reported increased sleep across the cycle (Dahlgren, 1981a; Dirkx, 1993). It is possible the sleep differences may actually reflect the differences between fast and slow rotations on sleep duration. The studies by Paley and Tepas (1994) and Paley et al. (1998), were not designed to directly compare diary and survey sleep measures.

Sleep diaries are not without difficulties. Survey questions require far less effort from respondents and this, may increase the response rate. Diaries impose a greater demand because they are required to be completed over a number of successive days. This additional demand increases the opportunity for missing data (Totterdell, Spelten, Smith, Barton & Folkard, 1995). Compliance difficulties may be resolved via the use of hand held computers to record sleep variables (Totterdell et al. 1994). An added advantage is that computer scoring of diaries will prove attractive to researchers.

Sleep diaries are also not without bias. However, whereas rating scales ask shiftworkers to discriminate variables for which there may be some attitudinal bias (eg. choose leisure over fatigue), sleep diaries ask shiftworkers to describe the present reality. This may less likely be distorted. It may be the case that actively involving shiftworkers in diary completion minimises bias because diaries serve as feedback tools.

1.9.1 An approach for calculating sleep duration

A method for calculating sleep duration using diaries is proposed. There are two main issues to be addressed: (a) how to best represent sleep, and (b) what boundaries should be considered for calculating sleep.

Shiftwork sleep researchers do not seem to have debated the issue of how best to score self reported sleep. There are a number of questions raised by this
debate. However, for each question there is no generally accepted answer.

Is it best to record sleep before a shift, after a shift or both? There is some indication that sleep is more strongly related to subsequent, than to prior well-being (Totterdell et al. 1994). Studies reporting sleep before a first night shift, have found very different estimates. While some have found a few hours (Alward & Monk, 1990; Dirkx, 1993), others have reported up to 9.4-h (Tucker, Smith, Macdonald & Folkard, 1998b). These studies are not necessarily defining 'before night shift sleep' in the same way.

Whilst a strong argument can be made that the main sleep period is most critical, identifying the main sleep for those shiftworkers who take two or more main sleeps (split sleeper) presents a difficulty.

The answer to some of these questions, of course depends on the aims of a particular study. The point however, is that from a methodological perspective, many of these practical issues have not been resolved.

The approach taken in chapter two is to calculate total sleep in a 24-h period. This decision was influenced by one of the goals for the sleep studies: to examine the total amount of sleep to the end of a night shift. Night shifts are typically regarded as problematic (Akerstedt, 1995a).

The remaining decision is how to best use the 24-h period to record sleep duration. Consistent with the notion of estimating sleep to the end of night shift, the resolution adopted was to use the period from 07.00 to 06.99.

Scoring sleep using this approach has some implications for the rotation speed debate. A major argument for faster rotation is a reduction in cumulative sleep debt. However, (as noted in section 1.4.2) this may be at the expense of increased acute sleep loss by increasing the number of first night transitions (see table 1.3).
In terms of the SDM model, the method to be used in chapter two calculates total sleep to the end of the first night shift. It therefore, represents an estimate of acute sleep loss. Subsequent sleep estimates reflect the amount of between night shift sleep. That is, sleep for the second night shift would be the sleep taken between the completion of the first and second night shift.

The additional benefit of using this approach in the calculation of sleep duration, is that it allows for the pattern of sleep to be examined. In particular, the changes in cumulative sleep loss and gains can be plotted across the shift cycle. In the context of evaluating shift systems, reliance on mean sleep durations alone is not sufficient. Sleep duration is a crude indicator of recuperative processes (Akerstedt, 1990) and may obscure broader changes in sleep behaviour.

1.10 Summary

Shift design holds the greatest utility for improving shiftworker well-being. In particular, rotation speed has received much of the attention. The benefits of rotation speed appear to depend on the nature of the dependent variable. A general summary of the effects of rotation speed on fatigue, social satisfaction and psychological well-being, can be found in table 1.8. Social and family advantages are found in the majority of CWW studies. While the increased number of days off may explain this finding, the poor former shift design may also be important in such comparisons (Lowden et al. 1998).

That is, 12-h shifts with ample free time are superior to slow 8-h shifts with few days off.

However, sleep restriction can have a number of detrimental effects on shiftworkers’ well-being and performance. These effects however, are not always detected in field studies. A review of the literature comparing 8-h and 12-h shifts (L. Smith, Folkard et al. 1998) concluded that the differences are largely equivocal but
<table>
<thead>
<tr>
<th>Outcome</th>
<th>Slow 8-h shifts</th>
<th>Fast 8-h shifts</th>
<th>Fast Extended Shifts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue</td>
<td>High - due to circadian disruption and cumulative sleep loss.</td>
<td>Cumulative fatigue is less but sleep is reduced relative to slow 8-h shifts. This may be problematic. Shorter shift allows more day to day recovery.</td>
<td>Extended shifts allow less day to day recovery, combined with cumulative fatigue and reduced sleep opportunity.</td>
</tr>
<tr>
<td>Social</td>
<td>Poor but regularity of system allows for scheduling events.</td>
<td>Good - fewer consecutive night and afternoon shifts allow for more regular contact with family and friends.</td>
<td>Appears best. Abolition of afternoon shift and fewer consecutive night shifts increases social opportunities.</td>
</tr>
<tr>
<td>Psychological well-being</td>
<td>Low due to reduced social opportunities and shift malaise.</td>
<td>Significant improvement over slow 8-h shifts due to increased social opportunity and fewer consecutive shifts</td>
<td>Appears best. More social opportunities than fast 8-h shifts and less shift malaise.</td>
</tr>
</tbody>
</table>
there are persistent concerns regarding fatigue and safety. In particular, they noted no major difficulties with sleep. This conclusion may be premature. The sleep data resulting from 12-h shift studies are problematic. The studies tend to be cross-sectional or simple before and after comparisons. Furthermore, most have relied on asking shiftworkers to indicate sleep need. Few studies have used sleep diaries. They provide a more complete assessment of sleep (Paley et al. 1998).

The purpose of the next chapter is to conduct two investigations of a change from 8-h to 12-h shifts. A number of dependent variables will be used to assess the change. In particular, sleep duration will also be used as an indicator of the adequacy of the change. In response to the methodological limitations of 12-h shift sleep studies, the proposed studies make use of sleep diaries in a repeated measures design.