BIOCOMPATIBLE SHIFT SCHEDULING: Reducing the Costs, Risks, and Liabilities of Operational Fatigue

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Extended hours operations are fundamentally more costly than daytime operations. Managers who are aware of these excess costs can be provided with solutions that help them to better manage the operation and reduce their costs, risks, and liabilities.

- The total excess costs of extended hours operations is $206 Billion per year, an average of about $8,600 per employee
- Increased absenteeism, lost productivity due to fatigue related human error, turnover, accidents and safety incidents, and health care drive these excess costs
- These costs are recoverable, and no longer have to be financed as part of doing business

Absenteeism: $50.4 Billion/year, $2,102 excess/employee, 24% of Excess Costs

- Only 1/3 of absenteeism is due to sickness

Lost Productivity: $79.4 Billion/year, $3,309 excess/employee, 39% of Excess Costs

- Costly errors caused by fatigue
- Human performance decreases at night by 5% - 10%

Turnover: $39.1 Billion/year, $1,631 excess/employee, 19% of Excess Costs

- Shiftworkers account for 17.6% of U.S. workers, but generate 44% of turnover costs
- Average turnover is 12% when schedules are mandated, 9.6% when negotiated with unions, and only 5.6% when employees select the schedule

Accidents & Workers Comp.: $8.5 Billion/year, $354 excess/employee, 4% of Excess Costs

- Over the course of a year 53% of shiftworkers had several or more errors due to lack of attention at work
- Experienced having to “fight” sleepiness several times or more per week

Health Care: $28.2 Billion/year, $1,181 excess/employee, 14% of Excess Costs

- Shiftworkers represent roughly employees are 10% of the U.S. insured population, but generate 17% of all U.S. health care costs

One of the main initiatives management can focus on to reduce the costs, risks and liabilities of extended hours operations is revisiting the shift scheduling system for their operation.

This system consists of (1) the means for determining the schedule that the employees are willing to work; making sure management's key operating criteria are met while facilitating employee involvement in the schedule selection, (2) the optimization of the work schedule; determining the right staffing levels and (3) the day-to-day management of the schedule using an automated scheduling solution.

Trends in Work Schedules

There are literally thousands of mathematically possible/different work schedules available for use in extended hours operations. However, **there is no single best schedule**. The optimal solution for any particular facility must not only be based on the business goals and operational needs of that site or facility, but also the family and social preferences and lifestyle needs of the employees who work there, and the human factor considerations that influence employee health, safety, and performance.

In extended hours operations, shift schedules are redesigned periodically. The key reasons for changes include:

- Staffing levels or number of crews are being adjusted (e.g., to permit training time, or to reduce excessive levels of overtime)

- Business expansion or contraction requires changes in the work hours or days in a week that a facility operates (e.g., a move from 5-day to 7-day operations, or from 24/7 to 24/5)

- A shiftwork risk assessment showing that the existing schedule is causing excess employee costs, risks or liabilities (e.g., absenteeism, errors, accidents and lost-time injuries, employee turnover, excessive overtime, etc.)

- Changing demographics of the workforce (e.g. increases in younger employees, more female workers, more imported labor) make the previous schedule no longer suited to employee needs and lifestyles

- Persistent complaints from the workforce about the current schedule

- Etc.

Circadian's *Shiftwork Practices Survey* of North American companies showed that 6% of 24/7 facilities have used their current schedule for less than one year, 19% have used their current schedule for two to five years, and 61% have used their current schedule for more than five years. Some facilities surveyed revise their schedules every two to three years to adjust to changing business and demographic conditions. Others keep the same schedule for 10 years or more.

Components of Best Practices in Shift Scheduling

There is no one single optimal shift system that could be used at all work places. The shift system must take into account business goals, operational constraints, employee preferences and ergonomic (physiological and sociological) criteria. It is also important to consider the work environment and the type of tasks involved. Although there is still some discussion in the scientific community regarding certain schedule features, there is general agreement about which are the best practices for designing safe, healthy, and productive schedules…and these have been validated by extensive field experience. Thus, the most important factors for evaluating the effectiveness of a shift system include:

Duration and distribution of working time:

- Number of consecutive working days
- Duration of shift
- Time off between shifts

Sequence of shifts:

- Fixed versus rotating
- Speed of rotation
- Direction of rotation

Position of working time:

- Start/end of shifts

Sleep/wake transitions:

- Daytime vs. nighttime sleep

Periodic long breaks (3 days or more):

- Full rest and recovery
- Return from long breaks onto day shift

Schedule pattern of work days and off days:

- Regular vs. irregular

Duration and Distribution of Working Time

Every worker needs a recovery period from work at regular intervals. Given differences in work environment, physical and mental work-related stress, and individual circumstances, it is difficult to recommend specific limits. In general, however, experts recommend limiting the number of consecutive working days to five, six or seven days (Knauth 1993). However, it is important to take into account the length of the workday when deciding the number of consecutive workdays. Circadian experts recommend limiting 8-hour shifts to a maximum of seven in a row, and 12-hour shifts to four or five in a row.

It is equally important to consider the number of hours worked per week. It has been noted that long work hours increase stress levels, both by increasing the demands of maintaining performance while facing increased fatigue levels, and by increasing the time a worker is exposed to other sources of workplace stress. There is growing evidence that excessive long hours directly correlate with health problems, as a result of the increased stress levels and chronic sleep deprivation and fatigue. High levels of stress are considered to be contributors to the development of cardiovascular and musculoskeletal problems, gastrointestinal disorders, and certain mental problems (Spurgeon et al. 1997). Moreover, a study analyzing the lifestyle of more than 200 people who have suffered a heart attack found that 65% of them regularly worked more than 60 hours/week, with some working more than 50 hours of overtime a month as well as half of their contracted holidays (Uehata 1992).

When considering the amount of hours worked, it is thus important to take into account not only the regular hours, but also the overtime, mandatory or voluntary. While the typical shiftworkers logs only 250-350 hours of overtime, there are those in every workforce who regularly exceed 500 to 600 overtime hours. Moreover, the annual overtime hours for shiftworkers has been steadily increasing over the past decade as businesses strive to do “more with less”.In 2004, for example, overtime rose to 16.2%, compared to 12.6% in 2003 (Shiftwork Practices Survey). It should also be noted that overtime is rarely evenly distributed among employees. As a result, it is not unusual to find people working 40% to 50% overtime levels within an organization that is only averaging 12% overtime overall.

In 24/7 operations, what drives overtime is the staffing level…not the workload. If the workforce is understaffed, overtime will increase, and the integrity of the work schedule will be compromised. This resulting irregularity of the shift pattern, in turn, creates further disruption in one’s sleep/wake pattern, thus increasing fatigue and the probability of human error. To avoid this scenario requires no only sufficient staff to fill the required positions, but also additional personnel to provide relief coverage for the scheduled benefit days off (e.g. vacations and floating holidays, etc.) and for any training and special assignments that must be completed on an ongoing basis. Otherwise, the required coverage will have to be achieved through overtime.

Time Off Between Shifts

The rest period between shifts should provide enough time for obtaining adequate sleep. Kurumatani et al. (1994) found a very high correlation with the length of the time off between consecutive shifts and sleep duration, and concluded that individuals need at least 16 hours of time off for a sleep duration of seven or eight hours. A series of studies have shown that rest periods of 10 hours or less between consecutive shifts result in short sleep episodes, sometimes only three to five hours of sleep. Thus, the time off between the end of one shift and the beginning of the next one should be at least 11 hours (Knauth 1997).

Time Off Between Blocks of Work Days

There is general agreement that a single day off between blocks of workdays is not enough for recovery (Knauth 1997). Research data has shown that mood and social satisfaction can tend to be worse on the first rest day compared with subsequent rest days. The amount of rest needed between blocks of working days is related to the number and length of consecutive shifts. Most studies have confirmed what every shiftworker knows…that feelings of well being are worse on days off after night shifts compared to days off after day shifts, especially on the first day off. Further research and field experience has confirmed that a minimum of 2 days off (i.e. 48 hours) should be provided to ensure full rest and recovery between shift turns, with a periodic long break (i.e. 3 or more days) built into each cycle.

The adaptation to night work never fully occurs, even after an extended series of consecutive night shifts, resulting in cumulative sleep deprivation. Some studies have shown that workers need three days off to recover from seven consecutive night shifts. Shiftworkers on a schedule with only three consecutive night shifts only need only two days off to fully recover (Kecklund and Akerstedt 1995). The length of the shift is also an important factor. Thus, schedules with 12-hour shifts often have short sequences of workdays (two to four) followed by several days off.

Long Breaks

However, long stretches of days off before night shifts could be challenging. Some studies have shown that certain performance measures are worse during night shifts following four or more consecutive days off than after two to three days off. This suggests that workers are more adapted to a daytime routine after a long break, which makes it more difficult to adjust back to night work. In addition, the mental adjustment required to catch up with the changes that occurred while they were off-duty is compounded by the physical adjustment that has to be made in terms of staying awake all night, and having to sleep in the daylight for the first time in a week or more. Thus, it is advisable to set up the shift pattern so that people return from the long break onto a day shift to ease the transition.

Duration of Shifts

The traditional workday has been 8-hours long in most industries. However, with the rapid growth of extended hours operations in the 1980s and 1990s, coupled with an influx of younger people, workers started demanding 12-hour shifts to obtain more days off and weekends off then possible with 8-hour schedules with the increase in automation came an increase in continuously operating environments requiring the same productive capacity 24/7. As a result, the most commonly utilized schedule structure became a four-crew "balanced" (same productive capacity) shift system. These schedules can be operated with 8-, 12-, or combinations of 8- and 12-hour shifts. When 8s are used, three of four crews are needed to cover each 24-hour period (thereby requiring employees to work 75% of all days). However, when 12s are utilized, only two of four crews are needed to cover each 24-hour period (thereby requiring employees to work only half of the days of the year). Compared to 8-hour shifts, 12-hour shifts are often popular among workers because they provide double the number of days off as well as twice as many weekend days off per year. In facilities where new schedules were implemented, and where when employees got to select their own work schedule through a human involvement process, they invariably selected 12-hour shifts. The key, however, was to provide the workforce with the factual information needed for them to make truly informed decisions, and thus take “ownership” in those decisions. Regardless of the length of shift or type of shift pattern, **all schedules work best when “owned” by the employees.**

Fixed Versus Rotating Shifts

One of the most challenging questions in shiftwork schedule design is whether to rotate crews or keep them fixed. With a rotating schedule, employees' scheduled shifts change periodically. Under a fixed schedule, employees' work hours are the same every workday.

From an employer's point of view, rotation provides the advantages of balancing skills and experience across all shifts, and of providing all employees with equal exposure to daytime management, training, HR support, suppliers, and other key daytime personnel.

From the employees' point of view, fixed schedules provide stable work hours, making it easier for them to organize their lives. Fixed shifts may also be related to less sleep disruption and fatigue, at least for the day shift personnel. However, workers on fixed night shifts may end up even more fatigued than workers on rotating shifts because they almost invariably switch back to a daytime schedule on their days off to pursue social activities with their families and friends. This essentially creates a fast, defacto rotation. Fixed evening shifts may also have a substantial negative impact on family and social life. All of these factors create difficulties in balancing the mix of skills, qualifications, and experience across each of the crews and thus imbalances in productivity. They also pose significant communication challenges for management.

There is still a lack of conclusive data on the effects of fixed versus rotating shifts on alertness, performance, and accidents. Studies comparing workers on fixed and rotating

shifts often find that the groups are not similar regarding age, marital status, freedom to choose the shift, or type of task performed or sleep management. Some studies have found that permanent night workers sleep less and have a higher prevalence of fatigue than rotating shiftworkers (Tepas and Carvalhais 1990, Alfredsson et al. 1991). However, some researchers have described a lower accident rate, a higher rate of performance, and a lower rating of effort in permanent night workers as compared to rotating shiftworkers (Gold et al. 1992, Totterdell et al. 1994). Certainly, the type of shift pattern also presents a confounding effect on these studies.

Other authors have noted that individuals who are "owls" (i.e. night types, who tend to go to bed late and get up late) adjust more easily to nightwork. There are a number of studies evaluating methods, such as bright light, to improve the adjustment to night work, but there is still much work needed (Rosa et al. 1990, Czeisler and Dijk 1995). In the final analysis, the decision on rotating vs. fixed shifts may best be left to the employees themselves, since “ownership” may again be the key factor to adaptation and thus optimal performance.

When implementing rotating schedules, two unique factors need to be considered: speed and direction of rotation.

Speed of rotation refers to the number of consecutive shifts worked (i.e., morning, evening, night) before changing to a different shift and the amount of time off in between those shift changes. Despite this being a key factor, it is still a controversial scheduling issue. Shiftwork experts in the U.S. tend to favor slow rotations (e.g. week 1), while European experts prefer quick (e.g. daily) shift rotations. The arguments in favor of quick rotations are as follows (Knauth 1993):

- Quick rotations are thought to keep the circadian rhythms in a daytime orientation; that is, the circadian rhythms are theoretically not in a constant state of disruption from switching between day and night work

- Many consecutive night shifts may cause chronic sleep deprivation, which could lead to long-term health problems

- Shiftworkers have some free evenings every week, allowing them more regular contact with family and friends

The benefits of slow rotations preferred by North American include:

- They usually result in more consistent or regular patterns, allowing workers better planning of their family and social life

- The body adjusts more readily to regularity in schedules

- They actually reduce the number of sleep/wake transitions between day, evening, and night work

- Quick rotations are foreign to North American mentality

This is further illustrated in the *Shiftwork Practices Survey* of North American plants. Among the facilities reporting 8-hour rotating shifts, the majority (63%) rotated on a weekly basis, 9% rotated on a monthly basis, 11% on a bi-monthly basis, and 17% every set number of days. For best results, however, the speed of rotation should be tailored to the specific shift pattern. For example, a 2-2-3 x 12 hour shift rotation is less stressful with a 2 week rotation, than with its customary rotation with every turn (i.e. every 2-3 days). However, with the 3-3 and 4-4 x 12-hour schedules, it is more effective to rotate with every turn to minimize the number of sleep/wake transitions.

Direction of rotation refers to the sequence of shifts in the schedule, but this is only a factor for schedules having three or more shifts per day. With an 8-hour schedule, for example, a forward rotation would have employees change from morning shifts to evenings and then to nights while a backward or counterclockwise rotation would have employees work mornings, then nights, then evenings.

Work schedules that move forward in time are easier and less physiologically stressful for our bodies because they are in accord with the body's natural tendency towards longer days. This is readily illustrated by comparing the direction of the rotation of a shift schedule with the direction of jet travel across multiple time zones. Forward rotations are comparable to westbound flights (with a "prolongation" of the day) and backward rotations to eastbound flights (with a "shortening" of the day). Jet lag symptoms are more severe when traveling east than when traveling west (Barton and Folkard 1993, Knauth 1995).

Position of Working Time: Start and End of Shifts

Regarding the shift start and end times, the main revolves around balancing the best time for starting the morning shift with the best time for ending the night shift, so that workers can get enough sleep before the morning shift and after the night shift. Evening shifts usually do not create a problem regarding sleep, and they only apply to 8-hour shift patterns.

During the human 24-hour (i.e. circadian) cycle, there are two periods when alertness is low and sleeping is easy, and two periods when alertness is highest and sleeping is more difficult. The largest alertness drop normally occurs between 3:00 and 6:00 a.m., and the smallest one during early afternoon between 1:00 and 3:00pm for most people. It is easiest to fall asleep during these times than at any other time during the cycle. On the other hand, alertness is highest during the morning and early evening, making it difficult to fall asleep at these times.

Start of Morning Shift

Most people require about seven to eight hours of sleep to feel well rested and at their best. However, with a shift start time before 6:00 a.m., achieving seven to eight hours of sleep is very difficult for most people (Folkard and Barton 1993). There is thus a general agreement that too early a start time reduces sleep before the morning shift because most workers go to bed at the usual social time. Moreover, there is a tendency for the body to reject sleep earlier in the evening. This creates cumulative sleep deprivation and fatigue for the day shift personnel, and consequently the risk of errors and accidents during their commute and in the early hours of their day shift.

End of Night Shift

Numerous studies have shown that daytime sleep is shorter and of worse quality than nighttime sleep. This is due not only to environmental factors (there is more light and noise during the day) that may disturb sleep, but also to physiological factors (our circadian clock releases hormones that promote sleep during the night and alertness during the day). Moreover, some researchers have demonstrated that the later the daytime sleep starts after a night shift ends, the shorter it will be (Foret and Lantin 1972). Thus, night shifts that finish late in the morning will not allow a person to obtain enough sleep and will lead to sleep deprivation and fatigue.

Besides the physiological factors, another factor to consider when deciding shift start and end times is the worker's commute. Late starts for the night shift, and early starts for the morning shifts may be difficult for employees depending on public transportation. Conversely, late morning shifts may conflict with traffic patterns in urban areas. It should also be considered that alertness is at its lowest for most people between 3:00 to 6:00 a.m. As a result, more single-vehicle accidents occur around 5:00 to 5:30 a.m. than at any other time of day. Thus, to (proportionally) ensure the safety of employees during their commutes to and from work, it is advisable that shift start and end times not occur during this time of day when alertness is at its lowest level. In the final analysis, all factors being considered, the best balance of shift starting times for both the day and night shifts is from 7:00 a.m. to 8:00 a.m…traffic conditions permitting. Earlier starting times negatively impact the alertness levels of the day shift, while later starts adversely affect the ability of night shift personnel to sleep.

Solutions

Optimization of the Work Schedule

The challenges faced by extended hours operations are diverse, encompassing a wide range of industries and employees. Developing and implementing an effective plan to optimize an extended hours workplace requires both a detailed knowledge of the site-specific issues and an expert grasp of extended hours operations and scheduling factors. While it is tempting to look for a one-size-fits-all solution to the challenges of extended hours operations, it simply does not exist. The "ideal" solution depends on many factors

including the makeup of one's workforce - male/female, younger/older, married/single, with children/no children, the nature of the work, local customs and culture, commuting issues, type of industry, corporate policies and state and federal laws, etc.

Employee Involvement on Schedule Planning and Implementation

Finding the ideal schedule for a particular facility that will minimize the costs, risks, and liabilities of the 24/7 operation requires careful attention to the process of shift schedule design. Who chooses the shift schedule, and how they choose it, is vital to its success. Management-mandated schedules often do not properly take into account the needs of employees and can result in increased employee fatigue, decreased morale, turnover, and absenteeism, and therefore sub-optimal 24/7 facility performance.

The conflicting interests of the parties involved, and difficult labor-management relations, often complicates the successful implementation of a new shift schedule. At the company or corporate level, there may be concerns regarding financial aspects and production needs. From the employees' side, there may be resistance to change due to insecurity about dealing with new conditions, as well as fear of loss of money or jobs. Conversely, there may be a desire to change expressed by some segment of the workforce, usually for personal reasons that may be inconsistent with the company's needs. To reach a compromise between operational constraints and employees' preferences, which are key to the success of the new schedule, the involvement of both labor and management in the process of developing and implementing the new schedule is essential. Moreover, the participation of a neutral, subject matter expert has proved extremely beneficial in providing objectivity and the technical and facilitation support, as well as managing the conflicting interests to achieve an acceptable compromise.

Summary

Management has a substantial opportunity to reduce the costs, risks and liabilities of extended hours operations (on average $8,600 per employee per year). When management focuses on employee involvement in shift schedule selection and in the optimization of the work schedule and implements automated scheduling solutions to assist with the day-to-day management of the schedule, its ability to realize this opportunity is greatly enhanced.

Achieving the Best Results

There are a number of ways to engage the workforce in the pursuit of cost reduction through alternative work schedules. While it is always best when a significant percentage of the workforce is lobbying for change, putting management in the positive position of responding to the shiftworkers in a supportive way…management can also initiate the change tactfully:

a. Put the focus on a more global fatigue or shiftwork risk management initiative
b. Make it part of a health and wellness drive

c. Lead with shiftwork lifestyle training to initiate dialogue for other issues
d. Address increases in turnover, absenteeism, productivity, and other key performance indicators
e. Tie the discussion to a recent incident, site issue, or other company objective
f. A change in operating requirements is usually a good lead in
g. Blame the need to reduce costs on this economic crisis
h. Etc.

Whatever way best fits the company situation, the attached Biocompatible Schedule Design Criteria, and Health and Safety Schedule Analysis charts (Figures 1 and 2) would be a good start towards assessing at least the physiological soundness of your current shift schedule(s). Keep in mind that this only addresses the health and safety aspects of the schedule. The operating and sociological components are equally important, must be addressed separately, and may well turn out to be the over-riding factors.

Now comes the matter of which schedule...from literally thousands of mathematical possibilities...is the best one for your specific operation and unique workforce composition? To answer this question, one must consider that, short of early retirement...**there is no perfect schedule**. Straight day shifts, worked Monday through Friday, is not too bad, because we humans are designed for daytime performance and nighttime sleep. Moreover, as a society, we treasure weekend time off. When we enter the world of continuous, 24/7 operations, every 24/7 shift pattern brings with it inherent physical stress (born of our biology) and social conflict (due to our sociology). So how do we determine the "best" schedule from such a conflicting situation? By what criteria can we make a rational decision, and would that decision apply to all shiftworkers in all industries, or is there one best schedule for each industry? As it turns out, the **best schedule is a site specific phenomenon**, driven by the site specific operational needs, by the biological impact of different shift permutations, and by the family/social needs and lifestyle preferences of the unique, demographics of one's workforce. To paraphrase Billy Crystal..."there are 9 million stories in the naked city, and every one of them is a shiftworker with a different need for accommodation"! That's why mandated, negotiated or arbitrarily selected schedules often have negative outcomes. That's why the shiftworkers not only need to be involved in every step of the scheduling change process, but they need to be educated as to all of the possibilities and of their pros and cons in order to be able to make informed decisions, rather than emotional and irrational ones. Thus, in the final analysis, **the best schedule will be the one that best satisfies the operational requirements, that is the most physiologically healthy and safe, and that best aligns with the personal needs and preferences for the majority of the workforce.**

Thus, the key to determining the best schedule, improving morale, and reducing site costs is to help the individuals in the workforce to make informed value judgments as to what they truly want and need (within a square of operational parameters to ensure the integrity of the business), and then to build healthy and safe schedules around those needs…rather than trying to force-fit a set of arbitrarily determined schedules on top of a

workforce that has widely divergent preferences. The net result is a win-win for both the business and its employees.

Figure 1. Biocompatible Schedule Design Criteria (Physiological Health and Safety)

Design Criteria	Weighted Scale
Forward rotation	15
Min sleep-wake transitions	15
Max rest-recovery days off	14
Slow rotation (or fixed)	14
Maximum 12-hour shift length	10
Min consecutive shifts	10
Periodic long breaks (3 days or more)	8
Return from losing breaks onto days	8
Max schedule pattern regularity	6
7:00-8:00am shift start time	Implementation Issue
Total	100

Figure 2. Health & Safety Schedule Analysis (for Schedule Biocompatibility)

Criteria	Weight Factor	Southern Swing	Northern Swing	2-2-3 2 Week Rota	2-2-3 Fixed	3 x 3 - 1 Wk Rota	4 x 4 - 1 Wk Rota	4 x 4 Fixed	Dupont	Modified Dupont
Forward rotation	15	0	15	15	15	15	15	15	15	15
Min sleep/wake transitions	15	15	15	7.5	7.5	15	15	7.5	15	15
Min consecutive shifts	14	0	0	14	14	14	10.5	10.5	12.25	12.25
Max rest/recovery days	14	0	0	7.5	7.5	14	14	14	10.5	14
Max 12-hour shift length	10	10	10	10	10	10	10	10	10	10
Slow rotation	10	0	0	10	5	10	10	7.5	7.5	10
Periodic long breaks (3+)	8	8	8	8	8	8	8	8	8	8
Long breaks onto days	8	8	8	4	4	4	4	4	5.3	8
Max schedule pattern regularity	6	6	6	6	6	6	6	6	3	3
7:00-8:00am start time	-	-	-	-	-	-		-	-	-
Total biocompatibility	100	47	62	79	76.5	96	92.5	82.5	86.55	95.25

References

- A Spurgeon, JM Harrington, CL Cooper. Health and safety problems associated with long working hours: a review of the current position. Occup. Environ. Med. 54, 367-375. 1997.

- Akerstedt T, Torsvall L, Kecklund G, Knutsson A. The shift cycle and clinical indices of insomnia. In: Costa, G, Cesana G, Kogi K, Wedderburn A (eds.) Shiftwork: Health, sleep and performance. Peter Lang, Frankfurt. 421-426. 1990.

- Akerstedt T. Psychological and psychophysiological effects of shiftwork. Scand. J. Work Environ. Health. 16, 67-73. 1990.

- Akerstedt T. Work hours, sleepiness and the underlying mechanisms. J. Sleep Res. 4 Suppl. 2, 15-22. 1995.

- Barton J, Folkard, S. Advancing versus delaying shift systems. Ergonomics 35, 125-133. 1993.

- Bonjer FH. Temporal factors and physiological load. In: Measurements of man at work, Singleton WT, Fox JG and Whithfield T. (Eds.)Taylor and Francis, London. 1971.

- Circadian Technologies, Inc. Shiftwork Practices Survey. www.circadian.com

- Dembe AE, Erickson JB, Delbos RG, Banks SM. The impact of overtime and long work hours on occupational injuries and illnesses: new evidence from the United States. Occup. Environ Med. 62(9), 585. 2005.

- Folkard S, Totterdell P. Circadian variations in performance. Implications for abnormal work hours. International Symposium “Shiftwork and Job Demands”. Paris 10-14. 1994.

- Foret J, Lantin G. The sleep of train drivers: an example of the effects of irregular work schedules on sleep. In: WP Colquhoun (ed.) Aspects of Human Efficiency. The English Universities Press, London. 273-282. 1972.

- Gold DR, et al. Rotating shiftwork, sleep and accidents related to sleepiness in hospital nurses. Am. J. Publ. Health. 82, 1011-1014. 1992.

- Harma M et al. A controlled intervention study on the effects of a very rapidly forward rotating shift system on sleep-wakefulness and well-being among young and elderly shift workers. Int. J. Psychophysiol 59(1), 70-79. 2006.

- Harma M. Individual differences in tolerance to shiftwork: a review. Ergonomics 36 (1-3), 101-110. 1993.

- Harrington JM. Shift work and health. A critical review of the literature on working hours. Ann. Acad. Med. Singapore 23, 699-705. 1994.

- Hedden I, Grzech-Sukalo H, Nachreine4r F. Classification of shift rotas on ther basis of periodiv components. In: Costa, G, Cesana G, Kogi K, Wedderburn A (eds.) Shiftwork: Health, sleep and performance. Peter Lang, Frankfurt. 197-202. 1990.

- Ingre M, et al. Variation in sleepiness during early morning shifts: a mixed model approach to an experimental field study of train drivers. Chronobiol. Int. 21(6), 973-90. 2004.

- Jee Ng-A-Tham, Hk Thierry. An experimental change of the speed of rotation of the morning and evening shift. Ergonomics 36 (1-3), 51-57. 1993.

- JM Harrington. Shift work and health. A critical review of the literature on working hours. Ann. Acad. Med. Singapore 23, 699-705. 1994.

- Kecklund G, Akerstedt T. Effects of shifts on sleepiness and sleep duration. J. Sleep Res. 4 Suppl. 2, 47-50. 1995.

- Knauth P, Kieswetter E, Ottmann W, Karvonen MJ, Rutenfranz J. Time-budget studies of policemen in weekly or swiftly rotating shift systems. Appl. Ergon. 12, 247-252. 1983.

- Knauth P, Schonfelder E. Effects of a new shift system on the social life of shiftworkers. In: Costa, G, Cesana G, Kogi K, Wedderburn A (eds.) Shiftwork: Health, sleep and performance. Peter Lang, Frankfurt. 537-545. 1990.

- Knauth P. Changing schedules: shiftwork. Chronobiol. Int. 14(2), 159-171. 1997.

- Knauth P. Design of shiftwork systems. In: Shiftwork: problems and solutions, Colquhoun WP, Costa G, Folkard S, Knauth P (Eds.) Peter Lang, Frankfurt am Main. 1996.
- Knauth P. Speed and direction of rotation. J. Sleep Res. 4 Suppl. 2, 41-46. 1995.
- Knauth P. The design of shift systems. Ergonomics 36 (1-3), 15-28. 1993.
- Rosa RR et al. Intervention factors for promoting adjustment to nightwork and shiftwork. In: Shiftwork. AJ Scott (Ed.) Occupational Medicine 5(2), 391-416. 1990.
- RR Rosa. Extended workshifts and excessive fatigue. J. Sleep Res. 4 Suppl. 2, 51-56. 1995.
- Saito Y, Kogi K. Psychological conditions of working night and subsequent day shifts with short sleep hours between them. Ergonomics 21, 871. 1987.
- Samel A, Vejvoda M, Maass H. Sleep deficit and stress hormones in helicopter pilots on 7 day duty for emergency medical services. Aviat. Space Environ Med. 75(11), 935-40. 2004.
- Spurgeon A, Harrington JM, Cooper CL. Health and safety problems associated with long working hours: a review of the current position. Occup. Environ. Med. 54, 367-375. 1997.
- Tepas DI, Carvalhais AB. Sleep patterns of shiftworkers. Occup. Med. 5, 199-208. 1990.
- Totterdell P, Spelten E, Smith L, Barton J, Folkard S. Recovery from work shifts: how long does it take? J. Applied Psychol. 80 (1), 43-57. 1995.
- Tsaneva N, Nicolova R, Topalova M, Danev S. Changes in the organism of shift workers operating a day and night 12-hour schedule in carbon disulfide production. In: Costa, G, Cesana G, Kogi K, Wedderburn A (eds.) Shiftwork: Health, sleep and performance. Peter Lang, Frankfurt. 324-329. 1990.

