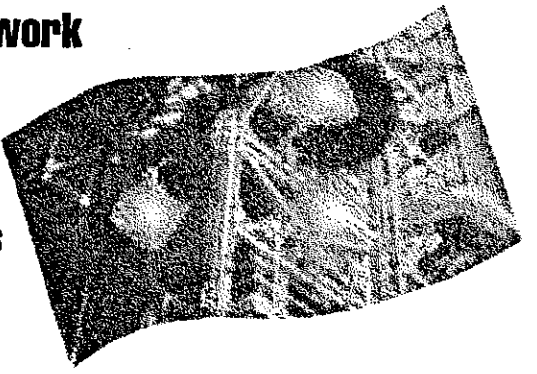
Effects of rotating 12-hour shiftwork on the health and safety of petroleum refinery operators

Phase 1 : Survey, assessment and shiftwork design considerations



ÉTUDES ET RECHERCHES

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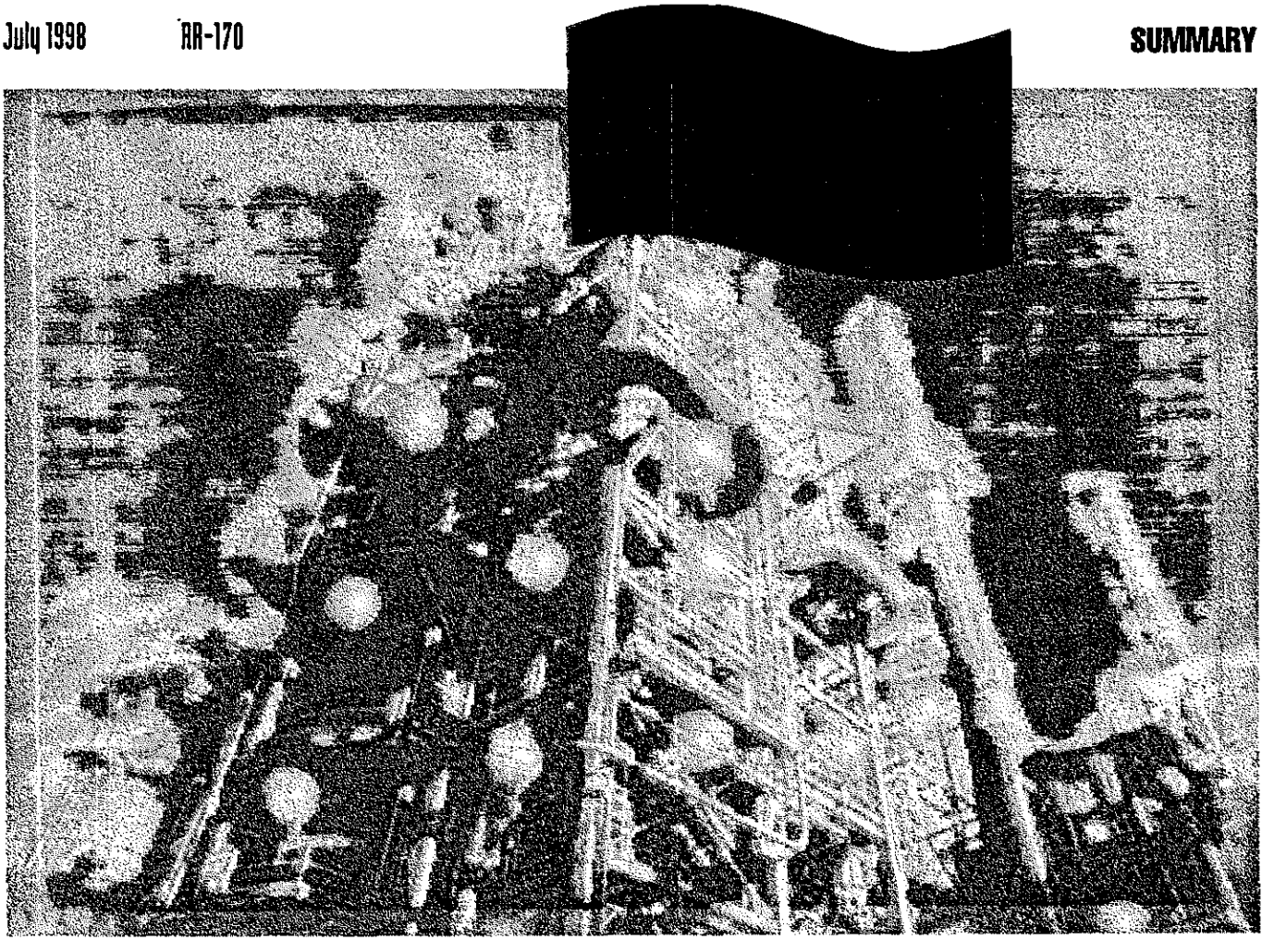
SUMMARY



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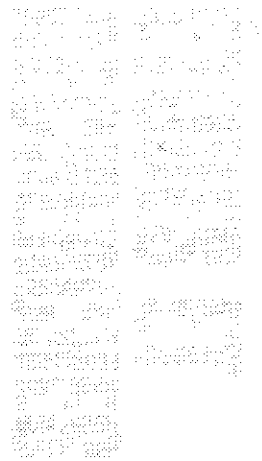

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SUMMARY

This study was financed by the IRSST. The conclusions and recommendations are those of the authors.

SUMMARY

Objectives: For the last 20 years, the work schedule for operators at a petroleum refinery has taken the form of rotating 12-hour shifts. Management and labour at this company, concerned about the need to know if this schedule should be modified or not, asked an interdisciplinary research team to conduct an initial survey of its effects.

Approach and methods: A convergent approach was adopted, based on the following sources of data: chrono-ergonomic observation, task analysis, questionnaires administered to operators and their spouses, interviews with former operators, discussions with supervisors, review of medical records, mortality data, absenteeism records, occupational accident reports, reports of serious incidents, and the difference between real and nominal work schedules. Foremost of the analytical methods employed were descriptive statistics and qualitative analyses. The final assessment was oriented along 7 axes, in keeping with the theoretical model: recognition of the unique nature of shift work, health, sleep and fatigue, workload, social and family life, job satisfaction, and safety/reliability.

Results: Among current shift workers, the most obvious effects of this schedule were sleep disturbances, sleep deficit and chronic fatigue, all of which were observable even when operators were working day shifts. Negative effects on health — in the form of digestive, cardiovascular, and psychological problems —were also observed. Although social and family life was disrupted, the disruption was less than that caused by a schedule consisting of 5-7 consecutive days of 8-hour shifts. The most marked negative effects of the schedule were observed among former shift workers. The main problems faced by operators at this time, however, are related to under-staffing, as much as the schedule. Reductions of the size of the workforce directly affect the work schedule by necessitating overtime and causing the real work schedule to differ from the nominal one so that the actual number of rest days is substantially reduced. Furthermore, by increasing workload during both day and night shifts, they also affect fatigue and reliability.

Conclusions: The results illustrate the difficulty in dissociating the effects of work schedule, age, and workload. The final assessment also highlights the effects of workload and schedule on health, sleep, fatigue, safety, work, and private life. The limitations placed on the size and replacement rate of the workforce and the elimination of reassignment to day shifts has prevented the selection process — the healthy worker effect — from playing its protective role. It is possible that operators still active 5 to 10 years hence will exhibit deteriorations in health, due to the practices of extending retirement age by five years, failing to hire new operators, and failing to allow transfers to permanent day shifts. The issues of overtime and the aging of operators should be discussed within the company, because of the problems they reveal and those they cause.

Recommendations: Operators and their social circle like the schedule, because of the abundant free time and high salary it affords. However, the problems identified in this study and the desire for change expressed by operators are so significant that it would be appropriate to consider modifying the schedule. The recommended modifications concern work organisation, prevention, research and the schedule itself. To facilitate the planning of work schedules, 23 practical guides covering subjects in the fields of time management and shift organisation, personnel management, and task organisation have been developed.

Structure of this report: This report is a summary of the detailed research report. Chapter 1 describes the projects' origins, company characteristics, work schedule, and operators' tasks. The theoretical framework, operating model, data collection methods, databases and analytical tools are summarised in Chapter 2. A summary of results and highlights of the final assessment are found in Chapter 3. Chapters 4 and 5 contain conclusions and general recommendations respectively. Appendix I is comprised of a bibliography, while company-specific recommendations, including 23 mini-guides for shiftwork redesign, are contained in Appendix II.

ACKNOWLEDGEMENTS

The refinery's director general, the union's president and the company's training supervisor deserve the credit for having initiated this research. Their preoccupation with the health of their operators and questions about the relation between health and shift work drove them to contact the IRSST. This report is the fruit of their efforts and of ours, almost five years after that initial contact.

It is impossible to thank all our informants (both workers and management) individually, as we guaranteed we would safeguard the anonymity and confidentiality of the data they provided. However, we would like to thank them all — particularly the 93 operators who completed a questionnaire or agreed to be interviewed, and gave us access to their confidential medical records — for their patience. The spouses of participating operators provided useful data in several areas, including social and family life, and their collaboration is greatly appreciated. We would like to especially thank the two groups of operators who graciously agreed to be the object of chrono-ergonomic observations: thank you for your warm welcome, the enthusiasm with which you explained your work to us in depth, and the quality of information you provided us with. The interviews with management, union and health service representatives, and supervisors provided us with valuable information on the management of work schedules and tasks, as well as on health and safety prevention activities. The personnel of the human resources department helped to reconstruct the job histories of former employees. We dedicate this research report to all these people, both management and operators, who will be the first to read, and hopefully, use it.

We would also like to thank the members of the bipartite research advisory committee and the various groups they represent — refinery management, the union, supervisors, health service and training service — for their stimulating support. It should be noted that the representative of the training service also acted as the ongoing contact between the refinery and the researchers. It would be no exaggeration to state that without his ongoing efforts to promote the project and facilitate our access to people and data, this study would have been simply impossible. The operators who volunteered to act as ambassadors at their sites have our gratitude. In addition to the indispensable support of the executive and of union representatives, they were the direct contact between researchers and operators.

The project's funding was provided by the IRSST, with a contribution from the company. We would like to thank the IRSST's director general, its director of Operations and the director of its Quality Management and Special Projects Programme, whose encouragement and help lead this project to its successful conclusion.

THE RESEARCH TEAM

The contribution of the researchers to this interdisciplinary study took many forms, depending on the stage of the project. The success of several of these stages depended on teamwork, e.g. the meetings with the Advisory Committee and the working sessions devoted to designing and implementing the methodology, integrating the analyses, and deciding the report's content and format. In addition to these group activities, the members of the team worked in groups of two or three on different facets of the survey, reflecting their skills and level of responsibility in the project.

Under the scientific leadership of **Yvon Quéinnec** (D. État Sc. psychophysiology, D. 3e Cycle Sc. entomology, L. Sc. biology; professor des universités 1° Classe, Université de Toulouse 2, director of the Work and Cognition Laboratory at the URA 1840 of France's National Scientific Research Centre) and of **Denise Granger** (Ph. D. and M.A. sociology, B.A. social sciences, director of the IRSST's Work Organisation Programme), **Madeleine Bourdouxhe** (M.Sc. demography, B. Sc. anthropology, G. physiotherapy, scientific professional in the IRSST's Work Organisation Programme) developed the research protocol, produced the materials required for the field protocol, assumed responsibility for data collection and the analysis of 10 of the 11 data sources, and wrote the detailed and summary reports.

Raymond Baril (Ph. D. and M. Sc. anthropology, specialisation in ethnology, B. Sc. anthropology, researcher in the IRSST's Work Organisation Programme) designed the methodology for the interviews with former shift workers, which he conducted with **Micheline Levy**. He also analysed the content of the interviews with former shift workers concerning the advantages and disadvantages of the work schedule, and hazards and duration of work as an operator, and made suggestions concerning the integration of the analyses and the detailed report.

Using the experimental design developed by Yvon Quéinnec, and with the help of Madeleine Bourdouxhe, **Serge Guertin** (B. Sc. A. industrial engineering, D.E.S.T. ergonomics, engineer, director of Ergo-Norme Inc.), conducted pre-tests, real-time chrono-ergonomic observations, and multi-site analyses of operators' work. His suggestions concerning ergonomics and his knowledge of workplaces helped improve the content of the questionnaires and the final version of the detailed report.

Paul Massicotte (B. Sc. linguistics, scientific professional in the IRSST's Work Organisation Programme), with the help of **François Lemay** (M. Sc. and B. Sc. mathematics, scientific professional in the IRSST's Customer Service Programme) and **Christian Casanova** (M. Sc. Work and Cognition Laboratory, Université de Toulouse) coded and analysed the data from several sources. **Micheline Levy** (research and administration technician in the IRSST's Work Organization Programme) helped collect and enter data from some of the sources, and played a key role in the publication of the questionnaires and the various versions of the detailed report.

Marcel Simard (Ph. D., M. Sc., B. Sc. sociology, professor in the Université de Montréal's School of Industrial Relations) collaborated on the preparation of the initial research protocol and participated in initial meetings between the researchers, management, and labour. He subsequently read, commented on and criticized successive versions of the questionnaires and detailed report.

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1 INTRODUCTION

1.1 The project's origins

Rotating 12-hour shifts have been adopted by an increasing number of companies engaged in continuous production or services. These include companies in the pulp and paper, petrochemical, metallurgical, mining, manufacturing, transportation, emergency medicine and ambulance, nursing, police services, firefighting, mechanical maintenance, cleaning, and retail sectors. Extended work shifts have been introduced even when their long-term consequences are unknown. This type of work organisation is very popular with workers since the extension of the work day (and night) is compensated for by a reduction of the work week and by more rest periods, days off and free week-ends. In light of the absence of adequate and precise data on this question, management and labour of a Montreal-area petroleum refinery requested the IRSST to undertake a study in order to shed light on the effects of rotating 12-hour shifts on operators responsible for the monitoring and control of production processes.

The main objective of this study was to review the state of affairs after 20 years of rotating 12-hour shifts in this refinery, analyse the relation between the components of the final assessment and certain problematic aspects of the management of work time, and recommend solutions and preventive measures. These objectives dictated the research's nature and main characteristics, i.e. a wide-ranging interdisciplinary descriptive field study, drawing on multiple sources of archival data and, above all, on observation of the work of operators working 12-hour shifts and interviews with operators, ex-operators, operators' spouses, and management — all of whom must live with the consequences of this type of work.

1.2 Presentation: The company, the schedule, tasks, supervision

1.2.1 The refinery

The refinery was built in 1932 and processes an average of 125 000 to 130 000 barrels of petroleum each day. The source of the petroleum depends on current market prices. The refinery produces light oils, automobile and aeroplane fuels, asphalt, and lubricants. Production and service operations are spread out over eight sites. Apart from management, laboratory personnel, and office staff, plant personnel includes:

- maintenance personnel, accounting for slightly more than 100 workers in specialized trades, e.g. pipe-fitters, welders, mechanics, and electricians. These work a non-rotating 8-hour day shift, 5 days per week. The work is physically demanding and often performed outdoors. Their mean age is 47 years.

- operators, the subjects of the present study. There are 180 operators[1], responsible for the monitoring and control of refinery operations, spread out over 8 sites. Approximately 160 operators work rotating 12-hour shifts and eam a mean annual salary of $60 000, excluding overtime (paid as double-time). Their mean age is 43 years.

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[1] At the height of production, between 1975 and 1980, there were over 250 operators and over 200 maintenance workers.

In addition, the company regularly employs sub-contractors for certain specialized tasks, especially during major equipment shut-downs. In 1996, the total number of workers present simultaneously on the site during planned shut-downs was almost 1 200, i.e. 8-10 times the size of the normal workforce.

1.2.2 Operators' work schedule

Operators work on any one of four rotating teams. At any given site, the four teams are generally the same size, this size dictated by the number of production units requiring monitoring. In theory, operators work rotating 12-hour shifts 37½ hours per week, for an annual total of 1 940 hours. Day shifts begin at 06:30 and night shifts begin at 18:30.

The schedule in place for over 20 years is based on a 54-day shift cycle, with rotation every 3 days (3 Days - 3 Off - 3 Days - 3 Off - 3 Nights - 3 Off- 3 Nights - 3 Off - 3 Days ..., etc.) and one free weekend out of every three. In 1983, a rest period of 9 days was introduced at the end of the cycle. It should be emphasized that the real work schedule differs significantly from this nominal schedule. For example, the real number of hours worked annually exceeds 2 200 hours, as noted below. These differences were so large that it was necessary to reconsider their contribution and treat them as principal components of the final assessment.

1.2.3 The control of continuous production processes

As technology developed and more centralised control and action systems were implemented, the extent to which operators acted directly on products diminished. From that point on, their work became oriented towards the anticipation and prevention of system malfunctions. Practically, this consisted of detecting and correcting changes likely to affect the process or product in such a way as to hinder the attainment of optimal production goals. To accomplish this, operator teams use means and work strategies tailored to individuals' experience and fatigue, and to factors such as the time of day, state of the production facilities in the process unit and in units downstream and upstream from it, weather, and state of the products and materials. The coordination of tasks or activities this requires itself depends on the acquisition of minimum levels of common knowledge or reference points. For this reason, great importance is given to communications in the analysis of work (Quéinnec and de Terssac, 1981; Daniellou, 1986).

1.2.4 The characteristics of the refinery operators' work

Each shift crew has a "operator in charge", also known as the "lead operator", responsible for the overall monitoring of site operations. This operator is in charge of the control room and provides remote support for other operators when they are out of the control room, guiding them by radio through their rounds. The other operators are assigned to one or two process units, depending on the site and shift. A shift crew is composed for up to 7 operators, with assignments rotated weekly on the basis of operators' qualifications. At each shift change-over, lead and unit operators wait their opposite numbers and give them an oral report on the state of the processes and the actions taken to correct malfunctions.

Operators divide their time between work in the control room (60% of their time on average, with great inter-site, diurnal and individual variation) and work outdoors (40% on average). A recent agreement between management and labour has led to the introduction of a new career programme known as "Progression" whereby operators rotate through the position of lead operator on a voluntary basis and perform related tasks (maintenance, training, tasks related to the optimization of production, safety, and environmental protection, etc.), in non-rotating day shifts over a 54-day cycle, with a 50-day training period for new tasks, also on a non-rotating day shift.

- *Control-room work*

The refining process is computerized and work primarily consists of monitoring computer screens on which production information is displayed. From the control room, operators also control and modify system operation and monitor visual and acoustic alarms. At least one operator is always in the control room while the others perform their rounds. Control-room work entails a significant mental workload, due to its high reliance on memory (primarily for the recall of the content of the many computer screens displayed, but also for the memorisation of parameters observed during previous verifications), the need to construct a mental picture of system trends as the shift progresses, and, especially, the constant extrapolation of information displayed on the screen to actual field operations.

- *Outside the control room, operators perform many tasks*

This includes routine inspection rounds during which they gather information that helps them make decisions and take actions in their operations units, or confirms their decisions and actions. These rounds are distributed throughout the shift, with a main round at the beginning of the shift, a major one at its end, and several secondary ones in between. During their inspection rounds, operators walk through the outdoor facilities of their units and :

- evaluate the state and operating conditions of the main equipment
- check for leaks and fire hazards
- identify or confirm selected parameters displayed on control room screens (e.g. valve openings, level indicators)
- perform corrective measures (e.g. modify set-points, perform purges, check products, clean burners).

These activities draw heavily on operators' sensory and cognitive capacities. The sensory functions called upon include touch (vibration, product viscosity), temperature perception (pipe temperature), hearing (noise and vibration from motors, pumps, fans, compressors and duct-work), smell (product odour, gas leaks) and, above all, sight (level indicators, gauges, dials, steam, gas or ice trails, glass containers, metal rods, product colour, flame colour and direction, duct-work alignment, state of valves, reservoir mixing). Memory is the most important cognitive function operators rely on during the inspection rounds, since there is an impressive array of parameters whose temporal evolution and consistency with the control-room display must be checked.

The inspection rounds also require physical exertion, due to the stresses of weather, climbing, work in cramped spaces, and the force required to open or close valves. There are also significant safety hazards, and the control and monitoring of outdoor facilities exposes operators to explosions, fires, poisoning, leaks of gases and scalding-hot steam, splashes of toxic or burning liquids and falls.

In addition to their inspection of outdoor installations, operators are also responsible for minor emergency repairs, product sampling and verification, verifying check-lists, and ensuring equipment safety prior to maintenance activities

During shut-downs and start-ups (the stopping — usually planned — of a unit's systems for the purposes of verification, maintenance, or repair; it should be noted that the other units, both on the same site and on other sites, continue to function normally during these periods, thanks to short-circuiting of the shut-down unit), operators are also responsible for stopping and starting the units, as well as helping workers involved in the shut-down.

1.2.5 Supervision

Each production site has a supervisor, known as the "day supervisor", who is responsible for the technical aspects of production. These technical supervisors work a non-rotating day shift 5 days per week, and are the link between operators, engineers, and maintenance workers. They plan unit shut-downs and maintenance, analyse and diagnose problems, and propose solutions. Their responsibilities include establishing work priorities, environmental protection, and operational safety, and planning and managing operating budgets.

Each shift also has two "shift supervisors" — former operators promoted to the ranks of management, whose principal responsibility is personnel management. These supervisors are jointly responsible for supervising operators throughout the refinery and are present throughout the shift. Their responsibilities change however when there are no day supervisors: between 16:00 and 08:00 during the week, and at all times on weekends, holidays and vacations. During these periods, they help operators maintain production, and are responsible for equipment supply, the safety of operations, and implementing emergency measures in case of a major incident.

2 THEORETICAL MODEL, OPERATIONAL MODEL, AND METHODOLOGY

2.1 Brief review of the literature on shift work

The vast majority of research on shift work has examined 8-hour shifts. These studies remain relevant to the study of 12-hour shifts however, as they provide a foundation for the development of a theoretical model. The detailed research report includes a detailed review of this question, as well as a thematic bibliography of some 360 sources.

The structure and functions of human biology exhibit temporal variations, e.g. the circadian variation in body temperature. These rhythms control human physiology and influence all human activities, especially work. For example, reaction time is the slowest and errors, memory lapses, attention deficits, and serious incidents more frequent when body temperature is at its lowest (Folkard and Monk, 1979). Shift work in general, and night work in particular, challenges biology, as it forces workers to be active and alert precisely when their body is at its lowest ebb, and to try to sleep when their physiological activity is at its most intense.

The inversion of biological rhythms during night shifts is never complete, even after prolonged periods of night work. The body's attempts to maintain high levels of activity at inappropriate times and its ineffectual attempts to adapt to a new rhythm exact a high toll. *Shift workers are thus in conflict not only with their biological clock but also with that of their social and family circle* (Quéinnec, Maury and Miquel, 1992). This conflict has consequences for health, work, and private life.

2.1.1 The health of shift workers

There are no recognized associations between specific occupational diseases and shift work. However, the "shift worker syndrome" — whose symptoms are variable but usually include disorders of sleep, mood and affect, and the digestive, endocrine, and cardiovascular systems — is being increasingly reported in the literature (Carpentier and Casamian, 1977; Harrington, 1978 and 1994; La Dou, 1982; Åkertsedt et al., 1984; Colligan and Tepas, 1986; Kogi, 1991 and 1996; Costa, 1996). The age-related deterioration of health is more rapid in shift workers than in others, particularly after the age of 35-40 years. However, because of the selection bias, the effects of shift work are most clearly seen among former shift workers. Conversely, workers better able to tolerate shift-work-related stresses exhibit better health than most of their colleagues, including those who have only worked permanent day shifts. This phenomenon is called "healthy worker effect" (Aaonsen, 1959; Marquie and Quéinnec, 1990; Quéinnec, Maury and Miquel, 1992; Tepas et al., 1993; Volkoff in Grossin et al., 1993; Quéinnec, Gadbois and Prêteur, 1995; Laville, 1995; Brugère et al., 1995; De Zwart and Meijman, 1996).

2.1.2 Shift work and sleep

Shift work is unanimously held to cause sleep disturbances. These disturbances are in fact the first symptom of desynchronized circadian rhythms among workers assigned to rotating shifts, and are one of the causes of the health problems and work difficulties suffered by shift workers. Estimates of the proportion of shift workers who suffer from sleep disorders range from 25-30% to 60-70% (Rutenfranz et al., 1977; Andlauer and Lille, 1982). In many cases both the quantity and the quality

of sleep suffers. The daytime sleep of night-shift workers is 2 hours shorter on average than their normal nocturnal sleep. Not only do shift workers not sleep enough, they don't sleep well: they have difficulty falling asleep, their sleep is agitated, and they wake up frequently or too early. *"This dysomnia also causes a non-specific pathology, and in many workers, digestive tract disorders."* (Andlauer and Lille, 1982). There is consensus that all the stages of sleep are necessary and it is therefore noteworthy that work on rotating shifts disrupts their organisation and distribution. The meagre quantity and poor quality of sleep have important effects, particularly on health, mood, wakefulness, sense of well-being, alertness, and performance. The degradation of performance is particularly obvious for tasks with a high mental workload and which require attention and alertness. *"A certain cost has to be paid when people short-change themselves on their sleep; the cost is to be paid in terms of mood, activation and well-being, and also in the ability to perform, particularly in tasks that are boring and monotonous (e.g. driving). Chronic partial sleep deprivation can lead to symptoms of malaise and fatigue which can significantly impair the productivity and quality of life of the individual."* (Monk and Folkard, 1992).

2.1.3 The social and family life of shift workers

The degradation of communication in family and social life is the most frequent complaint of shift workers (Pierce et al., 1989; Smith and Folkard, 1993). The periods of availability which rotating shifts accord shift workers are out of phase with most people's social calendar, and this discrepancy disrupts shift workers' private lives (Quéinnec, Maury and Miquel, 1992). The disruption of family life by non-traditional work schedules is in fact one of the most common and serious complaints of workers and their social circle (Bunnage, 1984). Rotating shifts often oblige workers to either work or recover from work at times that are extremely important for family life. On their days off following night-shifts, shift workers spend considerable time recovering from their fatigue and are often in bad moods, which reduces the quantity and quality of time available for family life. Shift workers report feeling that they don't have enough time for their families and friends and are unable to discharge their family and conjugal responsibilities (Nachreiner and Rutenfranz, 1975).

Some researchers have suggested that these problems worsen over time and exert a cumulative effect on conjugal and family relations, as workers become unable to provide their spouses with sufficient companionship, protection, support, sexual satisfaction, and intimacy (Mott et al., 1965). On the basis of several American and European surveys, Gadbois describes the effects of shift work on the quality of life of shift workers and their circle thus: *"they are often only available at times of day (or of the week) when many activities are impossible or can only be accomplished under inappropriate conditions... shift workers often accord more importance to these family and social disruptions than to physiological consequences such as fatigue, sleep disturbances, and health problems."* (Gadbois, in Grossin et al, 1993).There are few studies examining the impact of work schedules on the partners of shift workers, but those that have been reported reveal a degradation of family life, particularly with regard to weekend leisure activities (Banks, 1956). Spouses report being disturbed with shift work, feeling "unhappy" and dissatisfied, having their lives disrupted (Smith and Folkard, 1993) and their sleep shortened (Dekker et al., 1993).

2.1.4 Operator safety and the reliability of operations under a rotating shift schedule

System reliability and personal safety are a concern in operations relying on shift work, primarily because operators working the night shift must remain alert when their body is at its lowest level of

performance and wakefulness: *"circadian rhythms affect psychophysiological functions, including some information-processing processes"* (Quéinnec, Maury and Miquel, 1992). As a result, performance of tasks with a high mental workload or great reliance on memory or reaction time decreases, and the rate of accidents, serious incidents, and assorted errors increases (Folkard and Monk, 1979, 1985; Monk and Folkard, 1992).

2.2 Extended work shifts — 12-hour shifts

Research on the effects of extended work shifts on health, safety, and performance falls into three categories: laboratory studies on sleep, field studies, and analyses of reports of accidents and serous incidents (Duchon and Smith, 1993). Although extended work shifts are suspected of exerting multidimensional effects on performance, health, and biological, social, and psychological factors, most studies have focussed on physiological effects and psychomotor performance (Rosa et al., 1986, 1988, 1989, 1993; Duchon and Smith, 1993; Moore-Ede, 1993), with studies emphasising social aspects or health being much rarer (Harrington, 1978, 1994; Walker, 1985; Scott and La Dou, 1990; Tucker et al., 1996). Thus, practically no experimental field studies have directly measured the effects of extended work shifts on all of the various aspects of workers' lives, including health, physiology, sleep, fatigue, psychomotor performance, psychological well-being, and family and social life. However, other types of research are relevant, and can provide partial responses to these questions. Since the duration of work is obviously the primary factor of interest in assessing the effects of rotating 12-hour shifts on operators' physiology and performance, studies of its effects on fatigue, performance, and accidents are particularly useful, even if reported in settings other than 12-hour shifts. Some studies have reported that prolonged day or night work involving sustained physical effort or constant alertness may, under certain conditions (e.g. overtime work), increase operator fatigue, diminish performance, compromise the safety of operators and of people for whom they are responsible, and affect production (Moore-Ede, 1993; see also the very complete review of the issue of safety and prolonged work shifts by Duchon and Smith 1993).

When comparing rotating 8-hour and 12-hour shifts, it should be recalled that "compressed" schedules (12 hours, 3 days) not only extend the work shift but also shorten the work week. The following points must therefore be taken into account when assessing workers' tolerance of one or the other of the schedules (Tepas, 1985):

- Prolonged work shifts may significantly affect performance and safety. Night-shift workers have been reported to exhibit a 5% decrease in work capacity (Wojtczak-Jaroszowa, 1977) and an even greater decrement has been reported among workers assigned to 12-hour shifts, due to an increased workload (Bonnet, 1990). Overall, 12-hour shifts may be expected to result in decreased performance and safety, although this will depend greatly on the type of work.

- Shorter work weeks result in less disruption of circadian rhythms and less cumulative fatigue (Wilkinson et al., 1989).

- The reduction of rest time between work days has a definite negative effect on recovery from fatigue and the potential duration of sleep.

- 12-hour shifts are associated with more days off, which has beneficial consequences on recovery from fatigue and sleep deficits.

- 12-hour shifts require a more rapid shift rotation, which in turn has advantages in terms of adaptation of circadian rhythms, especially those controlling sleep (Knauth and Rutenfranz, 1982).

- Workers assigned to 12-hour shifts work longer but less frequently. This facilitates social and family life, and leisure activities. Furthermore, time and financial costs of transportation are diminished.

In summary, a review of scientific articles dealing specifically with 12-hour rotating shifts allows the following conclusions to be drawn:

- This type of schedule causes cumulative negative effects typical of rotating shifts, and night shifts, and extended work days.

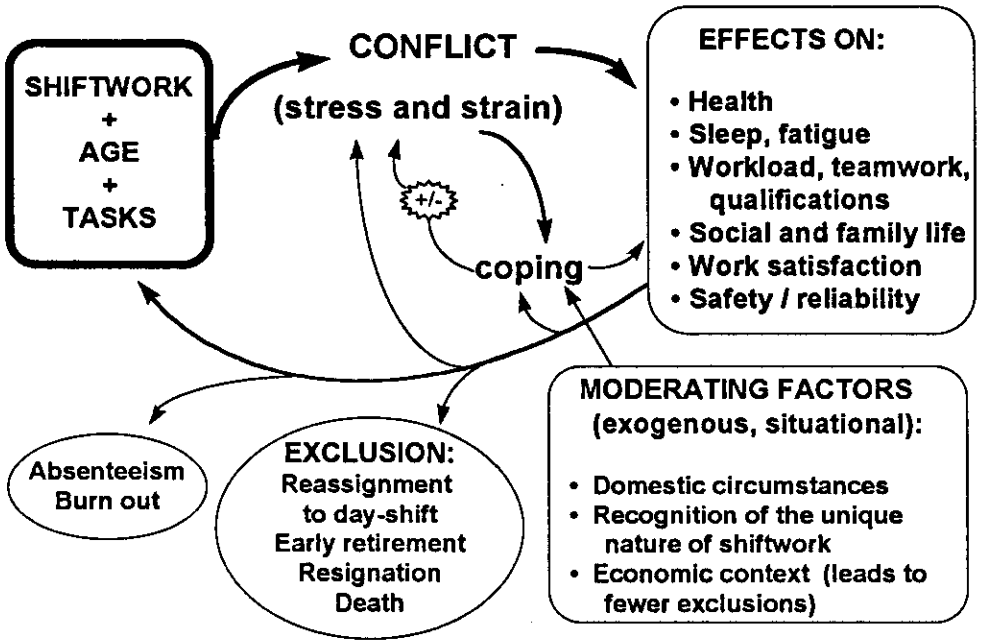
- This type of schedule affects physical health (sleep, digestion, fatigue), emotional health (mood, motivation, consumption of sleeping medication), work performance (alertness), and social and family life, although these effects may be either positive or negative.

- The effects of this type of schedule depend on the task and operators' age and experience with the schedule.

- The net effect on health is a compromise between the advantages associated with a shortened work week and the disadvantages associated with a extended work day and — to an even greater degree — extended work night.

- 12-hour schedules have been reported to have both positive and negative effects on workers' health and the safety of operations.

Researchers therefore conclude that industries in which alertness, public safety, and the risk of accidents, serious incidents, and potential health effects are preoccupations would be well advised to evaluate the effects of this type of schedule and apply measures designed to palliate their main disadvantages (Kelly and Schneider, 1982; Duchon and Smith, 1993; Moore-Ede, 1993; Knauth et al., 1995).



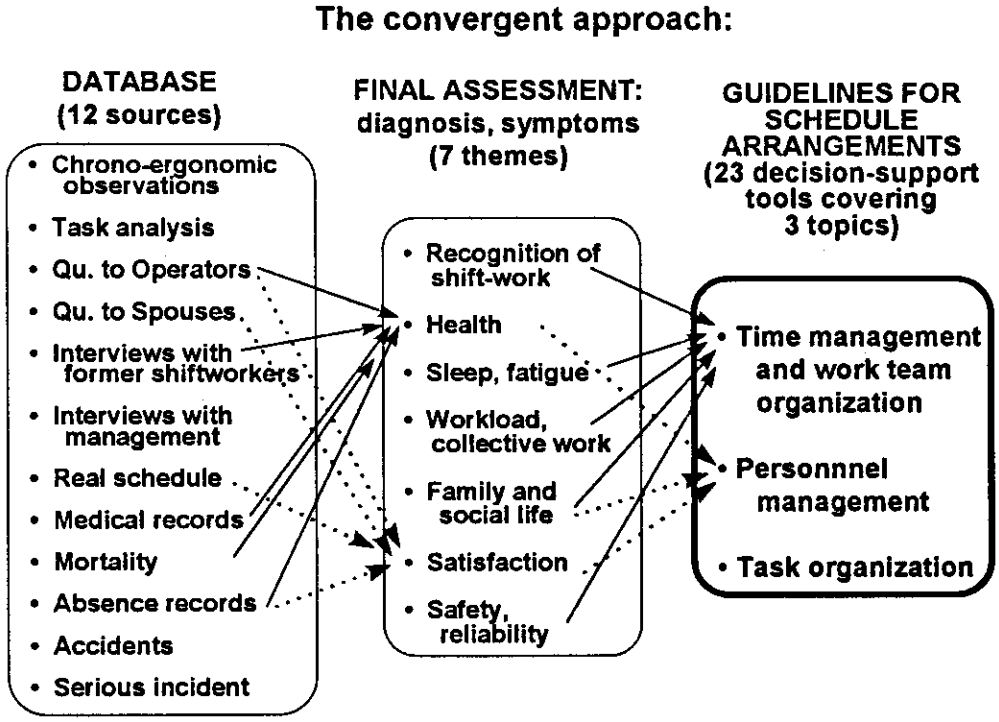


Figure 1 Theoretical model and application: the convergent approach

2.3 Development of a theoretical model and rationale underlying the method

Shiftwork ***conflicts*** with biological rhythms and social and family life, and this conflict causes stress and strain among workers (Colquhoun and Rutenfranz, 1980; Quéinnec, Maury and Miquel, 1992; Folkard, 1993). Human beings are subject to temporal constraints, and cannot do anything they want at any time they want or in any state they are in without paying a price: in practice, it is not only work schedule that determines the net effect, but rather the ***schedule + task + age interaction*** (Figure1).

This has consequences on health, sleep, fatigue, workload, teamwork, individual qualifications, social and family life, work satisfaction, reliability, and productivity. The magnitude of these effects depends on individual coping mechanisms that are themselves shaped by both individual physical, mental, and psychological factors, and external factors, particularly family status, the nature of the domestic environment, the extent to which the unique nature of shift work is recognized by the company and the workers' social circle, and economic conditions. All these factors influence an operator's decision to continue working shifts. Workers unable to cope with the stress of shift work will try to remove themselves from it, either temporarily or permanently. These attempts may take several forms, including repeated absences, burnout, requests for reassignment to day shifts, quitting, early retirement, and even death.

The specific effects of 12-hour shifts are a compromise between the advantages of a shortened workweek and the disadvantages of long shifts, especially at night (Tepas, 1985; Duchon and Smith, 1993; Rosa and Bonnet, 1993; Knauth et al., 1995; Tucker, Barton and Folkard, 1996).

The present study's research methodology was designed to provide responses to questions derived from the theoretical model's underlying hypotheses, i.e the existence of observable effects of shiftwork on health, sleep, work, social and family life, work satisfaction, safety, reliability, requests for reassignment to day shifts, absences, etc. The analytical approach was based on convergence: each of the 12 sources of data contributes to the final analysis in each of 7 themes. The results of these analyses converge towards 23 tools for improvements in 3 main areas: time management, personnel management, and task organisation (Figure 1).

2.4 Methodology

2.4.1 Objectives and hypotheses

2.4.1a Research objectives

The general objective of the study was to elucidate the long-term effects of this type of schedule. The secondary objectives were to develop and test a new approach to schedule and task redesign that would allow management and operators, should they decide that such redesign was indicated, to minimize the negative effects of the schedule but maintain as many of the advantages of the current design as possible.

The specific objectives were to:

- Evaluate the situation in detail. Analyse the positive and negative effects of rotating 12-hour shifts on 7 sentinel parameters (extent to which the unique nature of shift work is recognized,

health, sleep, workload and teamwork, social and family life, job satisfaction and desire for change, and reliability and safety), and determine both the severity of the problems associated with this type of schedule and the need for change.

- Analyse the point of view of people assigned to this schedule, and its variation as a function of status or occupation (current shift worker, former shift worker, spouse, supervisor, management), and demographic characteristics (age, marital status, experience in the job and with the schedule).

- Help internal bipartite bodies determine the need for future evaluative research concerning the implementation of new schedule and task arrangements, and identify the health and safety hazards, psycho-social problems, and management problems to be studied in this second phase.

2.4.1.b General research hypotheses

The six general research hypotheses underlying the analyses reflect the descriptive nature of this research.

To what extent...:

- does the schedule affect safety, health, work, private life, and management?
- do status and occupation (current shift workers, former shift workers, spouses, supervisors, management, maintenance personnel) and demographic characteristics (age, marital status, experience in the job and with the schedule) influence the problems experienced by individuals?
- are the health problems of operators currently working rotating 12-hour shifts significantly different from those of maintenance workers working 8-hour day shifts, 5 days per week, and of former shift workers?
- are the problems and symptoms current shift-work operators reported in the questionnaire qualitatively and quantitatively the same as those mentioned by former shift-work operators in interviews?
- are the constraints and stresses of shift work recognized by the company and operators' social circle? Is there any organisational openness and flexibility which would facilitate operators' strategies for coping with stress and choosing schedules?
- are operators satisfied with their current schedule? Is there any desire for change?

2.4.2 The convergent approach

Several hypotheses and questions were submitted to simultaneous analysis, using techniques drawn from classical ergonomics, chrono-ergonomics, sociology, ethnography, statistics, physiology, and the health sciences. Consider, for example, the analysis of fatigue and sleep disturbances, where we had to know if there was convergence in the results obtained from the following data sources:

- questionnaire administered to operators
- questionnaire administered to operators' spouses
- interviews with former shift workers
- interviews with management

- clinical analysis of work situations (peaks and dips of the circadian chrono-ergonomic cycle)
- synthetic ergonomic evaluation of workload (inter-site analysis)
- absenteeism records.

Surveys concerning shiftwork are very often based on only one source of data and one type of analysis. This, however, may be inadequate to confirm a hypothesis. On the contrary, conclusions based on convergent results obtained from data from multiple sources and points of view from different disciplines are much more credible: this is the power of convergent analysis.

Table 1 Database: 12 sources for the convergent analysis

Data sources	N	Response rate
Questionnaire administered to operators (current shift workers)	77/156	50%
Questionnaire administered to operators'spouses	51/66	77%
Interviews with former shift workers having left shift work within the last five years; 1 group interview and 16 individual interviews	16/17	94%
Chrono-ergonomic observation	6 days, 6 nights	n/a
On-site task analysis	8 sites	100%
Real vs nominal schedule	cycle of 54 days over 4 sites	50% of the refinery
Medical records over the last 10 years: current shift workers, non-rotating day-shift maintenance personnel and former shift workers	workers: 367 exams: 934 diagnoses: 1 534	85% of workers had medical examinations.
Absences: all medical absences among a sample of operators with an average of 17 years of experience	operators: 21 total years: 359 total absences: 959 absence days: 2 392	2 392 days = equivalent to the absence of all operators for 4 years
Accidents and incidents: medical records of a sample of operators with an average of 16.6 years of experience	operators: 66 total years worked: 1 099 accidents with no time lost: 223 accidents with time lost: 68 lost days: 449	accident records for 42% of operators
Interviews with management: unions, health service, supervisors, management	13	key positions in the organization
November 1995 production incident: final report containing an analysis of the incident; comments of three supervisors and one representative of the health and safety committee	1 incident report 4 resource individuals	individuals present during the incident or participated in the inquest
Mortality study of individuals with at least 5 years experience in the refinery (Thériault and Provencher, 1983)	period: 1928-1981 workers: 1 343 deaths: 171	93% of subjects were traced

2.4.3 Data sources, collection, processing, and analysis (Table 1)

The sources of data for this study are summarized in Table 1, and the objectives of using each one of them are briefly described in the following sections. Readers with a special interest in methodological issues will find further information on the type of data provided by each source, characteristics of the groups or samples studied, data collection tools and protocols, data processing and analysis in the detailed report and its appendices. It should be noted that the analyses were conducted so as to protect the confidentiality and anonymity of the respondents.

2.4.3.1- 2.4.3.2 Questionnaires administered to operators (current shift workers) and their spouses

The objective here was to collect information on the seven diagnostic themes directly from people actually coping with shift work. The questionnaire also provided information on operators' desire for schedule change, and, if that proved to be the case, the parameters they most wanted modified. The objective of the questionnaire administered to operators' spouses was to collect information on sleep and fatigue, social and family life, satisfaction, and the extent to which the specific nature of shift work was recognized. The responses were compared to those of current operators and of spouses of workers assigned to different work schedules.

50% of the 156 operators working 12-hour shifts and 77% of their spouses responded to the questionnaire inspired by the Standard Shiftwork Index (SSI) (Barton & al., 1993) and complemented with questions concerning the characteristics of operators' work. These questionnaires provided data for bivariate descriptive statistics, especially Pearson's correlations.

2.4.3.3 Interviews with former shift workers having left shift work within the last 5 years

One group interview and 16 one-hour semi-directed individual interviews were conducted with former shift workers transferred to conventional permanent day-shift work to identify any improvement or deterioration of their health, work, and private life since their work schedule changed. The interview technique used was a free adaptation of the Inventaire du Système des Activités (ISA). The content of the interview transcripts was analyzed with the Atlas program, a specialized computer-aided text-interpretation package. Interviewees' comments covered a wide range of topics. Some of these formed the basis for questions used in individual interviews, while others provided valuable information for the development of a coding scheme for content analysis or the creation of two-way links between the two mutually reinforcing data sources (group and individual interviews).

2.4.3.4 Chrono-ergonomic observations

The objective of chrono-ergonomic observations was to evaluate the circadian variation of monitoring activities in outdoor facilities, and confirm that the pattern of physical activity exhibits the same temporal variation (mirroring chronobiological curves, i.e. with a significant dip between 02:00 and 04:00 and a weaker one around 13:30) as previously observed with computer-display activities (Quéinnec and de Terssac, 1981; de Terssac, Quéinnec and Thon, 1983; Quéinnec, Maury and Miquel, 1990; Maury, Fezzani and Quéinnec, 1994; Andorre and Quéinnec, 1995). Chrono-ergonomic observations of 6 day- and 6 night shifts were conducted at one of eight sites. For each activity, graphs of the three-hour means, observed over six day- and six night shifts, were developed.

2.4.3.5 On-site task analysis

To identify needed modifications and redesign schedules, it was necessary to draw up an inventory of the leeway available for changes to control and monitoring tasks and operator activities. Data was collected during site visits to all the 8 sites, using classical ergonomics techniques, in order to characterize task requirements and conditions, with emphasis on time-related variations and differences between nominal and real work. At each site, data collection began with observation of operators performing their rounds and continued with an interview with the shift team. This analysis provided detailed information on the nature of the tasks, potential interfering or disruptive factors, and on each task's temporal variation and contribution to operator workload.

2.4.3.6 Real vs nominal schedule

Before evaluating the effects of the work schedule and proposing modifications to it, it was necessary to identify precisely which schedule was actually being followed, and especially, whether operators were actually taking advantage of mandated inter-shift rest periods. The calculation of an acceptable inter-shift rest period must take into account everything that affects the theoretical schedule. In practice, the duration of the real rest period is dictated by transportation time and disruptions such as replacements due to absences, shift prolongation (even doubling), and shut-downs. Any new schedule should anticipate the occurrence of absences and provide appropriate management strategies for their replacement.

The schedule of 78 operators (50% of sites) was studied over a 54-day cycle. Analysis of the differences between the nominal and real schedules were essential, especially for the purposes of estimating workload and establishing the extent to which prescribed inter-shift rest periods are followed. The differences should be interpreted as an early warning of malfunction, malaise, and excessive workload for the personnel assigned to a task. Meanwhile, these differences may also be positive, reflecting a certain flexibility in work organisation that allows the company and operators to tailor their schedule to their own needs, as well as an openness to eventual modifications.

2.4.3.7 Computerized medical records of day-shift maintenance personnel, and of former and current shift workers

There were two objectives in gathering this type of data. The first was to determine whether the diseases diagnosed by physicians during periodical medical examinations were similar to those reported by current shift workers in their questionnaire on the one hand and pathologies known to be related to shift work on the other. The second objective was to determine whether the *healthy worker effect* was operating in this group of workers, by comparing data on current shift workers, former shift workers, and workers never having worked shifts. In fact, literature reports indicate that current shift workers having successfully experienced shift work for a long time are kinds of empowered "survivors" in whom shift-work-related stresses exact a lesser physiological toll. Consequently, due to the selection bias, health effects should be most evident among former shift workers, current shift workers surprisingly often being in better health than most of their colleagues, including those who have only worked permanent day shifts.

The computerized medical records of 85% of all workers over the last 10 years were used to calculate the difference in age-specific rates (i.e. number of diagnosed diseases per worker)

between operators currently assigned to shift work, former shiftworkers, and maintenance workers with no experience of shiftwork. The categories of the pathologies were also studied.

2.4.3.8 Medical absences

Although analysis of medical absences may shed light on the diseases and accidents suffered by operators, the theoretical model used in this study considers these absences primarily as strategies to escape shift-work-related stresses: in other words, absenteeism is considered here as an index of schedule intolerance.

Work absences over 19 years were analyzed in a sample of 21 operators. The effect of shift, day of the week, day rank in the shift (day/night 1,2,3), medical cause, duration of absence, age, and experience on shiftwork was studied.

2.4.3.9 Accidents and incidents

One of the main concerns about extended work schedules is their effect on system reliability and operator safety. To assess the effect of work schedule on safety, an analysis of occupational accidents was clearly indicated. Accordingly, the frequency and severity of these accidents were measured, the profile of the most typical ones drawn up, and their circadian distribution analysed. The time-of-the-day distribution of 291 occupational accidents suffered by 66 operators between 1969 and 1995 was studied. Ascendant hierarchical classification was used to establish typical task-specific accident scenarios.

2.4.3.10 Interviews with management

The semi-directed interviews with management had two objectives: diagnosis and prediction. The point of view of management, and especially of supervisors, was taken into account in the analysis of each of the seven topics. Furthermore, with an eye to future modifications, it was essential to identify who makes decisions concerning task organization, schedules, workforce size and personnel management, and to establish the openness, or lack thereof, to changes in these areas.

Five members of management, the president of the union, and eight supervisors were asked about the advantages and disadvantages of 12-hour shifts for both workers and the company (all the supervisors were either currently assigned to shiftwork or had formerly been so). Decision-making topics were also discussed.

2.4.3.11 Analysis of a serious incident

The analysis of the impact of the work schedule on the reliability of process control systems would require a comprehensive analysis of all production incidents. Unfortunately, there is no electronic database containing systematic and standardised reports of incidents occuring in the refinery. It was therefore necessary to turn to other sources, both direct and indirect.

In the course of the interviews described above, management described a serious fire occurring in November 1995 at approximately 02:30 on a weekend night. The final analytical inquest report of the incident, written by a bipartite committee, was analyzed and three supervisors and a representative of the health and safety committee, either present during the incident or investigators for the inquest team, were interviewed over the telephone and they comments analyzed.

2.4.3.12 Mortality study of workers with at least 5 years experience in the refinery

Mortality studies are used to assess the long-term impact of hazards on workers' health. Few studies of the effect of shift work on mortality have been conducted, no doubt because of the significant methodological and interpretative challenges they present. We were fortunate enough to have the results of such a study available, however. At the beginning of the 1980s, following a disturbing number of deaths due to brain cancer over a short period among workers at this refinery, two McGill University researchers were asked to investigate the causes of death of employees, with special emphasis on the relation between certain contaminants and causes of deaths (Thériault and Provencher, 1983). Our objective in consulting this study was to determine whether there were any differences in the age at death between refinery workers and the rest of the population and between shift workers and other workers.

Epidemiologists from McGill University analyzed the causes of the 171 deaths which occurred among the 1 343 workers having worked at least 5 years at the refinery between 1928 and 1981. Information on employee mortality, stratified by age group and type of work, was extracted from this study to determine differences in the age at death.

3 SUMMARY OF RESULTS: HIGHLIGHTS

Certain results appear to be particularly significant, as they are consistently observed in the seven topics and are supported by several sources of data.

3.1 Summary of the final assessment

While it would be incorrect to describe the situation as catastrophic, there are problems that should and could be corrected. However, the most pressing problems are not where one would have expected to find them in a study on work schedules: the main problems are in fact due to understaffing and to overwork during day shifts. These factors influence work schedule itself (by necessitating overtime, introducing differences between nominal and real schedules, and reducing the actual number and duration of rest periods), operators' fatigue, safety, and system reliability.

This does not mean that there are no problems with the schedule. The most obvious problems in this respect are sleep disturbances and chronic fatigue, suffered by the operators even when working day shifts. The work schedule also causes digestive, cardiovascular, and psychological effects which are most noticeable among former shift workers. By desynchronizing operators with their social circle, the schedule also disrupts family and social life, although to a lesser extent, it appears, than rotating 8-hour shifts worked 5 or 7 days per week.

Operators like their work and want to retain their work schedule, primarily because of the free time and high pay it brings. However, there are a sufficient number of workers either wishing to transfer to day shifts or expressing a desire for schedule modifications to justify adjusting the schedule.

Finally, the whole question of overtime should be discussed within the company, by virtue of the problems it reveals and causes. The following sections present a summary of each of the global assessment's seven component topics.

3.1.1 Recognition of the specific nature of shift work

The specific needs and stresses of shift work are recognized to some extent by the company and by the operators' social circle. Thus, operators enjoy great latitude in choosing their days off and vacations ahead of time, and can easily exchange their schedule with their colleagues at their convenience. Furthermore, almost half of the operators interviewed did not hesitate to admit taking short rests during the night shift when this was possible, proof of management's sensitivity to the physiological stresses of the work schedule. At the same time, operators reported receiving solid support from their immediate circle, particularly from their spouses, who are very tolerant of the inconveniences caused by the work schedule.

Unfortunately, there are also signs of misunderstanding alongside these encouraging signs. For example, there are few references to shift work or night work in the discourse of day-to-day management, such as official documents and the collective agreement. Similarly, shift workers are not differentiated from regular day-shift workers, nor night work from regular day work, in personnel, health and safety records, at least not directly. This greatly hinders the assessment and follow-up of shift workers. In addition, there are no specific policies concerning the reassignment and retirement of shift workers.

Reductions in the size of the workforce have led to overwork at some positions. Hiring some more operators would relieve the pressure on aging or overworked operators at some sites, but this is proceeding at a painstakingly slow rate. Management decisions sometimes contradict the appearance of a sympathetic discourse. Examples of this include:

- the absence of management and technical personnel during night shifts and on weekends. As a result, operators feel insecure when serious incidents occur and management fails to understand the nature of shift work.
- the common practice of operators working 30 consecutive days or nights without a break during planned shut-downs
- the fact that the real work week is 40-50 hours on the average, compared to the nominal duration of 37⅓ hours
- the short notice of changes to schedules or teams
- the sometimes unsympathetic attitude towards short-term medical absences
- the start up of equipment during weekends or at night, when technical personnel is unavailable on the site to provide support for operators in case of problems
- the closing of the cafeteria and the health service at night and on weekends
- the corporate culture's emphasis on non-rotating day-shift workers.

On the one hand, there are several signs of a willingness to recognize the specific needs of shift workers. For example, operators enjoy great flexibility in organizing their schedule to best suit their needs. Evidence of this includes the (high) frequency with which operators exchange their schedules for personal reasons and the choice they have of receiving compensation for holidays worked in the form of either double-time pay or days off which can be accumulated and taken at their convenience (Table 2).

Table 2 Real schedule : Number of schedule exchanges and days taken from the accumulated holidays bank, by shift (half the 8 sites of the refinery, N = 78 operators, over one 54-day cycle, from 95-12-29 until 96-02-20)

Shift	Number of schedule exchanges	Number of absences for days taken from the accumulated holidays bank
DAY	7	84
NIGHT	10	116
TOTAL	17	200

On the other hand, examination of the real schedule reveals that much overtime work is occasioned by replacement of operators absent for medical reasons or transferred from their normal team to other activities such as special projects, secondary tasks, training, or other tasks related to the manner in which work is organized. Although these two types of absence account for practically identical amounts of overtime (Table 3), efforts to reduce overtime costs focus primarily on medical absences. Production imperatives conflict thus with the recognition granted to shift-work-related stresses.

Table 3 Real schedule : Number of overtime periods by reason, and by shift (half the 8 sites of the refinery, N = 78 operators, over one 54-day cycle, from 95-12-29 until 96-02-20)

Shift	Number of 12-hour overtime periods, by reason						
	activities requested by the company (projects, training)		replacements for medical absences		other reasons		Total
DAY	46	(59 %)	20	(26 %)	12	(15 %)	78
NIGHT	17	(26,5 %)	30	(47 %)	17	(26,5 %)	64
TOTAL	63	(44 %)	50	(35 %)	29	(21 %)	142

Meanwhile, contradictions also exist within the operators' social circles. For example, the vast majority of spouses declared themselves in favour of overtime even though they feel that the schedule does not leave their partner enough room for some activities.

3.1.2 Health

Operators currently working rotating 12-hour shifts are generally in good health. Their health declines with age, of course, but less so than that of former shift workers or maintenance personnel never having worked shifts. Former shift workers' number of diagnosed diseases by age is 40% higher than that of current shift workers, with this excess most notable among older workers. For example, current shift workers aged 50-54 years had a mean of 4 different diseases recorded in their medical charts over the period studied, while the comparable figures for maintenance workers never having worked shifts and former shift workers were 5 and 6 respectively (Table 4 and Figure 2).

This should not be construed as indicating that rotating 12-hour shifts are good for one's health, however. Because of a selection bias called **"healthy worker effect"**, the effects of work schedules are most noticeable among workers having prematurely left shift work. Interviews and analysis of medical records indicate that former shift workers found rotating 12-hour shift work intolerable as they got older, a finding consistent with reports in the literature.

Although current shift workers may be considered fortunate to be in better health than many people of their age, they are not exempt from health problems. In fact, data from most of the sources — self-reported symptoms, illnesses diagnosed by the company physician or reported by the workers themselves, pharmaceutical records, interviews of former shift workers, and interviews of spouses — indicates that this demanding schedule has a negative impact on health which manifests itself as a constellation of symptoms known as the "shift worker syndrome". The cardinal signs and symptoms of this syndrome are disruption of circadian rhythms, quantitatively and qualitatively inadequate sleep, and poor nutrition, all of which eventually lead to digestive, cardiovascular and psychological disorders. Health problems were observed most frequently among workers with sleep disturbances. Operators dissatisfied with this type of schedule, with a very heavy workload, and who find their work boring also tended to exhibit more health problems.

Table 4 Periodical medical examinations, 1984-1993. Frequency rates of diagnosed diseases, by age at the last examination: operators (current shift workers), former shift workers (current maintenance workers), and workers with no experience of shift work.

age at the last examination	FREQUENCY RATES (nb of pathologies [2]/ nb of workers)			
	operators shift workers	maintenance former shift workers	maintenance no shift work	total
23-29	1,7	*	*	1,7
30-34	2,8	*	*	2,8
35-39	3,8	4,0	3,7	3,8
40-44	4,1	4,9	3,8	4,1
45-49	4,5	5,4	4,3	4,5
50-54	4,1	6,1	5,1	4,9
55-61	5,0	6,3	5,4	5,4
TOTAL	3,9	5,5	4,5	4,2

* Missing data, or too few

[2] Total number of diagnoses found in each worker's records over all his periodical examinations

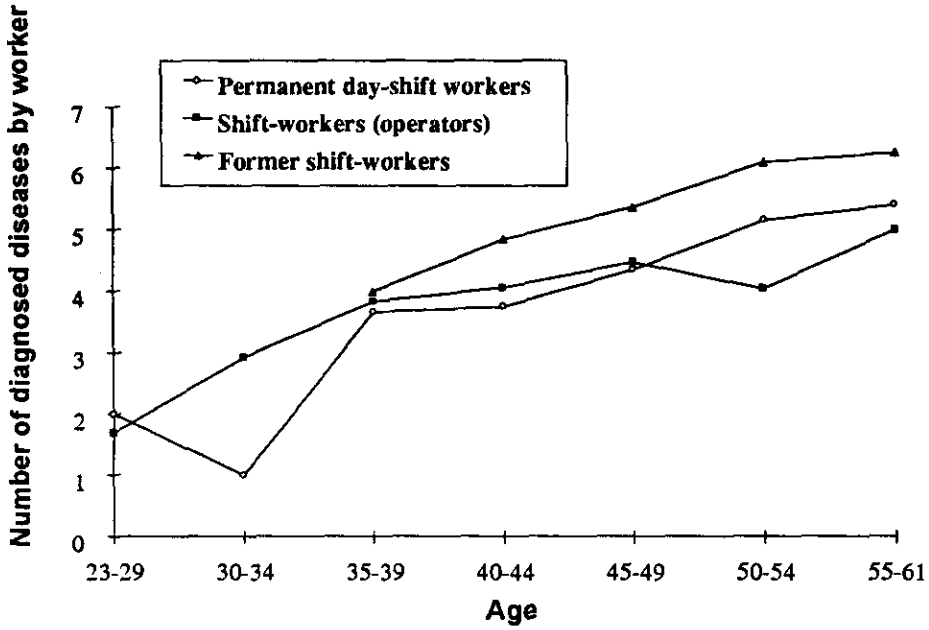


Figure 2 Number of diagnosed diseases per worker, by age group: shiftworkers, former shiftworkers and permanent day-shift workers

3.1.3 Sleep and fatigue

Monitoring activities are at their lowest between 02:00 and 04:00, the period during which chronobiological activity is also at its lowest.

In general, sleep disturbances, fatigue, and impaired recovery are the main disadvantages of the schedule now existing in the refinery. Many current shift workers suffer from **sleep disorders** (inadequate quality or quantity), and in fact, this is the most obvious effect of the work schedule among these workers. The operators are tired, and suffer from **chronic fatigue** and sleep deficits, especially on night shifts. After working three nights, they accumulate a **sleep deficit** of 6 hours (compared to the duration of their normal sleep), and even suffer from a 2-hour sleep deficit when working day shifts. As a result, operators' work, health, mood, and family life all suffer. With regard to family life, it is instructive to note that over half the spouses specifically complained about night workers' bad mood during the day. Diurnal sleep during periods of night work is of poorer quality, and this is reflected in the complaints of not sleeping long enough, sleeping poorly, not feeling rested after sleeping, inability to fall asleep, waking too often or too early, and feeling tired, reported by 50-75% of workers (Sleep disorders frequencies during day and night shifts: see Figure 3).

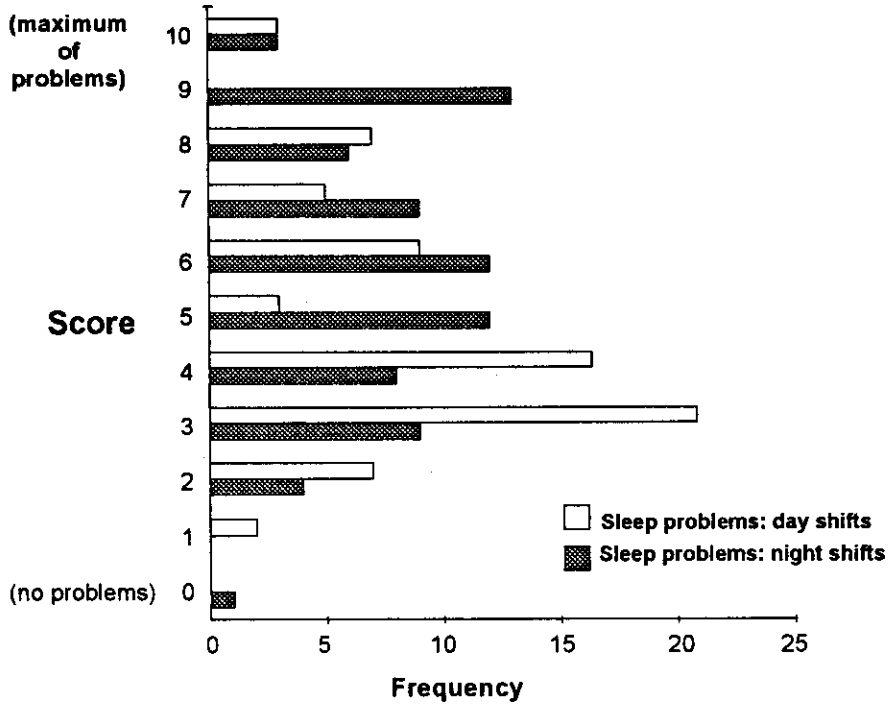


Figure 3 Frequency of the scores for self-reported sleep disturbances on day- vs. night-shifts

Although the problems they face appear less serious and less common than those suffered by former shift workers, current shift workers and supervisors nevertheless exhibited sleep disorders. During interviews, most former shift workers admitted suffering significant sleep disorders and fatigue when working rotating shifts. Former shift workers found these problems so difficult to bear as they grew older that they ranked improvement in the quality of sleep as the second most important advantage to changing work schedule.

In their own right, problems related to sleep and chronic fatigue justify modifying the work schedule and tasks. It is essential to find solutions to these problems, as they influence operators' health, safety, tolerance for the work schedule, and private lives, and the reliability of operations.

3.1.4 Workload and teamwork

Operators like their work because it allows them a fair degree of freedom, challenges them, drives them to learn new things and gives them an opportunity to resolve problems. However, the work is demanding, in terms of job qualifications, the range of tasks, inventiveness, and creativity. Job qualifications have increased over time, as the work has become more intellectual and new skills are needed to successfully perform secondary tasks ("second skill"). Moreover, the new career path for operators requires rotation through all jobs, culminating in the position of lead operator, which requires learning the commands and operations of all the units.

With the arrival of new control technologies and more efficient and reliable monitoring and safety systems, the workload should have decreased. Instead, operators consider their mental workload to be very high, with 56% of them describing it as "rather high" and over 20% considering it "very high". The components of this workload include memory, reaction time, accuracy, conceptualization of the entire site in order to integrate all the information, anticipation of incidents, rapid diagnosis of problems, and resolution of problems before they can develop. At the same time, operators must also maximize the reliability of operations, personal safety and profitability. Despite all this, the perceived workload was much more dependent on contextual difficulties such as schedules, downsizing, pressure to improve profitability, and the quality of relations with supervisors and colleagues than on task requirements per se, sleep disturbances, or fatigue.

The pressing problems were not what one would have expected at the outset of a study concerning work schedules. Aside from schedule-related disturbances, the other problems of operators — and the company as a whole — are a lack of personnel and heavy workload, especially during day shifts. These two factors not only affect the schedule, by increasing overtime and reducing prescribed rest periods, but also have repercussions on operators' fatigue and safety and system reliability.

This does not mean that the schedule itself is risk-free. The graph of process control activities exhibits a significant dip between 02:00 and 04:00, corresponding to a chronobiological dip during the same period (The deep dip in the curve between 09:00 and 15:00 is an indirect symptom of operators' heavy workload during day shifts: it demonstrates that the control activities are reduced to allow for other activities, e.g. maintenance. The two peaks of the curve around 07:00 and around 19:00 indicate the high level of activity of what we called the « shift take-over effect ») (Figure 4).

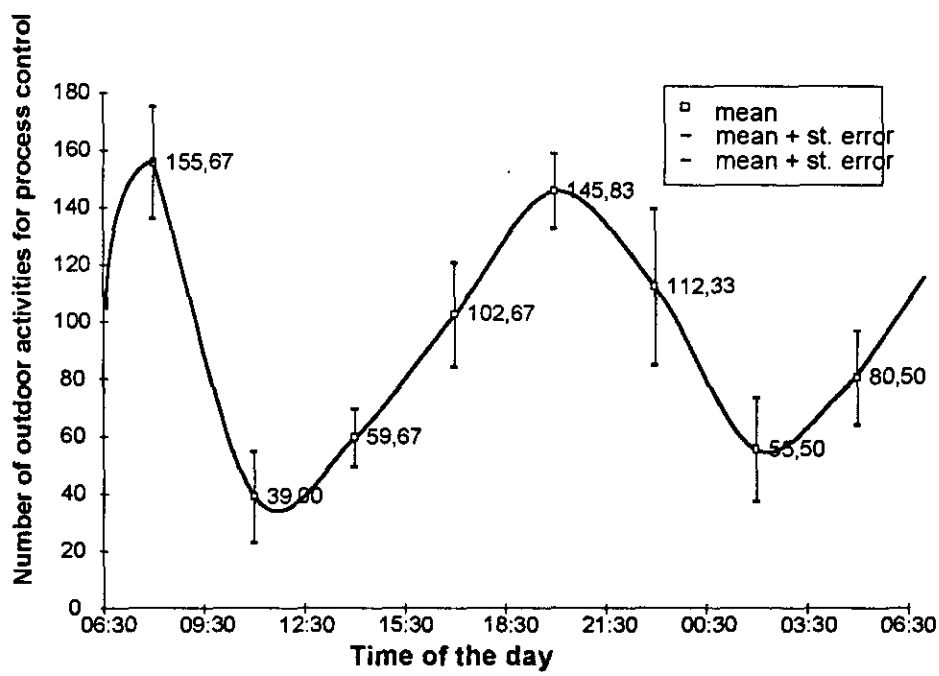


Figure 4 Chrono-ergonomic observation: outdoor activities for process control during the 24h-cycle (means for 6 day- and 6 night-shifts)

Workload was found to be **highest during day shifts**, for the following reasons:

- Operators must perform tasks other than those related to monitoring and operations, since day supervisors, technical groups, and maintenance personnel only work day shifts.
- To lighten the workload of night-shift workers, supervisors and operators have long tended to transfer as many demanding control activities as possible to day shifts. From a chrono-ergonomic point of view, this is to be encouraged.
- Training and activities related to secondary tasks and special projects take place during the day, but operators engaged in them are unavailable for regular shift work.
- Despite the preceding points, there are no real reinforcements available to day-shift workers. Replacements are provided by operators on holidays or days off — and who consequently lose their expected inter-shift rest.
- Day-shift workload varies between sites, with higher workloads observed at sites with a reduced workforce or low proportion of operators with multiple qualifications.
- The social circle of operators working night shifts readily adjusts to the constraints of the schedule. However, the social and familial demands on shift work operators working days are similar to those of permanent day-shift workers, and they themselves expect to live at a normal rhythm, despite working 12 rather than 8 hours per day. This situation may become particularly problematic if operators must fulfill other responsibilities after their work.

3.1.5 Social and family life

By shifting operators out of phase with their surroundings, this work schedule disturbs family and social life, especially for those with working spouse and children between 6 and 12 years old, although to a lesser extent, it would appear, than 8-hour shifts over 5-7 consecutive days.

Most respondents found the schedule incompletely compatible with normal life, but were prepared to make the necessary adjustments to the schedule as long as its advantages outweighed its disadvantages. A common criticism of rotating shifts is that it leaves workers and their families with the impression of leading a fragmented life. In this study, this was reflected by the fact that workers who reported having enough time for satisfactory conjugal, family, sexual and social activities (13-30%, according to the questionnaires) were also the ones who most appreciate shift work and consider it compatible with normal life. In fact, the free time available to shift workers on weekends and days off may facilitate the organization of leisure time, errands, and meetings with professionals, and allow the procurement of services and leisure activities at lower rates or at a less chaotic times. Shift workers appreciate being better able to care for their young children, perform household chores, and enjoy better and more frequent contacts with their spouses (when the latter are at home). On the other hand, the major drawback to rotating shifts is the desynchronisation of workers from the social circle (spouse, children, immediate family, relatives, and friends), especially at Christmas and New Years' Eve, on weekends, and during night shifts. Operators' responses to the questionnaire and absence records clearly show that they avoid preferably night and weekend work (Figure 5).

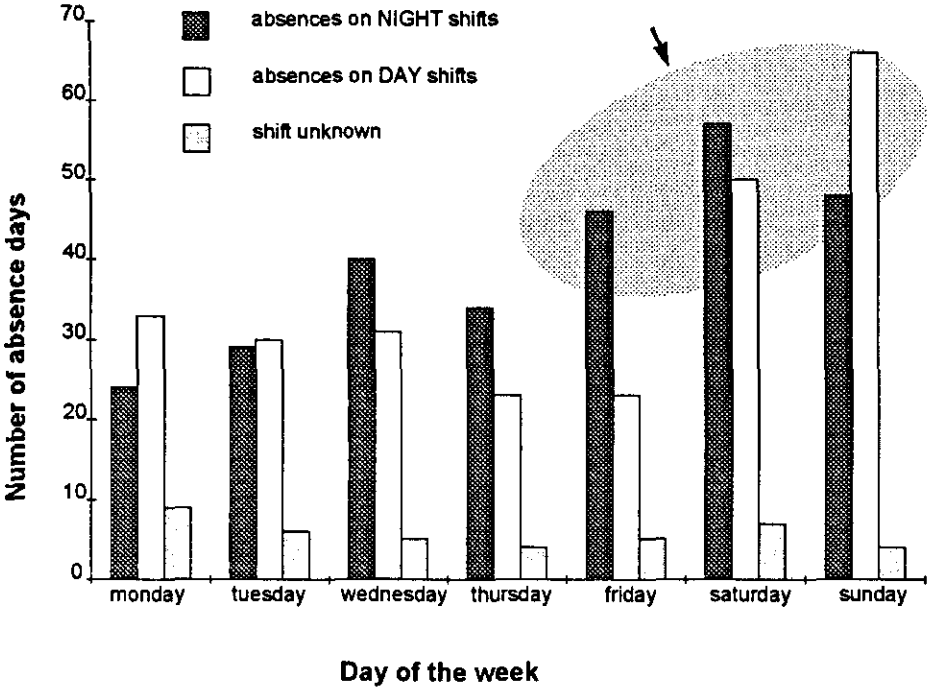


Figure 5 Number of one-day absences, by day of the week and by shift

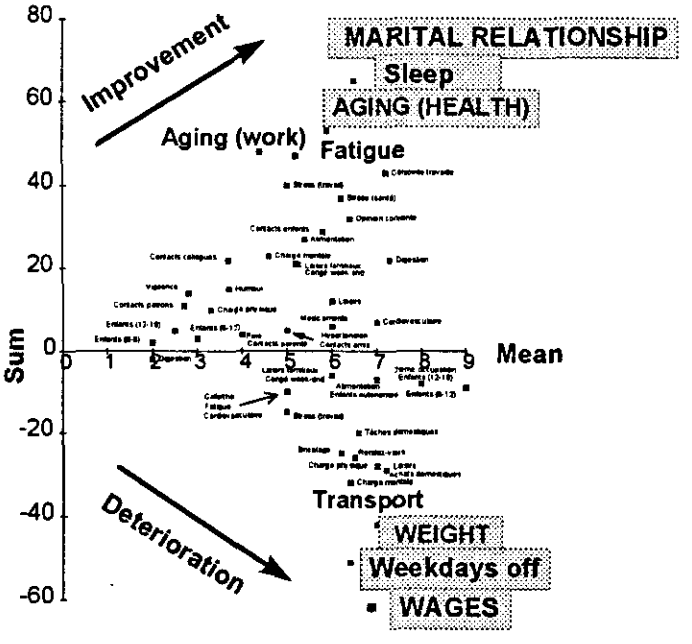


Figure 6 Improvements and deteriorations in former shiftworkers'life since adopting permanent day-shift work

Some operators find this desynchronisation from their spouses problematic, especially if their spouse's work schedule is incompatible with theirs. This is reflected by the fact that the benefit most appreciated by former shift workers upon changing to permanent day-shift work — ranking ahead of improved sleep or health — was the improvement in relations with their spouse (Figure 6).

In terms of family responsibilities, desynchronisation prevents operators from fully participating in their children's education, especially once the children attain school age. Furthermore, operators find it difficult to make and keep friends outside the refinery.

Operators whose spouses do not like rotating shift work find it harder to adapt and, conversely, spouses of operators who do not like shift work find it most difficult to adapt. Operators with sleep or health problems find the work schedule incompatible with normal family and social life. Most spouses feel lonely and insecure during night shifts, but many operators are unaware of these feelings or minimise them. During the little time that operators spend at home, they either sleep or, according to their spouses, are in a bad mood— a state of affairs they are also unaware of.

Operators probably like their work schedules more than their spouses do, although most spouses are rather favourable to it. Spouses participating in this study exhibited much more positive attitudes towards rotating shift work than those reported in studies of traditional 8-hour shifts. This is presumably because 12-hour shifts do not merely extend the work day (and night), but also shorten the work week and increase free time and extended periods of days off. Many operators devote their free time to familial and domestic responsibilities and most respondents felt that these advantages render rotating 12-hour shifts more compatible with conjugal, family, and social life than rotating 8-hour shifts worked 5-7 days per week.

3.1.6 Job satisfaction and desire for change

Four out of five operators stated unequivocally that they like their schedule, and many said that they like their work. Their reasons for liking the schedule include the numerous days off and extensive free time it affords, the flexibility they have in managing their time, and the high salary they receive. The operators who are the most satisfied with their schedule are young or single, have few or no children aged 6-18 years at home, suffer no sleep disturbances or health problems, have a spouse who also likes the schedule, and greatly appreciate the free time they have for other activities.

All is not perfect however : 4 out of 10 operators would leave their job for a day job and almost half would like to see their schedule modified. Surprisingly, improvements were even suggested by operators who did not desire their schedule to be modified. The main disadvantages of the schedule are the paucity of free weekends, necessity of working nights, effects on health and sleep, and decreased availability for social and familial activities. During the week, operators prefer night shifts to day shifts but it should be noted that the problems reported for week-day day shifts are related to workload, rather than the schedule per se.

Half of the spouses would like the operator they live with to take a day job, even though two out of three claim to favour the current schedule and the majority of them like the benefits of overtime work. Spouses who do not work outside the home, with few or no dependent children, and whose spouse is himself satisfied with the work schedule are the most favourable to the schedule. Spouses cite a number of disadvantages not mentioned by operators: loneliness and insecurity at night and effects on family life, health, and operators'poor mood and impatience when working night shifts.

Sleep disturbances, fatigue, and health problems were among the factors influencing the career choices of former shift workers, but these were not the only or most important ones. The key factors were rather the quality of family life, relationship with their spouses, and desire for a balanced lifestyle.

The three-day rest periods, six annual 9-day breaks, vacations, flexibility in the choice of time off, and the ability to swap schedules with other operators allow operators to organise their time as they see fit, with little need to resort to work absences to accommodate their needs. Although absenteeism is low, all things being equal, absences are more common during night shifts, on weekends, and on the third day or night of the shift (table 5, figure 5 and figure 7).

Table 5 Real schedule: Number of overtime periods by reason; number of schedule exchanges; number of absences for days taken from the accumulated holidays bank: distribution by shift (half the refinery sites, N = 78 operators over a 54-day cycle, from 95-12-29 until 96-02-20)

Shift	Number of 12-hour overtime periods by reason				Number of schedule exchanges	Number of absences for days taken from the accumulated holidays bank
	Activities requested by management (training, special projecs)	Replacements of medical absences	Other reasons, e.g. replacements of vacations	Total		
DAY	46 (73%)	20 (40%)	12 (42%)	78 (55%)	7 (41%)	84 (42%)
NIGHT	17 (27%)	**30 (60%)**	**17 (58%)**	64 (45%)	**10 (59%)**	**116 (58%)**
TOTAL	63 (100%)	50 (100%)	29 (100%)	142(100%)	17 (100%)	200 (100%)

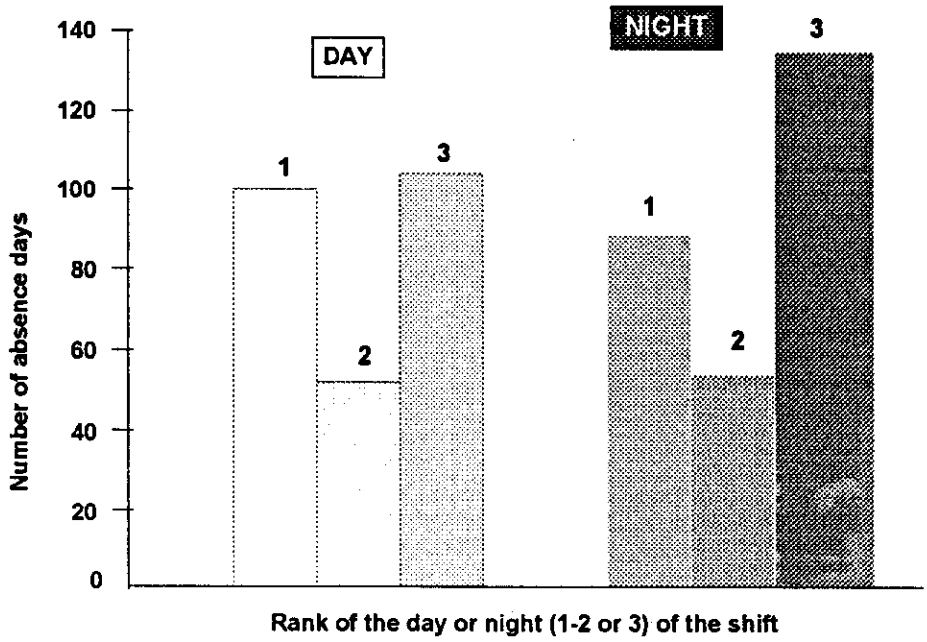


Figure 7 Distribution of the number of absences, by shift and by rank of day or night of the shift (day or night 1-2-3), one-day absences (source: absence records over 17 years from a sample of 21 operators).

3.1.7 Safety and reliability

At first glance, the data concerning occupational accidents is encouraging: accidents involving operators are less common and, more importantly, less serious than the average in this sector. The annual incidence rate of accidents resulting in work absences among operators of this refinery was 6%, and the mean duration of work absence per accident was 13-16 days, compared to 7% and 24 days for the petrochemical sector as a whole. Furthermore, the accident rate has also declined over the last five years. However, several factors favour the underestimation of the number and severity of minor accidents, particularly those occurring at night, when first-aid services are closed, and at the very end of the shift, when injured operators prefer to go home as quickly as possible and take care of their injury themselves or to have it cared for elsewhere. It should also be noted that the 3 days off and the 9-day breaks of the current schedule allow the operators time to recover from relatively serious injuries which would otherwise (i.e.: in a standard 8-hour schedule for 5 consecutive days) have resulted in a work absence, for which they would therefore have received compensation from either the company or workers' compensation.

Table 6 and Figure 8 show the distribution of accidents throughout the 8 three-hour portions of the 24-hour cycle and the accidents/activities ratios for the same 8 periods of day and night shifts. Accidents are most common in the late morning and early afternoon (40% of all accidents occur between 09:30 and 15:30), due to interference between multiple tasks, during the day (65%, vs 35% at night), at sites where the workforce has been reduced, and at sites where there are fewer operators with multiple qualifications. Higher accident ratios are associated with certain tasks, such

as maintenance and repair, but the fact that tasks and workload are risk factors for accidents should not overshadow the contribution of chronobiological factors.

Table 6 Distribution of accidents (number, percent, number of days lost), of control activities and of accidents/activities ratios by the 8 three-hour periods of the 24-hour cycle [3]

3-hour period	Accidents			Average number of control activities [4]	accidents/ activities ratios
	N	%	Number of days lost after the accident *		
DAY shift:					
06:30 to 09:30	32	11,0 %	-	156	0,20
09:30 to 12:30	**55**	**18,9 %**	**> 4 days**	**39**	**1,41**
12:30 to 15:30	**60**	**20,6 %**	-	**60**	**1,00**
15:30 to 18:30	30	10,3 %	-	103	0,29
(total DAY)	*(177)*	*(61 %)*		*(358)*	*(0,49)*
NIGHT shift:					
18:30 to 21:30	34	11,7 %	1 to 4 days+	146	0,23
21:30 to 00:30	23	7,9 %	-	112	0,20
00:30 to 03:30	18	6,2 %	**1 to 3 days**	**55**	**0,33**
03:30 to 06:30	18	6,2 %	-	81	0,22
(total NIGHT)	*(93)*	*(32 %)*		*(394)*	*(0,24)*
Time unknown	21	7,2 %		-	-
TOTAL	291	100,0 %		752	0,36

* $p < .05$

Even if operators themselves do not suffer more reported accidents at the end of their shifts, other data clearly demonstrates that the reliability and safety of refinery operations are compromised by extended shifts and that system reliability is lower at certain times of the night. For example, the accidents/monitoring activities ratio is highest between 00:00 and 03:00 (0.33 vs 0.22 for the other periods of the Night shift)(Table 6, Figure 8).

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[3] According to the chronoergonomic analysis the circadian cycle was divided in 8 three-hour periods

[4] Total number of control activities per operator by 3-hour period (source : results of the chronoergonomic analysis of operators's work)

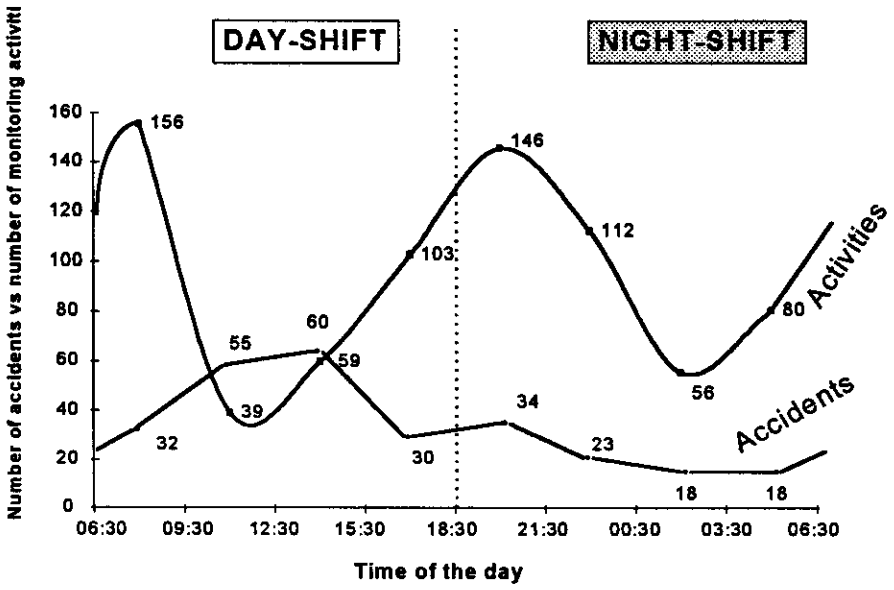

Figure 8 Number of accidents and number of outdoor activities for process control during the 8 three-hour periods of the 24h-cycle

In spite of the «chronobiological dip» in the curve of process control activities between 00:00 and 04:00, more monitoring activities are performed during nigh-shift than during day-shift, on an average (figure 9).

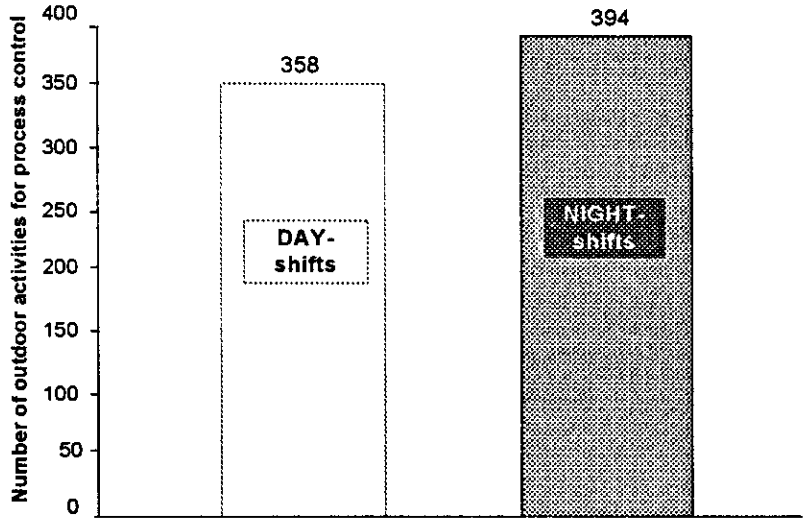

Figure 9 Number of outdoor activities for process control during the 24h-cycle : comparison day-vs night-shifts (means for 6 day- and night-shifts)

Looking at the November 1995 incident from a chrono-ergonomic point of view, it appears fair to conclude that although the time and day (02:00 on a weekend night) were not the incident's true causes, they could have played a role in its late detection and could have affected reaction time.

Any attempt to identify the more hazardous of the two shifts must recognize that shift duration is a risk factor common to both. Although it affects system reliability, it exerts no direct effect on occupational accidents *per se*. Each shift also has its own risk factors: during day shifts, the primary risk factors for accidents are workload and type of task, while at night it is decreased alertness and slowing of cognitive processes.

According to management, operators are more experienced, better trained, and more independent than ever before. As a result, breakages and outages are rare, workers are more efficient, and productivity is increasing. Operators know their work and the specific hazards at each site. It is thanks to constant monitoring of equipment, which exacts a toll (in the form of stress) on many operators, that serious incidents due to process inertia, the time necessary to reestablish full production capacity after disruptions, and the snowball and domino effects are prevented and the refinery is profitable.

Since descriptive statistical analyses point typical accident "scenarios" as related to specific tasks, prevention should be planned by drawing attention to those specific hazards. For example, maintenance and repair operations may interfere with operators' core tasks of control and monitoring of refining processes. This conflict leads to a deterioration of safety and reliability. Similarly, weekend start-ups and the absence of technical support on weekends and on night shifts compromises process reliability. These convergent results identify downsizing as an important risk factor.

3.2 Discussion

3.2.1 Workload and staffing

Because of the high demands on memory, reaction time, precision, and synthetic ability, operators' mental workload is very high. There are several signs that the workforce is currently too small, and that this has led to excessive workloads, especially during day shifts. In practice, the work week of day-shift operators lasts 40-50 hours, and not the 37½ hours mandated by the nominal schedule. Furthermore, despite the fact that aging operators have had several tasks added to their monitoring responsibilities, there has been no proportional staffing. The signs of the excessive workload include:

- an increase in task requirements (qualifications, adaptation, secondary tasks, planned rotation through all jobs) as operators get older
- chrono-ergonomic measurements indicate that monitoring activities are at their lowest on day shifts, at the end of the morning
- the increase in workload during day shifts vs night shifts
- the preference of operators for working night shifts during the week
- the fact that operators suffer from sleep deficits even when working day shifts
- the fact that more accidents occur between 09:00 and 15:00 than at other times
- the fact that accidents are more frequent at sites with a recent downsizing of the workforce or where there are few operators with multiple qualifications
- the tendency of peripheral tasks related to control and monitoring *per se* to concentrate risk
- the deterioration of the quality of inspections and the increased risk of breakages, with the situation being worst during shut-downs, due to the reduction in the size of the workforce responsible for operations, inspection, and maintenance.

3.2.2 Self-selection processes and the healthy worker effect

Over the long term, work schedules affect health. Due to self-selection biases, this is most noticeable among former shift workers, although current operators exhibit the signs and symptoms of digestive, cardiovascular and psychological disorders that constitute the "shift worker syndrome". There is no relief in site for aging operators, and no possibility of reassignment to day shifts at this time. The absence of escape strategies for current operators may render the healthy worker effect inoperative, and it is possible that older operators active over the next 5-10 years will be more affected by the work schedule than observed in this study.

Self-selection processes are global phenomena that can influence not only health data but also the assessment of sleep, fatigue, workload, and even conjugal, family and social life. In fact, the "healthy worker effect" ensures that the operators currently working a rotating schedule are those who are best able to cope with the schedule, stress, and new work responsibilities, and whose social circle can cope with the disadvantages of the schedule.

In contrast to other studies, this study did not reveal the existence of more health, sleep, safety, or workload, conjugal or family problems or a lower level of job satisfaction among older operators, i.e. those who have worked 12-hour shifts for a long time, comparatively with younger ones. Before seeking a schedule-related cause for this finding, it is necessary to eliminate any biases related to the age structure among operators. However, the age distribution within the group is varying enough to reveal real differences, if any. With this bias eliminated, selection is obviously the most likely explanation for the results. The oldest current shift workers are remarkably well adapted to the schedule, thanks to their initial good health, adaptation (or less negative reaction) of their physiology to this type of schedule, the existence of a social circle able to cope with the schedule, and the fact that they were sufficiently disciplined to use the schedule to their advantage. There may also be collective work strategies, either explicit or implicit, that spare older workers. To verify this last hypothesis, it would be necessary to study the ergonomics of collective coping strategies; this has not been done.

3.2.3 Contradictions between health/money, safety, reliability, sleep, family...

In every situation involving the effects of shift work, data shows that financial interests (operators' as much as the company's) are invariably in conflict with safety, health, sleep, family and social life. In most cases, it is possible to balance the two but when this is impossible and a choice must be made, our assessment indicates that economic interests usually predominate.

For example, reliability and safety appear to be adequate and are improving. However, this state of affairs can only continue if certain parameters are monitored and management keeps in mind that attempts to be profitable at all costs and keep the workforce as small as possible are incompatible over the medium term with the prevention of accidents and production incidents. For the moment, the system is operating without major losses, but the workforce is aging, older shift workers may not get reassignment, workload is borderline with safe limits, and maintenance is neglected — how long can this continue? The company's profitability continues to increase, thanks to the skills of its personnel, especially its operators, who take risks and mortgage their sleep for the benefit of refinery performance and everyone's (including their own) financial benefit. But the limits of reliability are sometimes very near, especially under abnormal or dangerous conditions such as shut-downs, start-ups, and maintenance operations.

We have focussed here on safety and reliability, but an analysis of health and sleep would have yielded similar conclusions, although in that case it is not the company but the operators themselves, encouraged by their spouses, who are prepared to mortgage their long-term health for the immediate financial gains associated with overtime.

3.2.4 The real schedule

For many reasons, the real schedule is very different from the formal one. It should first be noted that the nominal duration of 37½ hours a week is an ideal goal rather than a shared reality. Refinery operations are continuous, and since there are 168 hours in the week and 4 teams of production operators, each team's real work week must average at least 42 hours just to accommodate regular production activities. During planned shut-downs and start-ups, much of the work is overtime work, and it is not rare for operators to work 30 consecutive 12-hour shifts (day or night) with no days off. Operators also participate in training, special projects, and safety- and union-related activities, in addition to their normal production responsibilities. And in addition to those activities, there are schedule exchanges and replacements for operators with medical absences, on vacation, or

assigned to the non-production activities mentioned above. In practice, replacements, either worker- or company-initiated, account for much overtime work. For example, in January and February of 1996, a period during which there were no exceptional operations such as significant planned shut-downs, 78 operators in the northern half of the refinery worked 2 112 hours of overtime.

4. CONCLUSION

Two types of conclusions may be drawn from the results of this study: general observations, of interest to all companies considering schedule redesign and to field practitioners or researchers interested in the design of work schedules, and company-specific observations.

4.1 General conclusions

- Among current shift workers, the most obvious effects of this schedule are sleep disturbances, sleep deficit and chronic fatigue, even when operators are working day shifts. Negative effects on health, social and family life are also detected. The most marked negative effects of the schedule are observed among former shift workers.

- The results of this research illustrate the difficulty in dissociating the effects of work schedule from age and workload in workers currently assigned to rotating shifts. Several diagnostic elements indicate that these three factors are related, which confirms the relevance of the theoretical model underlying this study.

- The global assessment also highlights the significant effects of workload on health, sleep, fatigue, safety, work, and even private life.

- In this population, self-selection (the "healthy shiftworker effect") no longer exerts a protective effect, because of reductions in the size of the workforce, limitations on hiring, and barriers to the reassignment of operators incapable of tolerating the work schedule and aging operators to permanent day shifts . Consequently, operators still active 5 to 10 years hence may well exhibit significant deteriorations in their health.

- The pattern of physical activity associated with monitoring tasks exhibits a significant dip between 02:00 and 04:00, the period corresponding to the chronobiological low point.

- 12-hour shifts offer more advantages than do 8-hour shifts in terms of family and social life and more generally, extra-professional activities and personal needs. On the other hand, several results indicate that extended work shifts are a source of increased fatigue, hinder recovery, and may compromise the quality of monitoring.

- The significant differences observed between the nominal and real schedules are an important symptom and reveal that the nominal schedule is ill-suited to both production needs and operators' needs. The real schedule both reveals and imposes an excessive workload on operators.

- Otherwise, the mere existence of differences between the nominal and real schedules demonstrates that the system is flexible enough to accommodate organisational adjustments of schedules and tasks when these are required for the purposes of production. It should be possible to exploit this flexibility for the operators' benefit.

4.2 Company-specific conclusions

Although the operators' situation is tolerable for the moment, it may deteriorate in the near future, due to the aging of the workforce. Modifications, although not necessarily revolutionary ones, are therefore indicated, especially as half of the respondents expressed a desire for change and offered suggestions for such changes. Listed below are the most important and pressing issues to be addressed in prioritising any eventual schedule, task organisation or personnel management modifications.

- The only way to ensure that replacement operators are available and regular tasks, secondary activities, second skills and special projects performed is to resort to much overtime. Operators are thus overworked, particularly during day shifts, and there are not enough of them. This affects workload, sleep, fatigue, short-term recovery, long-term health, reliability of operations and the social and family lives of operators. In addition, under-staffing affects the work schedule, since the diversion of personnel for the purposes of replacements or for activities other than monitoring and operations, completely short-circuits the nominal regular schedule and reduces the effective number of rest days. This increases fatigue.

- Sleep disturbances and fatigue are the most obvious signs of schedule-induced disturbances in current shift workers.

- Rotating shifts accelerate the age-related deterioration of health in more fragile operators (who have in any event left shift work). Among current shift workers, digestive, cardiovascular, and psychological symptoms constituting to the "shiftworker syndrome" were observed.

- Of all the factors studied here, family and social life were the least affected, thanks to the extensive weekday free time that the schedule affords operators. However, all is not perfect, even here, with desynchronisation of operators and their social circle, particularly in cases where the spouse works outside the home and there are children of school age, being the main disadvantage observed. The paucity of free weekends was the main criticism formulated by operators' families.

5 GENERAL RECOMMENDATIONS

A list of company-specific recommendations designed to help the company resolve its specific problems can be found in Appendix II. However, the field observations, analytical results, diagnoses, and conclusions also have implications which exceed the scope of the specific company studied. General recommendations are therefore listed below, grouped into four categories: work organisation, prevention, research, and schedule design.

5.1 Work organisation (tasks and schedules)

In companies adopting rotating shifts, it is recommended that:

- the differences between nominal and real schedules be studied by all the stakeholders, and the situation concerning overtime be reviewed. Should this analysis reveal problems, the duration of the work week, number of shifts, and number of workers assigned to each shift should be modified.

- reassignment be facilitated. It is impossible to design a "healthy" shift-work schedule, but workers who cannot longer tolerate the schedule should not be exposed to it.

- the number of free weekends during which workers can see to family needs be increased.

- a local follow-up work team be instituted whenever schedules are modified. This committee should be responsible for monitoring modifications, the evolution of expectations, health and sleep status, social and familial aspects, hazards, etc. Committee members (management, unions, workers, supervisors, trainers, health service and technical groups) should therefore receive short training in chrono-ergonomics.

- advantage be taken of the times when operators are working non-rotating day shifts to review the effects of that temporary reassignment on their sleep, safety, and private lives.

- management of absenteeism for medical reasons be reviewed, and the role of absences as an escape mechanism from schedule-related stresses and nuisances be discussed.

- the reassignment of victims of serious accidents to light duties be encouraged, when convalescent periods are long. These reassignments should stimulate thought about the reassignment of aging workers incapable of tolerating the work schedule or new work requirements.

5.2 Accident prevention

The following recommendations are aimed at improving system reliability and preventing accidents.

- Develop procedures that relieve shift workers from long, complex, or hazardous tasks when support or emergency personnel is unavailable. This does not merely mean lightening the workload, but also affects production reliability and safety.

- Review auxiliary and secondary tasks. This study, in common with many others, has demonstrated that workers' safety and system reliability are most fragile during that part of the day devoted to these types of tasks.

- Open discussions on routes home after night shifts. Fatigue and shift duration reduce alertness at the wheel and increase the risk of road accidents.

- Consult shift workers prior to process or equipment modifications.

- Plan prevention and information campaigns by drawing attention to hazards related to specific tasks, sites, and departments, and to abnormal or emergency situations.

- Design a company-specific standardized accident report form (time, place, task, action, overtime status, consecutive days or nights worked prior to the accident, special conditions, e.g. shut-downs). If compressed schedules providing operators with several consecutive days off are in force, the form should clearly distinguish between the number of lost work days and the real date of return to work.

- Computerise accident data and analyse its trends regularly.

5.3 Research

Several questions remain unanswered, as they require further analysis. It is therefore necessary to:

- continue the present research. Support tools for the design, evaluation and follow-up of new schedules, should be developed.

- conduct a chrono-ergonomic study of weekend day shifts, using an experimental design similar to that used in the present study. The goals of such a study would be to compare the workload during weekend and weekday day shifts, explain the dip in monitoring activities observed at the end of the morning, determine the precise contribution to workload of interference by maintenance tasks, and assess the impact of this interference on system reliability.

- conduct a comparative field study of short- and long-term memory during day and night shifts, in order to identify circadian variations in memory and in the reliability of control and monitoring operations.

- document the impact of work schedule on the longevity of couples composed of former or current shift workers (a longitudinal qualitative study would be the most appropriate design).

- modify the questionnaire on sleep so that future studies of the effects of short-cycle 12-hour shifts can take into account the fact that the time at which operators fall asleep and wake up on days off differs depending on whether the day off falls between two blocks of day shifts, two blocks of night shifts, or a day and a night shift. Another interesting possibility, from the point of view of both research and intervention, would be to ask operators to keep a journal.

5.4 Guidelines for schedule organisation

In order to guide discussions and decisions concerning schedule design, the operational model proposes 23 indicators grouped into the following three broad categories (Quéinnec, Teiger and de Terssac, 1992):

- time management of individuals, and team organisation
- personnel management
- task design

In this general summary, the discussion has been limited to basic principles concerning schedule design or modification; it should be recalled that proposals designed to resolve the problems observed in the specific company studied are contained in Appendix II. For further concrete information on the organisation of work schedules, consult the 23 practical guides in Appendix II.

Principles and criteria for decisions concerning work schedules

- Minimise work between 00:00 and 06:00, or at least reduce the workload during this period.

- Reduce the duration of exposure to shift work by limiting the number of consecutive years during which workers are assigned to this schedule and ensuring that they are not exposed for a full year at a time.

- Introduce some flexibility into the organisation. Due to the stresses of night work, there is no such thing as a "good" schedule, a "good" solution, or a single solution applicable to everyone, but only multiple compromises that are more or less acceptable.

- Ensure that compensation is in kind: if workers contribute time they should be compensated in time, not money.

- Take into account the following factors when designing new schedules:
  - number and composition of work teams (shift crews)
  - characteristics of the individuals making up a team
  - real work (Note that the nature of the tasks, working conditions, and inter-and intra-departmental variations of conditions over time all modulate the effects of shift work.).

- Do not think of the three main themes — time management and teamwork, personnel management, tasks — or the sub-themes as isolated concepts, as they are all interdependent. For example, thinking of "redesigning the schedule" only in terms of rotation is pointless.

- Realise that there may be advantages and disadvantages to a given choice within a given field. Sleep affords an instructive example: delaying change-over time to 08:00 and 20:00 could improve sleep in day-shift workers but reduce the duration of their sleep when they work nights, as the later in the morning one goes to sleep, the shorter the duration of sleep.

- Realise that a solution may have positive effects in one field and negative ones in another. For example, most workers prefer early shift change-over because this affords them more time in the evening for normal family and social activities when they are working day shifts. However, as they must get up before 05:00, they incur sleep deficits, and suffer from reduced alertness

at the beginning of their shift.

All solutions therefore represent **compromises**. To be acceptable to all, these compromises must be **negotiated**. To this end, it is necessary to:

- review the situation and diagnose the effects of the current schedule (nature of tasks, workload, health, safety, reliability, sleep, fatigue, social and family life, satisfaction and desire for change)
- ensure that all stakeholders participate in the design of modifications
- inform and train stakeholders in the fundamentals of chrono-ergonomics.
- observe minimum criteria concerning safety, health, and reliability, while satisfying the needs of individuals who will have to live with future modifications. The best options are those that give the highest priority to the points that workers prioritise.
- review the choices adopted as working conditions and individual needs and characteristics change. Establish a follow-up policy for modifications. Review the modifications if the situation changes or new scientific findings become available.

The principles and conditions listed above have two consequences on the content of the 23 guides. Firstly, it is impossible to list all the potential options in the guides. Secondly, the best choice is often the one the groups in question develop for themselves by thinking about their priorities, tasks, group and individual characteristics.

APPENDIX I : BIBLIOGRAPHY

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APPENDIX II : COMPANY-SPECIFIC RECOMMENDATIONS

COMPANY-SPECIFIC RECOMMENDATIONS

This section is composed of five parts. The first is devoted to observations on the context of the intervention in the company. The second is concerned with the necessity of prioritising the problems to be resolved and the choice of the best way of doing so. The third part contains the main topics for reflection derived from the final assessment. The fourth part describes the key points for modifications. The fifth part contains the 23 practical guides.

1. The context of the intervention

It should be stated at the outset that a certain amount of optimism is warranted on reviewing the survey results, as there appears to be some flexibility in the manner in which schedules and tasks are designed. Even if this flexibility is primarily a response to production imperatives, it is reasonable to suppose that it will also be present when attempting to find solutions to problems and constraints faced by shift workers. Signs of openness to change were evident throughout interviews with management and discussions with the union, supervisors, and operators. "Almost everything is on the table", we were told, as long as the changes can be shown to be necessary.

Management has an explicit policy of viewing its employees as development capital which profits all parties, surrounding itself with individuals skilled in refinery operations, ensuring employees have pleasant conditions. This reflects its view that the ability of the refinery to remain competitive and of all its employees to keep their job depends on keeping operators happy. By "happy", management means more competent, motivated, responsible, satisfied socially and in their family life, and taking advantage of the company's flexibility to improve their potential. Management claims that the company is profitable and is therefore in a good position, with considerable leeway, to negotiate change. In large part, this is also true of operators, since they are the front-line producers. Of course, resistance to change must be taken into account. Finally, it should be recalled that the company is not a new one, and habits die hard — as one director said, *"implementing the work organisation in place at X (a refinery of the same company starting at a new site with new personnel) in this refinery would be like trying to change a tire on a car going 60 miles per hour."*

2. Why determine priorities? How to launch a pilot project?

To improve work schedules and task organisation, priorities must first be established. This study, by producing a global assessment of the situation, has helped the company and the operators identify the most pressing problems. Obviously, everything can't be fixed at once and the same solutions will not suit everyone. It is thus the partners' responsibility to negotiate a prioritised list of problems (which sites? which groups?) Concretely, the partners could identify volunteer groups in which to implement a pilot projet involving new schedules and tasks. These improvements would be designed as a function of the needs of the workers and of the assessment of *their* work group. If, for example, the group decides to prioritise the resolution of sleep problems, attention should be focussed on night shifts, rest periods, etc. If priority is given to family life, weekend work should be examined first; if aging is of concern, efforts should focus on reassignment to day shifts and the design of a less arduous schedule for older workers, etc.

3. What should be corrected? Avenues of reflection derived from the final assessment

Modification of work schedules requires commencing negotiations on 23 indicators in the fields of time management and team work, personnel management, and task organisation. Once well under way, the modification process demands that the group involved in the pilot project systematically examine each of the 23 indicators. In this section, we will limit ourselves to modifications which involve the four main diagnostic indicators that are applicable to the refinery as a whole (Figure 8).

- **The nominal schedule is not followed, because there are not enough operators to do all the expected work without overtime. Operators are thus overworked, particularly during day shifts. In addition, the rest days (days "off") planned in the theoretical schedule are not taken, and this increases fatigue.** Should the partners decide to address this problem and the question of overtime work, the main points to be considered are the duration of the work week[6], size of the workforce, multiple qualifications of operators (since this enlarges the possibilities of modifications), reassignment to day shifts, and task design accounting for schedules.

- **Sleep problems and fatigue** are other issues highlighted in the final assessment. To resolve these problems, it would be useful to devise solutions that provide operators with relief from the stresses of night work, and measures to attenuate the effects of extended shifts.

- **Rotating shifts have accelerated the age-related deterioration of health in less resistant workers.** As it is impossible to design a "healthy" rotating-shift schedule, the measures to be applied consist of using progressive, temporary, or permanent reassignment to remove individuals who are intolerant of these schedules.

- **The schedule degrades operators' family and social life.** However, the desynchronisation of operators from their social circle cannot be completely eliminated, as it is inherent in the choice of this type of work schedule. What can be addressed however is the desire expressed by both operators and their spouses for more free weekends. Other modifications that increase the time operators spend with their families should also be investigated (holiday and vacation schedules, shift change-over times)

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[6] The guides are interrelated. For example, the duration of the work week (first modification listed) cannot be modified without also considering several other points. This guide is linked to the one on rotation, weekend work, duration of day and night shifts, the number and size of shift crews, inter-shift rest periods, replacements, and rest days.

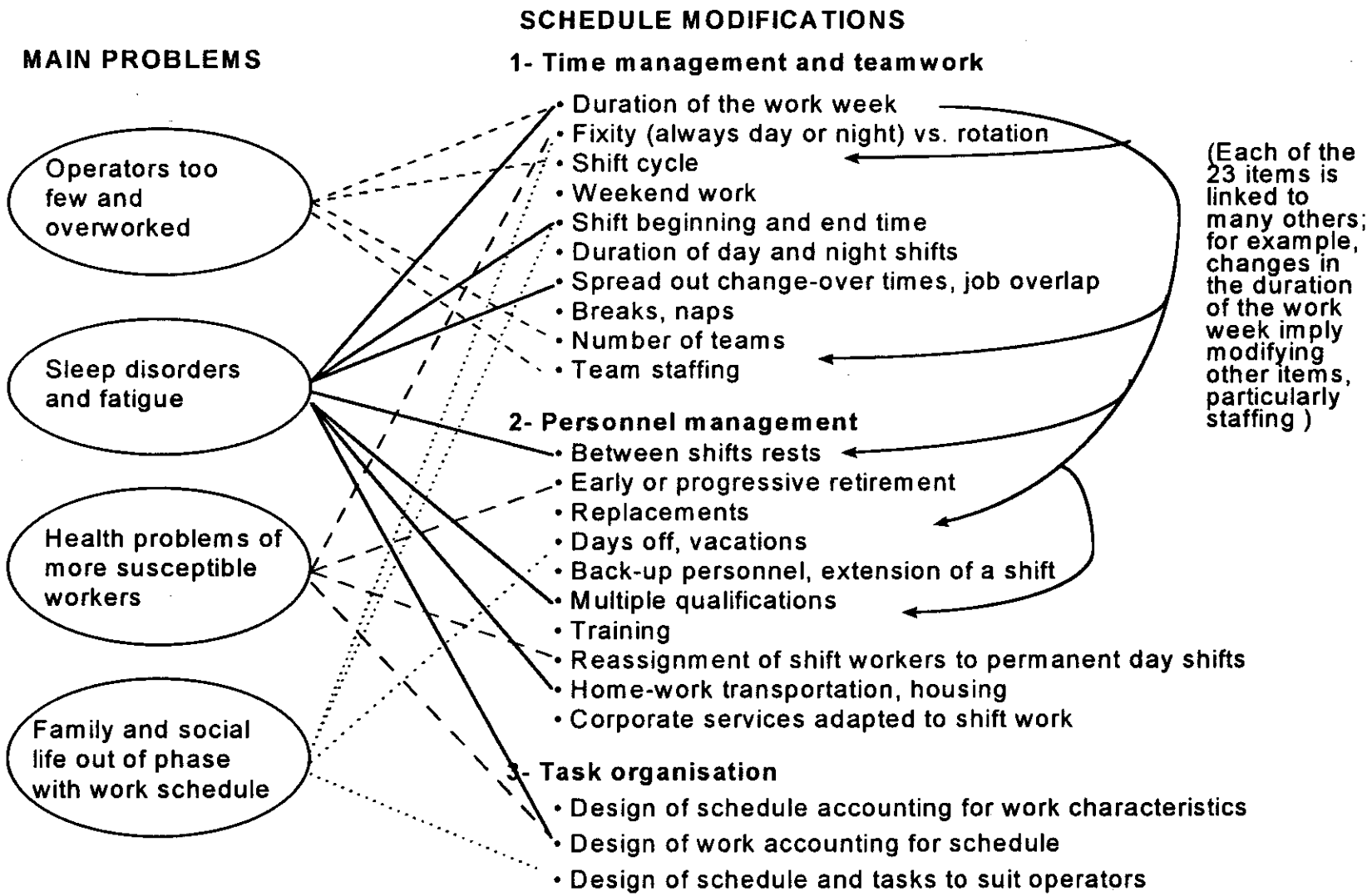

Figure 10 Schedule solution to the main problems detected in the refinery

4. Comments on certain redesign issues

- **The 23 guides concerning schedule redesign:** It should be recalled that these practical guides **are not miracle solutions**, and that they should only be used in conjunction with an assessment of the overall situation. The conditions governing their use and the fundamental principles concerning schedule organisation and redesign are discussed in section 5.4 of this summary.

- **Rest periods and naps:** In light of the fatigue-related problems detected during this research, the length of night shifts, and the heavy workload during day shifts, voluntary rest periods should be provided during both day and night shifts. The logistics of these rest periods (place, schedule, rotation, etc.) should be determined by the stakeholders, and should take into account production needs and safety.

- **Short or long shift cycles?** The available chrono-ergonomic data does not allow conclusions to be drawn concerning the variation of workload over the shift cycle (days 1,2, or 3). On the other hand, discussion with teams at different sites, interviews with former shift workers, and discussions with management all indicate that the mental workload on the first day of the shift and following three days off, a break of 9 days or vacations is particularly high. Day-shift technical supervisors considered a Day 1 with an entirely new team a nightmare, which is why they prefer to operate on a schedule of 30 days or nights of consecutive shifts during shut-downs. This arduous mental workload during the first day or night of a shift cycle argues in favour of a long cycle, although it contrasts with the current tendency among chrono-physiologists to favour 2- rather than 3-day shift cycles.

  Recent trends in chrono-ergonomic research favour short shift cycles, which minimise the long-term physiological cost of complete de- and re-synchronisation. It is interesting to note that even though operators claim to favour long shift cycles, their behaviour indicates otherwise: absences are more numerous on the third day or night of the shift cycle. The best design — i.e. that which minimises the accumulation of fatigue and ensures continuity at the site and regular follow-up of production — is based on short shift-cycles, extended shift relief, more intra-team mobility, and the creation of non-rotating-day-shift teams responsible for daily site monitoring.

- **It is difficult to alleviate the excessive day-shift workload without affecting staffing levels.** Traditionally, experts in the field of shift work recommend reducing the night-shift workload, by transferring as many activities as possible to day shifts, also responsible for all maintenance tasks and for technical orientation. In the company studied here, this transfer of tiring or hazardous activities has been largely realised — without no readjustment however of staffing levels for day-shifts. The end result has been to preclude any further transfer of tasks to the already overloaded day shifts. As complex or demanding tasks cannot be transferred to the night shifts, it is essential to devise other means of lightening the day shift workload, e.g. increasing the number of teams or assigning older operators to non-rotating day shifts.

- **Multiple qualifications** Currently, 58% of operators are qualified for work on all units of their site, although this percentage varies widely from site to site (for detailed figures, see the Appendices of the complete research report). Between 10% and 15% of operators have changed site in their career, and among these, a rare few are thus multiply qualified on two

sites. The company's current management favours multiple qualification (e.g. training on tasks other than monitoring and control, rotation through all the units of a site and eventually to the position of lead operator, performance of secondary tasks).

The stakes and hazards mentioned below notwithstanding, it should be recalled that multiple qualification, properly understood and applied, is a fundamental element of strategies designed to prevent the negative effects of shift work. It is essential that operators have the opportunity of occupying multiple positions within their team, as this renders the team more flexible. The benefits of this flexibility include:

- better management of absences and delays
- easier replacement of operators
- distribution of the workload over more people
- reduction of accumulated fatigue, sleep problems, and, over the long term, health problems
- facilitation of reassignment of older workers to more rewarding day work
- facilitation of problem resolution through teamwork, which reduces individual workload and increases process reliability.

Despite all this, multiple qualification has met with some resistance among operators, who rightly perceive it as a potential source of increased workload if new operators are not hired to compensate for the greater number of tasks. Furthermore, not all operators respond equally well to the need for multiple qualification once they get to a certain age: not everyone appreciates having to learn new tasks and take on new responsibilities.

- **Career progression and secondary tasks ("second skill").** Due to the tight links between the work schedule and this company-specific process, its advantages and disadvantages should be reviewed.

  Turning first to the advantages, it should be noted that training and day work devoted to secondary tasks removes some operators from the stresses of night work for prolonged periods. This also affords operators an opportunity to increase their skills, leave their site, and enlarge their social circle at work, learn stimulating things, and increase their competence.

  However, this is not without its drawbacks. There is currently an inadequate number of multiply qualified operators to allow operators to rotate through all positions. Even if adequately trained, operators who return to the position of lead operator after three or four months in the field experience serious difficulty in relearning the commands. Performing secondary tasks may rapidly become a second job in itself, and may so interfere with operators' principal responsibilities and the requirements of daily operations as to increase risks and reduce profits. One thing is clear: as long as the current hiring freeze continues, career progression and the performance of secondary tasks are unlikely to prove effective means of reducing operators' workload — a workload, it should be added, that they already perceive as heavy, since in the absence of new operators, their mean age increases by almost one year annually.

- **Technological changes.** It was obvious upon studying the impact of schedules on reliability and safety that the introduction of new technology also affects system reliability, by modifying tasks and by extension, mental workload. It therefore appears useful to discuss the new technologies with operators. Although these technologies provide very effective computerised control

mechanisms that increase safety, operators must be involved in their implementation if they are to fully use them. Furthermore, it is also necessary to ensure that in emergency situations machines do not take control away from the operators — operators' skills are the best guarantee of operational reliability.

In addition, the introduction of computerised tools has changed team dynamics. Previously, operators worked individually in their own unit only, at least in theory. Today, control mechanisms act on several units, and this has seen the emergence of teamwork. Paradoxically, these same technologies that allow action over a wider range are the same ones that reduce information access and sharing. Instead of the entire team receiving information on the entire site from the same general control panel, as was previously the case, operators must now individually access several screens to find the required information

- The role of operators in **maintenance and repair work** and related procedures should be reviewed by the groups concerned, i.e. the technical group, operators, maintenance personnel. This is a key point, since our analyses demonstrate that monitoring is reduced and operators run a higher risk of accidents when operators perform these tasks.

- **Work organisation and the scheduling of shut-downs should be reviewed.** The report on the incident of November 1995 made a number of recommendations regarding the technical organisation of work during shut-downs in general and inspections in particular. However, the fact that decisions concerning defective or missing equipment involved in the accident were taken during successive shut-downs, and that the site was encumbered and fatigue high during these shut-downs raises questions about work rhythms, interference of contractors with local personnel, and the number of consecutive days and nights worked.

- It would be useful to plan **preventive measures** and information campaigns concerning occupational accidents that emphasize the specific risks of the **four types of tasks** and the **circumstances identified in the accident profiles**: inspection rounds *per se*, physically demanding tasks associated with inspection rounds, peripheral maintenance and repair tasks, and abnormal or emergency situations. Prevention of occupational accidents should also reflect the **specific hazards of specific sites**.

5. The 23 practical guides for shiftwork redesign p.

1. Schedules: Time Management and Team-related Modifications

Guide 1.1 DURATION OF THE WORK WEEK

a) Objective

The total number of hours worked, on average, by operators during one week. Several important points, most of which concern the duration of the real work week, should be noted.

The French guide entitled "Repères pour négocier le travail posté" [Guidelines for the negotiation of shift work] does not discuss the duration of the real work week, as French law prohibits shift workers from working more than 35 hours per week. In the Québec company studied here, the nominal duration of the work week was 37⅓ hours, taking into account the 3-day break at the end of the 54-day shift cycle.

In fact, as the refinery operates continuously (i.e. 168 hours per week) and there are only 4 teams of operators, the mean work week of each team (and therefore each operator) must be at least 42 hours — and this only considers the time required for regular monitoring and control activities. Although many operators scrupulously take their breaks and limit their work to the officially prescribed 37⅓ hours, many others perform at least 42 hours of monitoring work each week, on an average. In addition to this work, operators are also called upon to replace operators who are enjoying vacations, absent, or assigned to special projects, and to attend meetings, receive training, participate in special projects, and perform secondary tasks. Even if the analysis is limited to monitoring and control activities, it is clear that **there is an inadequate number of teams and workers** to implement a work week of 35 hours, enforce the current nominal work week of 37⅓ hours, or even accommodate the current real work week of 42 hours. **Modification of the real weekly duration of shift work is therefore dependent on modification of these two parameters: number of teams (shift crews) and team staffing levels** (see guides 1.9 and 1.10).

b) Options

1. At least 42 hours per week (current situation)
2. 37⅓ hours per week (real, not nominal)
3. 35 hours per week
4. ----------

c) Analysis of options

Option	Advantages	Disadvantages
1	• For operators: Higher salary. • For the company: Higher (although illusory and short-term) profits, due to reduced costs and freezed hiring.	• Overexposure of operators to the stresses of shift work. • High overtime costs, even with this schedule.
2	• This schedule provides operators with a long break (9 days) every two months. • For the company: Hiring favours information transmission to new employees.	• Higher corporate costs due to new workforce
3	• Lower exposure to the stresses of shift work, either by a reduction of the duration of the work week or by granting the 9-day break every 6, rather than 8, weeks. • For the company: See above.	• Higher corporate costs due to a larger workforce • For operators: Lower salary.

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.3	Shift cycle	Guide 1.10	Team staffing levels
Guide 1.4	Weekends	Guide 2.1	Inter-shift interval
Guide 1.6	Duration of day and night shifts	Guide 2.3	Replacements
Guide 1.9	Number of teams	Guide 2.4	Days off, vacations and holidays

1. Schedules: Time Management and Team-related Modifications

Guide 1.2 FIXITY (ALWAYS DAY OR NIGHT) VS ROTATION

a) Objective

Fixity or rotation (day-night) of assignment of teams to the two 12-hour shifts. This choice profoundly influences operators' professional and private lives.

b) Options

1. Permanent assignment to either day or night shifts.
2. Rotating shifts (current situation).
3. Combination of the two: operators work day shifts for part of the year and rotating shifts for the remainder.
4. Alternate arrangement: some teams work non-rotating shifts (e.g. older workers only work day shifts), while others work rotating shifts.
5. ----------

c) Analysis of options

Option	Advantages	Disadvantages
1	• Ideal for day-shift workers but no advantage for night-shift workers, because the body resynchronises itself to a "normal" day cycle after only one day off spent on a traditional diurnal cycle; adaptation is therefore impossible. • Fewer workers assigned to night shifts. • Lower corporate costs. • Easier planning and organisation of private life.	• Permanent exposure of some operators to the stresses of night work. • Social and professional isolation of night-shift operators. • Chronic sleep disorders and diminished alertness among night-shift operators, with negative effects on health and the reliability of operations.
2	• Distribution of the negative effects of night work over more people, but at a lower individual intensity. • Alternation of difficult periods (in terms of sleep, family life and leisure) with easier ones. • Reduced resynchronisation-related effects on health and sleep, due to the very limited adaptation of biological rhythms if short shift cycles are chosen.	• Increase in the number of workers exposed to the stresses of night work and shift work. • Feelings of instability and difficulty in planning private life, due to schedule fluctuations. • Addition of the disadvantages of both rotating and non-rotating schedules if long shift cycles are chosen • Higher corporate costs.
3	• See Option 1 for the advantages of non-rotating day shifts and Option 2 for the advantages of rotating shifts.	• See Option 2 for the disadvantages of rotating portion of the schedule. Because there is no non-rotating night work, the disadvantages of Option 1 are absent. • Higher corporate costs.
4	• Takes into account the age of the operators. • See Option 1 for the advantages of non-rotating day shifts and Option 2 for the advantages of rotating shifts.	• See Option 1 for the disadvantages of non-rotating night shifts, and Option 2 for the disadvantages of rotating shifts. • Higher corporate costs.

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.3 Shift cycle

Guide 1.9 Number of teams

Guide 2.1 Inter-shift interval

Guide 2.6 Multiple qualification

1. Schedules: Time Management and Team-related Modifications

Guide 1.3 SHIFT CYCLE, ROTATION SYSTEM

a) Objective

The shift cycle determines both the number and rotation pattern of day and night shifts (see also Guide 2.1 for the distribution of rest periods). A wide variety of shift cycles are possible. In general, shift schedules may be:

- **Regular** (identical number of consecutive shifts: 2-2-.., 6-6-..., etc.) or **irregular** (e.g. 3-2-3-2).
- **Fast** (3-3-3-3-3-3-) or **slow** (6-6-6-6-6-6-)

***b) Options** (D: day; N: night; O: off; f-s-s: Friday-Saturday-Sunday; m-t: Monday-Tuesday; w-t: Wednesday-Thursday)*

1. Current cycle, but with a 2-day rotation:
   D-D O-O D-D O-O N-N O-O N-N O-O ...
2. Two-day rotation, with longer intervals between night shifts:
   D-D O-O N-N O-O D-D O-O N-N O-O-...
3. Division of the week into three sections (3-2-2), with alternation of work and days off, and alternation of day and night shifts:
   D-D-D O-O N-N O-O-O D-D O-O N-N-N O-O D-D O-O-O N-N O-O D-D-D...
   F-s-s m-t w-t f-s-s m-t w-t f-s-s m-t w-t f-s-s m-t w-t f-s-s
4. Two days off following day shifts and four days off following night shifts:
   D-D-D O-O N-N-N O-O-O-O D-D-D O-O N-N-N O-O-O-O...
5. Clustering the 6 night shifts within the current 24-day cycle:
   N-N-N-N-N-N-O-O-O-O-O-O-O-D-D-D-O-O-O-D-D-D-O-O-O...
6. ---------- (other options devised by the discussion group).

c) Analysis of options

Option	Advantages	Disadvantages
1	• Reduced sleep deficit. • Reduced resynchronisation-related effects on health, at least in theory, due to the very limited adaptation of biological rhythms during day shifts.	• Fewer consecutive days off. Difficulties in managing private life. Disruption of family life. • Supervisors fear that a two-day rotation will reduce operational continuity.
2	• Rest and work follow a normal diurnal pattern for prolonged periods between night shifts.	• See Option 1. • Disruption of family life.
3	• More free weekends, a frequent and pressing request by operators and their spouses. • A feeling of living on a normal weekly cycle, like most people.	• Only two days off before and after the Friday-Saturday-Sunday night shift. • Less free time during the week.
4	• Better recovery, due to more rest following night shifts. • Increased inter-team communication.	• Abolition of the current system whereby the same teams are either both active or boh off, since the number of days off no longer equals the number of active days. This complicates replacements and schedule exchange.
5	• Provides 18 consecutive days with no night work. • Improved utilisation of free time, thanks to the long series of days off. • Better organisation of social and family life.	• Accumulation of a mean sleep deficit of 6 hours by the end of the night shifts. • Increased health hazard. • Possible partial readjustment of biological rhythms.

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.5	Shift start- and end-times	Guide 1.9	Number of teams
Guide 1.6	Duration of day and night shifts	Guide 1.10	Team staffing levels
Guide 1.7	Distribution of teams over shifts	Guide 2.1	Inter-shift interval

1. Schedules: Time Management and Team-related Modifications

Guide 1.4 WEEKENDS: THE NUMBER OF FREE WEEKENDS AND THE FRIDAY-SATURDAY-SUNDAY SHIFT

a) Objective

One of the most frequent requests voiced by operators and their spouses during interviews was an increased number of free weekends throughout the year. There are essentially two ways of freeing the majority of operators from the necessity of working weekends: modification of the shift cycle or the training or hiring of weekend (Friday-Saturday-Sunday) teams. The latter option is a relatively recently introduced practice that is increasing in popularity around the world. Because of its recent introduction, there is however insufficient data with which to assess its effects on work, sleep, health, and social and family life. Friday-Saturday-Sunday teams are often composed of younger operators whose social life is more compatible with this type of schedule or who use their free time during the week to work at another job.

b) Options

(D: day; N: night; O: off; F-S-S: Friday-Saturday-Sunday; M-T: Monday-Tuesday; W-T: Wednesday-Thursday)

1. Modification of the shift cycle: Division of the week into three sections (3-2-2), with alternation of work days and days off and of day and night shifts:

D-D-D	O-O	N-N	O-O-O	D-D	O-O	N-N-N	O-O	D-D	O-O-O	N-N	O-O	D-D-D...
F-S-S	M-T	W-T	F-S-S	M-T	W-T	F-S-S	M-T	W-T	F-S-S	M-T	W-T	F-S-S

2. Permanent assignment of teams to weekend shift work consisting of 3 nights (Friday-Saturday-Sunday) and 2 days (Saturday-Sunday).
3. ----------

c) Analysis of options

Option	Advantages	Disadvantages
1	• More free weekends. • A feeling of living on a normal weekly cycle like most people.	• Only two days off before and after the Friday-Saturday-Sunday night shift. • Less free time during the week.
2	• Frees a significant number of shift-work operators from the stress of weekend work. • More free time during the week for Friday-Saturday-Sunday operators. • Schedules can be adjusted to reflect the social and familial needs of operators, and the needs of older operators.	• Limited contact between the two groups of operators. • Possible reduction of operational continuity, due to limited contact between operators and weekday technical personnel, including day supervisors. • Risk of Friday-Saturday-Sunday operators becoming marginalised in both their work and private lives. • Difficult to manage absences. • Possible increase in the workload and fatigue of Friday-Saturday-Sunday operators who have a second job during the week.

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.1	Duration of the work week
Guide 1.3	Shift cycle
Guide 1.9	Number of teams
Guide 3.3	Designing schedules and tasks to reflect operators' needs

1. Schedules: Time Management and Team-related Modifications

Guide 1.5 SHIFT BEGINNING- AND END-TIMES

a) Objective

These times determine:

- The time teams relieve each other.
- The beginning and end of work and, by extension, the beginning and end of private life.

b) Options

1. Earlier: 06:00-18:00
2. Later: 07:00-19:00, 07:30-19:30, 08:00-20:00
3. Unequal shift lengths: shorter night shift and longer day shift, or vice versa (see Guide 1.6).
4. Extended shift relief (See Guide 1.7).
5. ----------

c) Analysis of options

Option	Advantages	Disadvantages
1	• Day shift: None at the beginning of the day, but more free time in the evening for family life and social activities. • Night shift: Work finishes earlier, increasing the chances of satisfactory sleep during the day.	• Operators working day shifts have to get up early (04:30 for those living the farthest from work). • Even day-shift operators suffer the disruptive effects of night shifts and the 04:00 dip in biological rhythms.
2	• None for night-shift operators. • Day shifts are truly "day" shifts, due to major improvements in sleep.	• Day shift: Evenings are unavailable for family and social activities. This is particularly problematic for families with young children. • Night shift: The late hour at which operators go to sleep compromises sleep during the day.
3	See Guide 1.6	See Guide 1.6
4	See Guide 1.7	See Guide 1.7

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.1	Duration of the work week
Guide 1.6	Duration of day and night shifts
Guide 1.7	Distribution of teams over shifts

1. Schedules: Time Management and Team-related Modifications

Guide 1.6 DURATION OF DAY- AND NIGHT SHIFTS

a) Objective

The allocation of the 24 hours of the day, i.e. the number and duration of shifts, is determined by the manner in which shifts are implemented. Modifications of the duration of day and night shifts are usually undertaken to shorten the most stressful work periods.

The current system calls for two 12-hour shifts. In practice, however, the real duration of work exceeds 12 hours, due to the time needed to transmit instructions and information between teams. The mental workload associated with travel to and from work increases the workload already accumulated during operators' 12-hour shifts. This travel-related workload averages approximately 25 minutes at the beginning of the day shift (06:00), but is of special concern at the end of the shifts: 25% of operators reported fearing a fatigue-induced road accident, while 10% reported having already been involved in at least one such accident. On the other hand, operators consider day-shifts as the most stressful.

b) Options

1. Division of the 24 hours of the day into more than 2 shifts, e.g. a day shift of 12 hours, an evening shift of 6 hours, and a night shift of 6 hours.
2. A 10-hour day shift and 14-hour night shift.
3. A 14-hour day shift and 10-hour night shift.
4. ----------

c) Analysis of options

Option	Advantages	Disadvantages
1	• Reduction of the duration of night shifts. • Reduction of the frequency with which operators are exposed to work-related stresses between 00:00 and 06:00.	• Increased travel to and from work. • Reduced number of free-time periods. • Renders replacements more complex. • Incorporates several disadvantages of the 3 x 8 design already rejected by operators.
2	• Shortened day shifts, the shifts operators consider to be the most stressful.	• Night shifts, whose length is already a source of fatigue, are longer. • Sleep and recovery time of night-shift operators are reduced.
3	• Shortened night shifts, which exact the highest toll in terms of sleep, health, and family life.	• Longer day shifts, the shifts operators consider to be the most stressful. • Day-shift operators sacrify either sleep or social and family life.

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.3 Shift cycle

Guide 1.5 Shift start- and end-times

Guide 1.7 Distribution of teams over shifts

Guide 1.9 Number of teams

1. Schedules: Time Management and Team-related Modifications

Guide 1.7 DISTRIBUTION OF TEAMS OVER SHIFTS: INTER-SHIFT MOBILITY (EXTENDED SHIFT RELIEF) AND INTRA-TEAM MOBILITY, JOB OVERLAP

a) Objective

Determines the succession of teams from shift to shift. Normally, there is complete succession, with a new team relieving the entire team from the preceding shift. This requires teams to be completely interchangeable, limits their ability to accommodate delays in shift relief, and affords insufficient time for the transfer of process information (e.g. state, trends, incidents, preventive maintenance) relevant to monitoring activities. Job overlap ensures that at least parts of the two teams are on the site simultaneously. The duration of the overlap influences system reliability, the number and the duration of shifts (no overlap is possible in a schedule consisting of two 12-hours shifts), and staffing levels (number of teams, number of workers on teams over time).

b) Options (options 1 and 2 apply to the distribution of teams over the shifts, while options 3 and 4 apply to shift overlap)

1. Extended shift relief, with no change to shift duration (also known as *inter-shift mobility*). Allows operators responsible for the same unit in successive teams and with identical durations of work to relieve each other at any mutually convenient time within two hours of the nominal relief time.
2. *Intra-team mobility*: Variable individual schedules among the members of the same team comprised of fixed- and variable-duration components.
3. Overlap times of less than 20 minutes (current situation).
4. Partial overlap: Overlap times exceeding 1 hour.

c) Analysis of options

Option	Advantages	Disadvantages
1	• Improves information transmission while avoiding the costs associated with formal shift overlap. • Shift workers can make mutually convenient arrangements to manage their time and delays.	• Requires sufficient staffing levels. • Requires good coordination. • Over the long term, increases the duration of work for some positions. • Renders management of absences and the planning of days off more complex.
2	• Allows operators to devote some of their shift time to tasks other than monitoring and control, e.g. training, union, corporate life.	• See above.
3	• Reduced corporate costs.	• Inadequate transmission of Information and directives. • Inflexible management of delays.
4	• Accommodates delays in shift relief. • Facilitates shift initiation and return from days off. • Improves inter-team cohesion.	• Higher corporate costs due to a larger workforce.

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.3	Shift cycle	Guide 2.1	Inter-shift interval
Guide 1.5	Shift start- and end-times	Guide 2.3	Replacements
Guide 1.6	Duration of day and night shifts	Guide 2.5	Prolongation of shifts, emergency staffing
Guide 1.9	Number of teams	Guide 2.6	Multiple qualification
Guide 1.10	Team staffing levels		

1. Schedules: Time Management and Team-related Modifications

Guide 1.8 BREAKS, REST PERIODS DURING SHIFTS, NAPS

a) Objective

This guide is concerned with breaks paid as worked time. Break time is defined as the period during which operators interrupt their tasks and leave their workstations to recover, relax, or rest. This company, in common with most companies requiring continuous control and monitoring, does not formally mandate break times, or for that matter, meal times. The schedule has been designed with the assumption that operators remain in top condition and maximally alert throughout both day and night shifts, and that they can adjust their activity to reflect chronobiological variations without affecting the quality of their work. It should be recalled that "the obligation to remain at their work does not automatically imply the ability to keep a job".

b) Options

1. No formally mandated breaks (current situation).
2. Introduction of optional breaks. This means determining:
   - the time at which these breaks are to be taken (fixed times, on demand, as a function of work constraints)
   - the duration of the breaks; this may vary as a function of the time of day
   - the consequences on team dynamics. Staffing levels should be high enough to ensure that operators who take breaks do not cause delays or an increased workload.
   - the challenges to implementing breaks, e.g. abuses or inequitable attribution of preferred break times.
   - Space for operators to take their breaks must also be found.
3. ----------

c) Analysis of options

Option	Advantages	Disadvantages
1	• None	• Obliges operators to remain very alert for almost the entire length of their long (12-hour) shift. • Increases the risk of human error and diminishes process reliability and personal safety. • Renders prevention of, correction of, or compensation for fatigue and reduced alertness impossible. • Does not facilitate eating under good conditions.
2	• By allowing operators "time out", favours relaxation and rest, indirectly increases alertness. • Officially sanctioned breaks help counteract the effects of sleep deficit accumulated during night shifts.	• None, if staffing levels are increased accordingly; otherwise, the workload may increase or be transferred. • Difficult to attribute preferred break times equitably.

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.1	Duration of the work week
Guide 1.6	Duration of day and night shifts
Guide 1.7	Distribution of teams over shifts
Guide 1.10	Team staffing levels
Guide 2.6	Multiple qualification

1. Schedules: Time Management and Team-related Modifications

Guide 1.9 NUMBER OF TEAMS (SHIFT CREWS)

a) Objective

The number of groups necessary to ensure process continuity, and therefore, the number of groups assigned to other activities (e.g. special projects, corporate or union meetings, training) resting, or taking days off. The available options depend on the number of operators in each work team and the number of positions per team. **Note:** The continuous-work week requires devoting 168 hours to control and monitoring tasks, with additional workforce required to accommodate replacements for absences or vacations, assignment to special projects, and training. Simple arithmetic therefore indicates that it is necessary to add at least one additional team of operators to bring the real shift duration into line with the nominal duration of 37⅓ hours. In fact, it is recommended that there be more than 5 teams, in order to:

- making schedule planning more flexible
- avoid subjecting operators to the stresses of shift work throughout the year
- avoid subjecting operators to the stresses of shift work throughout their careers
- distribute the stresses of night work over more people and reduce the frequency of individual exposure to shift work.

b) Options

1. 4 teams (current situation)
2. 5 teams
3. 6,7, or 8 teams or half-teams, which would allow operators to alternate between shift work and assignment to non-rotating day shifts. It may be possible to assign only parts of teams to night shifts, but this requires task redesign and operators with multiple qualifications.
4. ----------

c) Analysis of options

Option	Advantages	Disadvantages
1	• None	• Impossible to operate the refinery 168 hours per week with only 4 teams without extensive reliance on overtime. • Even more overtime incurred because of replacements for absences, days off, or non-monitoring activities. • Same disadvantages as below.
2	• Allows implementation of a real work week with a duration of 37⅓ hours, as mandated.	• Rotating shift work on a permanent basis. • Difficult for operators to attend meetings without ruining their days off. • Difficult to manage replacements.
3	• Increased number of day-shifts worked. • Reduced number of nights and weekends worked. • Allows operators to be assigned to other tasks or receive training. • Facilitates meetings during normal hours, leading to better cohesion. • Probable reduction of absenteeism. • Better choice of days off and vacations. • Allows some teams to avoid all night work (an interesting option for older workers).	• Distributes exposure to night work over more people, but reduces the frequency of individual exposure to shift work. • Increased workload for half-teams working night shifts. • More complex schedule management. • Difficult to find, create, and manage permanent day jobs with interesting and rewarding tasks. • Possible loss of advantages officially associated with shift work (e.g. early retirement, salary).

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.2	Rotating vs non-rotating shift work	Guide 1.6	Duration of day and night shifts
Guide 1.3	Shift cycle	Guide 2.1	Inter-shift interval
Guide 1.4	Weekends	Guide 2.4	Days off and vacations

1. Schedules: Time Management and Team-related Modifications

Guide 1.10 TEAM STAFFING LEVELS

a) Objective

The number of operators per team is determined by two factors: the number of positions and the number of operators at these positions. **Note:** Although operators' work consists of monitoring and controlling one or two units per site, the number of positions is not a simple function of the number of units. Therefore:

- Calculation of the number of positions should take into account the nature of the real work and its irregular demands. This requires detailed analysis of the nature and temporal variation of tasks, and a full understanding of the frequent or occasional disruptions that may arise.
- System reliability depends on operators' ability to cope with different situations at any time. It is however known that this ability is very dependent on circadian psycho-physiological rhythms. The calculation of staffing levels should also take into account this phenomenon.
- In addition to their regular activities (control and monitoring of refinery production processes), operators are called upon to participate in special projects, give or receive training, perform secondary tasks, participate in union activities, and attend meetings. The calculation of staffing levels should take this into account.
- The calculation of staffing levels should also take into account the need to manage absences due to illness or personal reasons.

b) Options

1. Fixed team-staffing levels, i.e. the same number of operators and positions workstations on all shifts.
2. Lower levels at night, higher ones in the day.
3. Higher levels at night, lower ones in the day.
4. Variable levels from team to team, e.g. increased levels within a team facing unusual conditions such as shut-down or start-up, training of new operators, or special projects.
5. Increased levels in both day and night shifts, particularly at "little" sites, where workload is high.

c) Analysis of options

Option	Advantages	Disadvantages
1	• Team stability.	• Inflexible response to disruptions. • Inflexible task distribution.
2	• Fewer operators working the stressful night shift. • If well planned should lead to a reduction of night-shift tasks. • Reduced individual workload on day shifts, currently rather high. • Allows reassignment of older operators to day shifts.	• Reduced intervention capacity during night emergencies, due to reduced number of operators and their diminished functional capacity. • Isolation at night at "little" sites. • Requires all operators to have multiple qualifications at all site units.
3	• Improved reaction to night incidents. • Reduction of the individual cost of night work (distribution of workload, postponement of work).	• More operators subjected to the stresses of night work.
4	• Improved flexibility in the distribution of tasks.	• Requires tight planning
5..	• Reduces workload at these sites, currently rather high. • Increases operational reliability.	• Higher corporate costs, due to a larger workforce.

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.7	Distribution of teams over shifts	Guide 2.6	Multiple qualification
Guide 1.8	Breaks, rest periods during shifts, naps	Guide 2.7	Training
Guide 1.9	Number of teams	Guide 3.2	Designing work to reflect schedules

2. Personnel management

Guide 2.1 INTER-SHIFT INTERVAL

a) Objective

The inter-shift interval is the period between the end of an operator's shift and the beginning of his or her next one. In theory, it is determined by the shifts' type (day or night), duration, and cycle. In practice, it is also greatly influenced by transportation time and disruptions such as replacements, shift prolongation (or even doubling), recovery, and shut-downs. The definition of suitable or acceptable inter-shift intervals must take into account everything that disrupts conformity to the theoretical shift cycle. The inter-shift interval is one of the determinants of the duration of rest periods, albeit not the only one. "Rest" is defined for these purposes as the non-presence at work, be it between two successive shifts, at the end of identical shifts, on weekends, at the end of a work cycle, or annually. The choices in this area are related to the shift cycle, organisation of leisure time and the duration of the real work week.

b) Options (1-4 apply to the interval between two shifts; 5 and 6 apply to weekly and annual rest)

1. Short inter-shift interval: no more than 12 hours (current situation)
2. Inter-shift interval of 16 hours or more
3. 24-hour period with **no** night rest between 22:00 and 06:00 (current situation)
4. 24-hour period with night rest between 22:00 and 06:00
5. Maximum possible weekend rest (not counting recovery following a night shift)
6. Minimum annual rest of 6 consecutive weeks for shift workers

c) Analysis of options

Option	Advantages	Disadvantages
1	• Allows protracted rest (days off, 9 days) following several successive night or day shifts. These rest periods are marked by a return to a more "normal" life, a change of lifestyle, relaxation, travel, and other activities.	• Diminished rest time between shifts, leading to impaired recovery and accumulation of fatigue. Limited advantages in terms of social and family life in cases where operators' spouses work and children are at school.
2	• More opportunity for recovery. Lesser accumulation of fatigue. Smaller sleep deficit.	• Fragmented family, social, and leisure life. • Harder to manage schedules and work, due to lack of follow-up.
3	• See Option 1. • Easier planning and management.	• Significant unfavourable effects on sleep and health.
4	• In order to safeguard sleep and health, every night shift should be followed by at least one rest period during which sleep is possible between 22:0 and 06:00.	• See Option 2. • A feeling of living a fragmented life.
5	• Facilitates family and social life (see Guide 1.4).	• Planning of schedules is more complex. • Increased corporate costs.
6	• Eventual restoration of biological functions that have deteriorated as a result of shift work.	• See Option 5.

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.1	Duration of the work week	Guide 1.8	Breaks, rest periods during shifts, naps
Guide 1.3	Shift cycle	Guide 1.9	Number of teams
Guide 1.4	Weekends	Guide 2.3	Replacements
Guide 1.5	Shift start- and end-times	Guide 2.4	Days off and vacations
Guide 1.6	Duration of day and night shifts	Guide 2.5	Prolongation of shifts, emergency staffing
Guide 1.7	Distribution of teams over shifts	Guide 2.9	Home-work travel, transportation, housing

2. Personnel management

2.2 EARLY RETIREMENT, PROGRESSIVE RETIREMENT

a) Objective

Due to the short- and medium-term effects of shift work on well-being and social and family life, and to compensate for and delay the development of long-terms effects on sleep and health, shift workers should be able to opt for early or progressive retirement. This requires implementing flexible mechanisms.

Notes:

- Many operators have been exposed to the hazards of shift work for a relatively long time (over 17 years, on average). This includes work on both 8- and 12-hour shifts, in the company studied here and elsewhere.
- In 1994, the eligibility criteria for penalty-free early retirement was changed from 50 years to 55 years, and 25 years of seniority (2% of the mean annual salary over the three best years, for each year of seniority). This modification applies to all employees, regardless of whether they were ever shift workers.
- Any new measures must remain optional, not mandatory.
- Individuals have different health and needs. A single solution is not recommended: "flexibility" is the key here.

b) Options

1. Early retirement for all workers. Eligibility on the basis of years working shifts (3x8, 2x12, or other). **One year of retirement for every five years of shift work** would be an equitable arrangement, for example.
2. Progressive retirement for older workers, through a progressive reduction of the work week.
3. ----------

c) Analysis of options

Option	Advantages	Disadvantages
1	• Removes operators from shift work when it is no longer tolerable. • Partially compensates for stresses and other effects of shift work. Compensation is proportional to the duration of exposure and is in the same form — time — as the original cost.	• The salary on which pension income is based is less than it would be if early retirement was not taken.
2	• Removes aging workers from shift work. • The hiring of young operators, and their work alongside older ones, ensures the continuity of work skills.	• Possible isolation of aging workers and failure to transmit skills if some teams are composed exclusively of older shift workers.

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.1	Duration of the work week
Guide 1.9	Number of teams
Guide 1.10	Team staffing levels
Guide 2.8	Reassignment: planning and prevention
Guide 3.3	Designing schedules and tasks to reflect operators' needs

2. Personnel management

Guide 2.3 REPLACEMENTS

a) Objective

Mechanisms designed to compensate for the absence of team members by operators capable of occupying the same position(s). Failure to adequately organise this type of absence compromises operational reliability, especially during production disruptions.

Notes:

- Replacements may be either planned (e.g. non-monitoring tasks, special projects, training, meetings) or unplanned (health or personal reasons). Both types of absence should be foreseen and the management of replacements planned for accordingly.
- Replacements reduce the inter-shift interval, interrupt rest time, and reduce the number of days off and the duration of vacations.
- The ability to manage absences is a function of the number of teams, team staffing levels, intra-team mobility and the extent to which operators have multiple qualifications.

b) Options

1. Reliance on operators from other teams, with replacement overtime paid as double time (current situation). The demand should be distributed over all available operators, and replacement operators should have the right to refuse replacement work. The notice required, number and schedule of the replacement shifts, and recovery mechanisms all have to be defined.
2. Reliance on day personnel. This requires ensuring staffing levels adequate for the constitution of a replacement pool within the same team, and some operators from each site working permanent day shifts. Alternatively, each operator in each team could alternate between non-rotating day shifts — which would allow them to replace absent operators — and rotating shifts.
3. ----------

c) Analysis of options

Option	Advantages	Disadvantages
1	• For the company: Easy management of absences, since replacement operators already know the work well. • For replacement operators: Increased pay.	• For replacement operators: Disruption of work and rest. • Post-night-shift rest intervals shorter than the recommended 36 hours. This leads to the accumulation of fatigue and development of sleep deficits. • At the present time, a hazardous solution that compromises personal and site safety, due to the absence of adequate staffing levels.
2	• Great flexibility in the management of absences. • Replacement operators already know the work. • Considerable reductions in overtime (paid as double time). • Facilitates reassignment of older workers. • Increases operational reliability. • Reduces overtime shift work, thereby improving shift workers' sleep and health by .	• Higher corporate costs due to the need for additional teams or for more operators in each team. • Reduces real mean annual salary of operators, by reducing overtime.

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.3	Shift cycle	Guide 1.10	Team staffing levels
Guide 1.5	Shift start- and end-times	Guide 2.1	Inter-shift interval
Guide 1.6	Duration of day and night shifts	Guide 2.5	Prolongation of shifts, emergency staffing
Guide 1.7	Distribution of teams over shifts	Guide 2.6	Multiple qualifications
Guide 1.9	Number of teams		

2. Personnel management

Guide 2.4 DAYS OFF, VACATIONS, HOLIDAYS

a) Objective

Implement mechanisms allowing operators to take their days off and vacations at times of their choosing. Management of vacations and days off is complex, since demand tends to be concentrated in a few periods (summer, autumn, holiday season, February) during which the greatest number of workers take the greatest number of consecutive days off. Management options are highly dependent on staffing levels (number of teams and number of operators per team) and the availability of operators with multiple qualifications.

b) Options (N.B.: These may be combined)

1. Increased team staffing levels, either throughout the year or at selected times of the year. This is an especially important option given the small number of positions, particularly at "little" sites (Guide 1.10).
2. More teams (Guide 1.9).
3. Avoiding planned extraordinary activities (e.g. shut-downs) during these periods.
4. ----------

c) Analysis of options

Option	Advantages	Disadvantages
1	• More opportunities for operators to take days off and vacations when they wish. • See also the advantages of the different options listed in Guide 1.10	• See Guide 1.10 • More operators assigned to shift work. • Higher corporate costs due to a larger workforce.
2	• More opportunities for operators to take days off and vacations when they wish. • See also the advantages of the different options listed in Guide 1.9	• See Guide 1.9 • More operators assigned to shift work. • Higher corporate costs due to a larger workforce.
3	• More opportunities for operators to take days off and vacations when they wish.	• Complicates management somewhat. Requires tight and integrated planning of schedules and tasks, as well as good coordination.

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.9	Number of teams
Guide 1.10	Team staffing levels
Guide 2.1	Inter-shift interval
Guide 2.3	Replacements
Guide 2.6	Multiple qualification
Guide 3.2	Designing work to reflect schedules

2. Personnel management

Guide 2.5 BACK-UP PERSONNEL, PROLONGATION OF SHIFTS, EMERGENCY STAFFING

a) Objective

The ability to manage shift prolongation is a function of the resources available to cope with last-minute failures to relieve a shift or to prolonged delays in shift relief.

Notes:

- The duration of this prolongation should be minimised.
- Shift prolongation's direct effect is to prevent the immediate rest and recovery from fatigue that normally occur at the end of the shift. Because of their already stressful length, 12-hour shifts, particularly night shifts, exacerbate this effect. Operators working prolonged shifts may suffer from accumulated fatigue, and this may decrease their reliability. It is therefore necessary to limit shift prolongation through measures such as increased staffing levels.
- The feasibility of providing emergency personnel (reserve personnel available for unforseen operations) should be considered, and adequate staffing levels planned. These workers should have proven competence at several workstations on their site. Emergency staffing may be implemented in two ways: by reinforcing each team with multiply qualified operators, or creating refinery-wide day-shift teams comprised of operators from each site with multiple qualifications at their home sites.
- Since the first inspection round of each shift is the most critical for succeeding operations, choices related to shift prolongation have an enormous influence on operator fatigue and, by extension, operational reliability.

b) Options

1. Prolongation of no more than one hour, to compensate for late shift relief. Operators prolong their work time until their colleagues arrive (a frequent situation).
2. Prolongation of more than one hour, i.e. failure to relieve. Requires emergency staff (see above for the composition of special teams of multiply qualified day operators).
3. Sufficient staffing levels can ensure the ability of teams to accommodate failure to relieve. This requires reinforcing teams with one or two suitably qualified operators.

c) Analysis of options

Option	Advantages	Disadvantages
1	• Accommodates moderate delays without recourse to emergency teams.	• Significantly increases shift duration and workload. • Consequences for transportation. • Disrupts the social and family life of day-shift operators who had their shift prolonged. • Disrupts the sleep of night-shift operators.
2	• Accommodates long delays with recourse to emergency workforce	• Short notice for emergency staff. • Significant shift prolongation.
3	• A palliative measure designed to avoid frequent recourse to emergency staff.	• Requires great mobilisation and mobility of the team.

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.5	Shift start- and end-times	Guide 1.9	Number of teams
Guide 1.6	Duration of day and night shifts	Guide 1.10	Team staffing levels
Guide 1.7	Distribution of teams over shifts	Guide 2.6	Multiple qualifications

2. Personnel management

Guide 2.6 MULTIPLE QUALIFICATION

a) Objective

Ability of operators to occupy more than one position at a given site (N.B. Multiple qualification at more than one site is rare in this company). Multiple qualification designates both operators' knowledge of the monitoring tasks associated with the different units of their site, and the way this knowledge was acquired and is applied within their team (training and teamwork).

Notes:

- Discussion here is limited to the nature of multiple qualification, not its financial impact (salary).
- Currently, 58% of operators are qualified on all the units of their site.
- The company's current management encourages multiple qualification through training, career plans, rotation of all operators through all units on their site and to the position of lead operator, performance of secondary tasks, etc. However, this policy has met with strong resistance from many operators, who perceive it as an important source of increased workload.
- Notwithstanding the aforementioned stakes and hazards, it should be emphasized that multiple qualification, properly understood and applied, is **a fundamental component of strategies designed to prevent the negative effects of shift work**. It is essential that operators have the opportunity to occupy multiple positions within their team, as this renders the team more flexible. The benefits of this flexibility include:

    - better management of absences and delays
    - facilitation of replacements
    - distribution of the workload over more people
    - reduction of accumulated fatigue, sleep problems, and, over the long term, health problems
    - facilitation of reassignment of older workers to more rewarding day work
    - facilitation of problem resolution through teamwork, which reduces individual workload and increases process reliability.

b) Options

1. Review the current situation (task analysis, extent of multiple qualification in each team at all sites) to identify what works best at the site and refinery level. Partial data is available from the review of operators' career path and planning for the second skills, and from sites currently undergoing job redesign.
2. Draw up an inventory of the gateways from one job to another, especially regarding shift work vs permanent day work.

c) Analysis of options

Option	Analysis
1	Qualifications for team activities should be shared among team members. A review of the real situation at each site should allow identification of the extent and forms of shared competence.
2	An inventory of job gateways is an essential component of schedule redesign, and is especially useful for the resolution of problems related to reassignment.

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.3	Shift cycle	Guide 1.10	Team staffing levels
Guide 1.5	Shift start- and end-times	Guide 2.5	Prolongation of shifts, emergency staffing
Guide 1.7	Distribution of teams over shifts	Guide 2.7	Training

2. Personnel management

Guide 2.7 TRAINING

a) Objective

Identify the conditions for the acquisition and conservation of competence in operators' current positions (so that they can keep their current jobs now and as their work evolves), **and** for mobility, i.e. the ability to take another position in the same company. Training is not merely the process of knowledge acquisition but also includes the learning of methods with which to apply acquired knowledge. It is important to distinguish between:

a) Training that allows operators to keep their job in the face of change, both technical (computerisation) and organisational (progression of operators in their career path, job redesign), and
b) Training that prepares operators for other positions, e.g. secondary tasks, and especially training of current shift workers in day jobs.

In both cases, flexible schedules, team structure, and task distribution increase the accessibility of training.

Notes:

- The options listed below are not mutually exclusive and in fact would be usefully combined.
- This company attaches great importance to training, and organises courses and seminars for operators. These cover the acquisition and upgrading of the technical knowledge needed to perform control and monitoring tasks, secondary tasks, tasks related to operators' career path («second skills»), and special projects. For example, in 1995 the refinery's 180 operators received over 14 000 hours of training, equivalent to 78 hours per operator. Furthermore, new operators receive theoretical and structured practical training on monitoring tasks, with clear evaluation criteria — the work associated with each position is divided into approximately 100 modules and operators must respond correctly to a series of questions on each module to pass. Training takes place in the unit: 4 to 7 weeks are spent learning the unit from the lead operator, followed by 2 weeks of controlled practice. At the end of this training, new operators are placed in charge of their units, under the supervision of the lead operator.

b) Options

1. Training to maintain the current position: Update or increase knowledge, which implies **the availability of time** and the definition of conditions such as course schedule, training mode, and type of trainer.
2. Training for secondary tasks and second skills: Extend knowledge in fields other than the control and monitoring of refinery operations, which implies defining the time, place, and type of training.

c) Analysis of options

Option	Analysis
1	A) Shift work operators' schedules should not constitute a barrier to their attempt to advance their careers. It should be recalled that technical modifications are frequent, and failure to progressively integrate them will result in the elimination of some operators from newly modified positions.
2	B) This type of training is an effective means of rendering shift workers's professional life more flexible, as it facilitates access to other positions, especially day positions.

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.2	Rotating vs non-rotating shift work	Guide 1.10	Team staffing levels
Guide 1.7	Distribution of teams over shifts	Guide 2.6	Multiple qualification
Guide 1.9	Number of teams	Guide 2.8	Reassignment: planning and prevention

2. Personnel management

Guide 2.8 REASSIGNMENT OF SHIFT WORKERS TO PERMANENT DAY JOBS: PLANNING AND PREVENTION

a) Objective

Procedures to create, maintain, or increase the number of non-rotating day positions open to former shift workers, prepare shift workers to occupy this type of position, and ensure that the characteristics of non-rotating day jobs match those of the operators who wish to occupy them.

Notes:

There is no ideal minimum or maximum age to begin or end a career of shift work, but only operators who are more or less tolerant of shift work. Tolerance of shift work depends on both age and age-independent factors. The following points should therefore be kept in mind:

- Operators incapable of tolerating shift work should have the option of transferring to non-rotating day positions. This option should be available from the moment of hiring onward.
- There is an urgent need for these measures. The conversion to non-rotating day work can be long and difficult, and cannot be improvised.
- Professional skills must be taken into account. Offering day positions that have lower qualifications effectively precludes satisfying reassignment.
- There should be no financial obstacles to reassignment.

b) Options

1. Measures to facilitate reassignment of operators of all ages and seniority. These will concern primarily non-rotating day positions (their nature, number, and even their mere existence) and their prerequisites.
2. Preventive measures designed to prevent operators from reaching the threshold for inaptitude or intolerance for shift work.
3. Measures designed to limit the extent of shift work. After a certain number of years working rotating shifts, all operators should have the option of transferring to non-rotating day work.

c) Analysis of options

Option	Analysis
1	It is necessary to define the types of non-rotating day positions appropriate for operators who request reassignment because of their inability to tolerate the effects of shift work on health, work and private life, and the prerequisite training for these positions.
2	Thought should be given to alternating periods of shift work with sufficiently long periods of non-rotating day work.
3	Once operators' attain a certain age and seniority, they should have the option of working non-rotating day shifts.

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.7	Distribution of teams over shifts	Guide 2.2	Early retirement, progressive retirement
Guide 1.9	Number of teams	Guide 2.6	Multiple qualification
Guide 1.10	Team staffing levels	Guide 2.7	Training

2. Personnel management

Guide 2.9 HOME-WORK TRAVEL, TRANSPORTATION, HOUSING

a) Objective

Travel to and from work considerably extends shift workers' already very long work day, encroaches on inter-shift rest, and constitutes a hazard. The extent of the hazard it presents can be reduced through reduction of travel time and implementation of certain other measures.

Note: The time of day workers travel to and from work is a non-trivial consideration which affects the choice of shift start- and end-times (see Guide 1.5). Travel time is affected by other considerations, especially sharing transportation and using shift overlap (extended shift relief, see Guide 1.7) to vary shift start- and end-times

b) Options

1. No company-organised transportation (the current situation, common in North America).
2. Mass transit provided by the company (more frequent in Europe and Asia).
3. Measures to promote the use of collective transportation (car pooling).
4. Measures encouraging operators to live relatively close to the refinery (maximum of 15 minutes travel), e.g. bonuses for living nearby, or even a pool of company homes located near the refinery and rented or sold to operators at reasonable prices.

c) Analysis of options

Option	Advantages	Disadvantages
1	• Flexibility in organising private life. • Facilitation of partial shift overlap and inter-position and intra-team mobility. • Organisational flexibility at sites.	• Prolongation of the real duration of activity, if not actually work. • Increased fatigue. • Increased risk of accidents. • Higher costs for the employees, unless they receive a transportation bonus.
2	• Operators do not have to remain alert at the wheel. • Reduced fatigue. • Reduced risk of accidents. • Employees do not have to assume the cost of transportation by themselves.	• May prolong transportation time. • Complex to organise, given the current geographical dispersion of operators. • High corporate costs. • Reduced operator autonomy and flexibility in organising their time. • Incompatible with variable schedules and team overlap. • Obliges all sites to have identical relief times. • Difficult to plan drivers' work schedules.
3	• See Option 2. • More autonomy than Option 2.	• Fragile organisation, depends on designated driver not being absent or late. • Complicates design of variable schedules and team overlap.
4	• Reduced transportation time. • Reduced housing costs.	• Conflicts with operators' (and the general public's) increasing desire to live far from industrial centres. • Obliges shift-work operators and their families to live near the refinery even when they are not working, i.e. at least half the year.

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.5	Shift start- and end-times	Guide 1.9	Number of teams
Guide 1.6	Duration of day and night shifts	Guide 1.10	Team staffing levels
Guide 1.7	Distribution of teams over shifts		

2. Personnel management

Guide 2.10 ADAPTATION OF COMPANY SERVICES TO SHIFT WORKERS' NEEDS, AND PARTICIPATION OF SHIFT WORKERS IN CORPORATE LIFE

a) Objective

Sift workers in this company feel excluded from corporate life. In addition, permanent day workers and support staff do not always acknowledge the stresses of shift work. The measures presented in this guide are designed to provide solutions to these problems.

Operators' schedules conspire to isolate them from corporate life, despite the fact they are an essential part of the company. It is recommended that time be found for them to participate in their company's professional, social, union and cultural life. Participation in corporate life also means participation in the company's progress and performance, and time should also be allocated to allow operators to learn about modifications of the facilities, maintenance procedures, and instrumentation. Some companies meet this need through the creation of "shadow positions" for day jobs. In addition, better recognition of the stresses of shift work should lead to the company's opening or maintaining services adapted to shift work.

b) Options (1,2, and 3 apply to participation in corporate life; 4 and 5 apply to the recognition of the unique nature of shift work)

1. Provide operators with the technical means to leave the workstation.
2. Ensure adequate staffing levels within teams, so that temporary absences do not increase the workload of the rest of the team.
3. Ensure operators the right, the time, and the opportunity to eat some of their meals at the company cafeteria. This will help reduce the isolation caused by their abnormal schedules.
4. Keep the cafeteria, health service, bank outlet, and gymnasium open day and night.
5. Sensitize management, by immersion if necessary, to the stresses of shift work. This will ensure that they develop the right instincts in managing human resources assigned to rotating shifts (e.g. non-rotating-day-shift workers often forget that the work performed by shift workers on their days off during the week is equivalent to their working on Sunday).

c) Analysis of options

Option	Advantages	Disadvantages
1	• See Guide 1.7 : Distribution of teams over shifts • See Guide 1.8 : Breaks, rest periods	• See Guide 1.7 • See Guide 1.8
2	• See Guide 1.9 : Number of teams • See Guide 1.10 : Team staffing levels	• See Guide 1.9 • See Guide 1.10
3	• Breaks the isolation of operators. • Affords operators the opportunity to eat more regular and balanced meals.	• See Guide 1.10
4	• Possible adaptation of services to the shift workers' schedules. The recognition this reflects is likely to increase feelings of belonging.	• Direct corporate costs (site design, hiring of specialised personnel), but impossible to predict positive effects.
5	• Reduced stress among shift workers. • Increased cohesion of personnel. • Improved efficiency with which schedules and tasks are managed.	• None.

d) Other possibilities (guides) to be considered when making the final choice

Guide 1.7	Distribution of teams over shifts	Guide 1.10	Team staffing levels
Guide 1.8	Breaks, rest periods during shifts, naps	Guide 3.2	Designing work to reflect schedules
Guide 1.9	Number of teams		

3. Task organisation

Guide 3.1 SCHEDULE DESIGN ACCOUNTING FOR WORK CHARACTERISTICS

a) Objective

The design of effective work or team schedules depends on a full understanding of the real work performed, work prerequisites, operational procedures, and cognitive processes, and of their effects on operators' workload and fatigue.

b) Options (may be combined)

The following types of analysis are necessary before redesigning schedules and tasks:

1. **Analysis of nominal work and its conditions of execution:** Types of tasks and their variants, organisational and material conditions of execution (characteristics of tools, workstations, the work space, and the physical environment).
2. **Analysis of real work:** Manner in which the work is executed, nature and variation of operational procedures, cognitive processes (representation of tasks and installations, information processing), differences between nominal and real work.
3. **Analysis of the effects of work:** Perceived, observed, and measured workload, physical, sensory, and mental fatigue, long-term effects (chronic pathologies, premature aging, differential mortality).
4. **Consultation of operators** affected by the redesign.

c) Analysis of options

Option	Analysis of options
1	See section 1.2 of the complete report for information on the company, schedule, and tasks. See Appendix 6 for an analysis of operators' work, summary, and multi-site description.
2	See Option 1.
3	See the assessment of the seven indicators in chapter 3 of the complete report.
4	Future pilot projects should characterize the work at any site undergoing redesign that concretely and directly affects operators. This should be achieved by extending the work analysis appearing in the research report.

d) Other possibilities (guides) to be considered when making the final choice

- All guides.
- Consult parts 2 and 3 of Quéinnec, Teiger and de Terssac "Repères pour négocier le travail posté" [Guidelines for the negotiation of shift work] for information on technical, organisational and human stresses, and the effects of shift work.

3. Task organisation

Guide 3.2 WORK DESIGN ACCOUNTING FOR SCHEDULES

a) Objective

All technical and organisational modifications must take into account the fact that operators' work is **shift** work, and especially that it entails night work. In general, material resources, technical resources, and software are designed and implemented by people who not only do not use them, but work during the day and sleep at night. The same comment also applies to decisions related to work organisation.

b) Options (may be combined)

1. All modifications of working conditions must reflect the continuous nature of the work. Requests for technical or organisational modifications could be examined for conformity to this principle by a representative and competent body, for example.
2. Specifications for new technical designs could include a section on the functional competence required of night-shift operators who are to control the new units.
3. Operators affected by task redesign and technical and organisational modifications must be consulted.

c) Analysis of options

The effects of shift work are a function of both the duration and the nature of the work. **The functional requirements and rhythms of operators must be taken into account** in these fields, which characterise work and the conditions of its execution :

- buildings, work and rest spaces
- human-machine division of labour
- interface design: software design, presentation of information, commands
- workstation layout
- design of the physical environment
- work tools: diagrams, plans, drawings, notices, permits for maintenance work
- training
- **work organisation**, especially the distribution of tasks over time. For example, avoiding start-ups on nights or weekends, when there is no technical support for operators.

d) Other possibilities (guides) to be considered when making the final choice

- All guides.

- See section 1.2 of the complete research Report for information on the company, schedule and tasks. See Appendix 6 for the analysis of operators' work, summary, and multi-site description.

- Consult parts 2 and 3 of Quéinnec, Teiger and de Terssac "Repères pour négocier le travail posté" [Guidelines for the negotiation of shift work] for information on technical, organisational and human stresses, and the effects of shift work.

3. Task organisation

Guide 3.3 DESIGNING SCHEDULES AND TASKS TO SUIT OPERATORS' NEEDS

a) Objective

1. Minimise the frequency and duration of work between 23:00 and 06:00 and the number of operators subjected to this type of work. Shift work, particularly night-shift work, is harmful and nothing can render it harmless. However, some measures can reduce the duration of exposure and number of operators exposed. Since it is impossible to eliminate night work and work at inconvenient or costly times (e.g. weekends, holidays), the only alternative is to implement measures designed to minimise it.

b) Options

1. Devise solutions to avoid having operators work between 23:00 and 06:00
2. Devise solutions to minimise the number of operators subjected to this type of work (e.g. Guide 2.8: reassignment of older shift workers to permanent day work; Guide 2.2 : early retirement; Guide 1.9 : more teams; Guide 1.8 : introduction of breaks and naps; Guide 1.2 : alternation of rotating and non-rotating work; Guide 2.1, option # 6: introduction of a long annual break of 6 consecutive weeks.).
3. Redesign schedules and tasks to take into account operators' priorities.

c) Analysis of options

1. This is a fundamental principle and the most important way to achieve profound improvements in shift work. Issues related to project design, technical-system design, and measures that obviate work between 23:00 and 06:00 have rarely been studied in continuous-production settings, and further research is needed in these areas.

2. See each point's Guide for a summary of its advantages and disadvantages.

3. Priorities are established on the basis of the seven indicators described in chapter 3 of the complete report, and by the unique characteristics and specific needs of the operators at the sites affected by the redesign.

d) Other possibilities (guides) to be considered when making the final choice

- All guides.

- See section of 1.2 of the complete research Report for information on the company, schedule and tasks. See Appendix 6 for the analysis of operators' work, summary, and multi-site description.

- Consult parts 2 and 3 of Quéinnec, Teiger and de Terssac "Repères pour négocier le travail posté" [Guidelines for the negotiation of shift work] for information on technical, organisational and human stresses, and the effects of shift work.