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Managing Shiftwork in European ATM: Literature Review

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Abstract

This literature review represents the first deliverable as part of a feasibility study on Managing Shiftwork in European ATM (MSEA) to define with stakeholders common solutions and/or adaptations that will facilitate the planning and management of flexible working practices (with a focus on shiftwork) to improve safety and productivity/efficiency in ATM. The document summarises available research results on employee health and social requirements, safety, performance, and productivity/efficiency for shiftwork environments.

Keywords

Breaks	Circadian rhythm	Efficiency	Fatigue management
Health	Participation	Performance	Productivity
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Contact Person	Tel	Division
Úna Mellett	+32 2 729 3482	Human Factors Management Business Division (DAS/HUM)

Authors
(in alphabetical order)

Mette Arnvig, Beate Beermann, Birgit Köper, Maren Maziul, Úna Mellett, Cees Niesing and Joachim Vogt

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EATM Infocentre
EUROCONTROL Headquarters
96 Rue de la Fusée
B-1130 BRUSSELS

Tel: +32 (0)2 729 51 51
Fax: +32 (0)2 729 99 84
Email: eatm.infocentre@eurocontrol.int

Open on 08:00 - 15:00 UTC from Monday to Thursday, incl.

DOCUMENT APPROVAL

The following table identifies all management authorities who have successively approved the present issue of this document.

AUTHORITY	NAME & SIGNATURE	DATE
Project Leader Managing Shiftwork in European ATM (MSEA)	Ú. MELLETT	28/04/06
Manager Human Factors Domain	M. BARBARINO	28/04/06
Manager Strategic Safety Action Plan (SSAP)	A. LICU	28/04/06
Chairman EATM Human Resources Team (HRT)	A. SKONIEZKI	28/04/06
Chairman Safety Team	E. MERCKX	28/04/06
Director ATM Programmes (DAP)	G. PAULSON	01/05/2006

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CONTENTS

EXECUTIVE SUMMARY

This document is concerned with the management of shiftwork, especially in the context of Air Traffic Management (ATM). It constitutes one of the deliverables within the Project “Managing Shiftwork in European ATM (MSEA)” as part of the Human Performance and Training Enhancement (HPTE) Planning and Feasibility.

This deliverable contains a literature review about the impacts of shiftwork, its consequences for health, safety, productivity and efficiency as well as its social implications.

The report outlines questions to be answered in relation to shiftwork in the ATM context. It reveals issues for possible further investigation for a safe, healthy and efficient shiftwork management within ATM.

Chapter 1, “Introduction”, outlines the background, objectives and scope of the document.

Chapter 2, “Shiftwork and the ATM Context”, provides a definition of shiftwork and its evolution, the different shift systems and outlines key aspects of shiftwork in the ATM context.

Chapter 3, “Shiftwork and the Individual”, describes the impacts of shiftwork on the circadian rhythm, health, family and social life. The interactions with dispositions like age and morning / evening type are also reviewed.

Chapter 4, “Shiftwork, and Performance and Safety”, outlines the effects of shiftwork on performance and its impact for safety. Features such as the shift length, night work, breaks and number of successive shifts are considered.

Chapter 5, “Shiftwork and Productivity/Efficiency” defines productivity and outlines aspects of shiftwork which impact productivity.

Chapter 6, “Research Examples”, reviews aviation specific issues and delineates exemplary studies concerning shiftwork and atypical working hours in the field of aviation.

Chapter 7, “Shiftwork Design”, provides guidelines for shiftwork design and outlines aspects that need to be considered when implementing shift systems.

Chapter 8, “Conclusions and Insights”, summarises the main lessons learned and insights gained from the literature review. It concludes with suggestions for areas of further work associated with shiftwork management in ATM and what can be learned from experience.

Annex 1 provides a detailed description of some of the studies summarised in Chapter 6.

A list of references, a glossary of terms and a list of the abbreviations and acronyms used in this document are also provided.

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1. INTRODUCTION

1.1 Background

Based on stakeholder consultation, the Human Factors Domain allocated to the EUROCONTROL's Human Factors Management Business Division (HUM), Directorate ATM Strategies (DAS), has identified Managing Shiftwork in European ATM (MSEA) as one of the projects contained in the Human Performance and Training Enhancement (HPTE) Planning and Feasibility.

The rationale for this feasibility study on Managing Shiftwork in European ATM is as follows:

- Managing shiftwork practices designed to match adequately the predictable traffic demand benefits European ATM cost-effectiveness. This was highlighted in a study/report on the "comparison of performance in selected US and European En-route Centres"[1]. The study found that "staff planning and management is not always designed to match traffic. In many centres rosters have remained unchanged for some years and certain practices appear to be imperfectly adapted to current patterns of traffic variation."

- A greater understanding is needed of the interaction between shiftwork practices, health and safety implications, ATM productivity and the safe operations of ATM. In many cases, adopting best practices from other Air Navigation Service Providers (ANSPs) should bring improvements. It is believed that improving the awareness on shiftwork practices will enhance productivity in Europe as well as the health and safety aspects related to human performance:
    - cost/effective gains in the area of delay reduction and responsiveness to traffic changes;
    - solutions to manage the safety impacts of working in an ATM shift environment.

The objective of the feasibility study is to define with stakeholders common solutions that will facilitate the planning and management of flexible working practices (focusing on shiftwork) to improve safety and productivity in the safety critical shiftwork environment of ATM. A literature review of available research results is one of the first deliverables within the feasibility study.

[1] A EUROCONTROL comparative study (2003a) carried out during February 2002 and March 2003 by the Performance Review Unit (PRU) on the request of the Performance Review Commission (PRC), with the cooperation of a number of ANSPs and the US Federal Aviation Administration (FAA).

1.2 Purpose

The main purpose of this document is to provide an overview on available research results in the area of safety, productivity and efficiency in shiftwork environments.

The document also aims to provide insights into areas where possible further development work / enhancements to current practices would facilitate the planning and management of flexible working practices to improve safety and productivity in the safety critical shiftwork environment of ATM.

1.3 Scope

This document is intended to provide a review of the literature on the subject of shiftwork in general (its impact on health, safety, productivity and efficiency) drawing on research results within ATM and related industries. The review is not intended to be exhaustive.

1.4 Structure

This document is divided into eight chapters as shown in Figure 1:

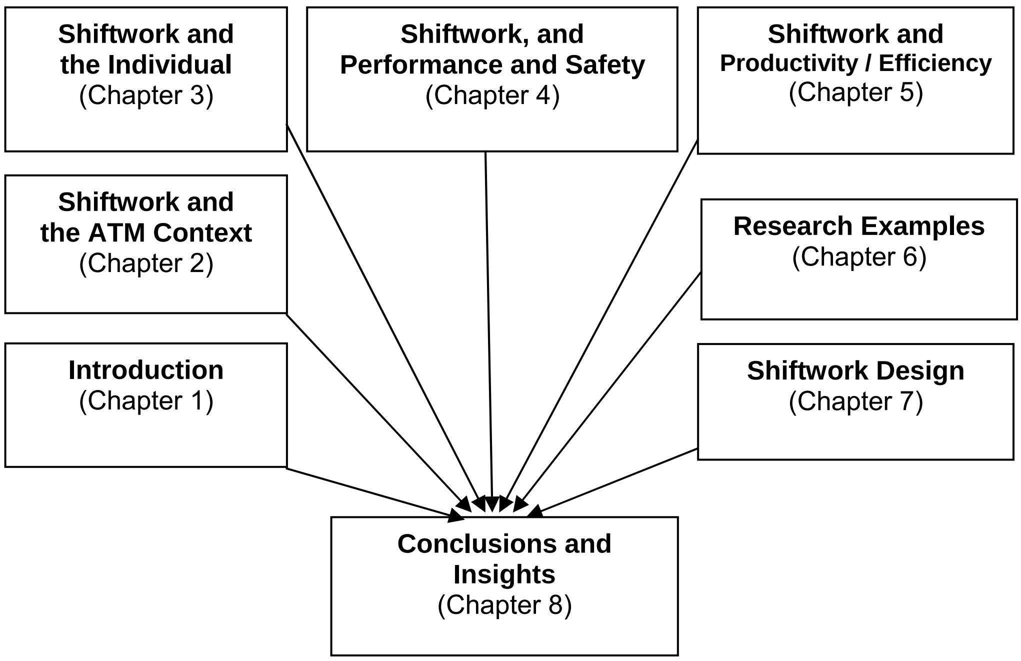

Figure 1. Structure of the document

2. SHIFTWORK AND THE ATM CONTEXT

2.1 Introduction

To understand the specific features of shiftwork in the ATM context a general definition of shiftwork and its development is given. A set of features that characterise shiftwork systems in general is described. In addition, current trends in shift systems are outlined. Finally, similarities and peculiarities of shiftwork in ATM compared to other industries are identified.

2.2 Shiftwork Evolution

The term 'shiftwork' refers to those working-time systems in which work is done at different times over the day or at the same, but unusual time (like night shift; ergonomic definition according to Rutenfranz and Knauth, 1987).

The standard working hours are defined as the period between 6 am and 6 pm five days a week.

The EC Directive 93/104 contains the European regulation for working-time design. The Directive aims at an average maximum weekly working time of 48 hours. Employees working for more than six hours a day are entitled to have a resting time of thirty minutes per day. Moreover, every employee should be granted a daily resting time of eleven subsequent hours within each 24-hour-period. One day per week should be off.

The EC Directive 93/104 defines that the regular working time for night shiftworkers should not exceed eight hours per 24-hour period. A regular medical examination is required for night shiftworkers. Moreover, a shift system should take into account the basic principle that working-time arrangements have to match the requirements of the employees.

While the individual average working time has decreased in Europe during the last years, the average operating time in the production and service sector increased. According to Boisard *et al.* (2002 in Costa, 2003) more than 18.8% of all working people in the European Union have work schedules with night duty.

2.3 Features of Shift Systems

Hahn (1984) delineates several features of shift systems. The most relevant features are the following:

- **Type of Shift**: The position of the shifts within a day (24 hours) characterises the shift type. Early, late and night shift are considered common shift types. However, variations exist.

- **Direction of Rotation**: The sequence of the separate shifts defines another shift feature. Backward and forward rotating shift systems are differentiated. A forward or clockwise rotating shift system begins with early shifts, followed by late and night shifts. In the backward rotating shift system the sequence is *vice versa*. Generally, forward rotating shift systems are more tolerable by the body since they can be better adapted by the circadian rhythm (Chapter 3.2). The subjects of Landen *et al.* (1981) for example were in favour of a clockwise rotation due to health (better sleep, less fatigue, less irritation at work, less stomach problems) but also social reasons (more occasions to be with family and friends). However, backward rotating systems usually offer more free time *en bloc*.

- **Shift Length**: The shift length is simply defined by the number of working hours within one shift. The eight- and twelve-hour shifts are common shifts.

- **Shift System**:

  - **Continuous shiftwork or conti-systems**: Shiftwork 24 hours a day, seven days a week with an operating time of 168 hours per week. They can be found in traditional work fields that have to ensure a 24-hour supply, and in areas that demand work ‘around the clock’ due to technological and economic targets. Employees can work:

    - **permanent shifts**, e.g. permanent early, permanent late or permanent night shift[2];
    - **alternating shifts**, e.g. the conventional system of one week early, one week late, and one week night shift;
    - Other working-time schedules with regular duties on Sundays and public holidays.

  - **Semi-continuous shiftwork**: Shiftwork 24 hours a day, five days a week.

  - **Non-continuous systems** have a weekly working time of up to 120 hours.

- **Shift change cycle** which refers to “how many shifts of the same type have to be worked in a row” (Hahn, 1984). A daily change of the shift type – working the early shift the first day, the late shift on the second day and the night shift the third day – characterises a very quick change (short

[2] Traditional shiftwork research has rejected permanent night work for ergonomic reasons because of the physiological de-synchronisation, but permanent night work still constitutes an issue of today’s research (Folkard, 1992; Wilkinson, 1992; Wedderburn, 1992). Taking the fact that the physiological de-synchronisation is not the only influencing parameter as a starting point the question arises if permanent night work can be approved given the specific individual dispositions, social situation, and an appropriate task. Some research results support this view having found a certain percentage of shiftworkers who adapted to night work – in contrast to the conventional view of occupational medicine (Wilkinson, 1992). The persons affected had adapted physiologically and mentioned only little impairment. The characteristic criteria that create this adaptation cannot clearly be defined yet (Folkard, 1992).

cycle). Apart from a daily change there can be for example changes every two, three or seven days (long cycle).

- **Shift organisation:**

  Shiftwork can be organised in:

  - **Individual rosters** considering most of the preferences an individual person might have with respect to shiftwork.
  - **Team rosters** organising shiftwork on the basis of teams. The team is responsible for distributing free time (days off, holidays, etc.) among the team members, who thereby have some democratic vote on their preferred free time. Certainly, this requires cooperation, communication, flexibility and that all members can work at all positions.

Table 1 summarises the different features of shift systems and gives examples.

Table 1. Features of shift systems

Shift System Feature	Example
Type of shift	e.g. early, late, night shift
Direction of rotation	forward and backward rotation
Shift length	e.g. eight- to twelve-hour shifts
Shift system	e.g. continuous, alternating, permanent night shifts
Change of shift cycle	e.g. daily change of shift type (short cycle), change of shift every second, third, seventh (long cycle) day
Team vs. individual	the individual employee can mention preferences for his/her shiftwork vs. teams of employees organise the roster in a democratic way

2.4 Shiftwork in Times of Global and Organisational Change

Globalisation, market and competition pressures are changing our life in general and our work in particular. The organisational changes require less structure (hierarchy), more flexibility and more innovation in less time. Mergers, outsourcing, downsizing, lean management, project work, and different forms of entrepreneurship have led to an intensification of work.

The main trends are (modified according to Frese, 2000):

- dissolution of work unity in space and time;
- faster rate of innovation;
- increased complexity;

- global competition;
- catabolic and anabolic processes in unit size at the same time, i.e. organisations grow larger or smaller, just as managers think it is appropriate at a certain time;
- changes in job and career concepts;
- more teamwork and projects, less supervision and leadership;
- increased cultural diversity.

Due to the increasing complexity, dynamics, flexibility, and intensity of work, there has been a move away from the **tripartite division of the day** – eight hours work, eight hours leisure, eight hours sleep – suggested by Rutenfranz *et al.* (1976). The development of working-time schedules has shown that the 'normal' working time in a conventional sense is an obsolete model because more people are working shifts. The current development of shiftwork reveals that the standard working time loses its role as a general model and is used only as a norm for deviations (Seifert, 1993a, 1993b).

There is an enormous amount of different shift systems. In the last few years systems with short rotations have spread considerably. Alternate shift systems are more common in Europe than permanent systems.

The 'traditional' classification framework (Table 1) is often not suitable to describe the variety of today's working-time models. A simple categorical classification is hardly possible. There are systems with little resemblance of traditional shiftwork for example (Kutscher & Weidinger, 1992; Weidinger *et al.*, 1989; Gaertner, 2003):

- **Split-shifts**: A split-shift is a day of work divided into periods with some hours off between them. For example, a waiter might work at a restaurant from 7 am until 11 am and from 6 pm until 11 pm. The hours between 11 am and 6 pm are off. A split-shift combining morning and afternoon has been typical for hospitals in the past. However, these rotas very often do not match the needs of employees and therefore shiftworkers are frequently dissatisfied with split-shifts. In ATC case studies it is assumed that split-shifts in combination with high workload and night duties to potentially affect the health of individuals (Chapter 6.2.3).

A scientifically and statistically validated analysis of the effects of working-time patterns is getting more and more complex. Shiftwork systems have to prevent health and social problems, which are associated to specific working-time patterns. Particularly, shiftwork systems need to consider the following:

- The definition of **single criteria**, such as number and duration of night shifts, clockwise (forward) or counter clockwise (backward) rotation, cycle of the systems, duration of the working time, etc., which are connected specifically to a higher risk of health or social impairments.

- The **concentration of working time**, so-called 'compressed work weeks' or 'condensed working hours' is considered a problem.

Condensed working hours arrange as much working time as possible in a small period of time. Within these systems, the **daily working time goes beyond eight hours and/or the weekly working time goes beyond 48 hours**. For example, there are arrangements like working early shift in the morning, being off for the afternoon and starting to work again in the evening for the night shift. This kind of time arrangement does not agree with the legal framework which determines a break of at least eleven hours between shifts. Another possibility of condensing working hours is a twelve-hour shift system. Thus, sixty hours can be worked in five days. With a collective work agreement of for example 36 hours per week, employees can finish their normal working time of three weeks (108 hours) within less than two weeks, having a whole week off. This arrangement is very attractive for people who do not work where they live.

Condensed models within the conti-system have been widely explored (Nachreiner *et al.*, 1975; Hoff, 1983; Meggender, 1993; Kaupp, 1991). They can traditionally be found in the chemical industry and in public services. From the ergonomic point of view these models are only acceptable if the structural conditions are beneficial (Knauth & Schönfelder, 1992).

2.5 Shiftwork and ATM Context

Compared to other industries that make use of shiftwork, ATM has common features with some of them but also differs in other aspects substantially. Like many (but not all) ATM units, hospitals, water and electricity suppliers for example have to maintain round the clock services. In these examples, also safety is of importance but it carries probably not the rank it has in ATM. Moreover, the complexity and dynamics of the monitoring tasks in e.g. a power plant are smaller than at busy ATM units. Boredom is the only problem in the former example as it is also at night in many ATM units with low nocturnal traffic loads. The most significant difference to most other industries is the substantial variation of workload during the day (inbound and outbound traffic peaks), during the week (weekday vs. weekend) and during the year (seasonal factors i.e. summer vs. winter traffic).

Within the ATM context, the following shiftwork aspects are especially important:

- ATM requires round the clock service in many units.
- Safety is of critical importance relative to other businesses.
- Complexity and dynamics are high relative to other businesses. Technology and organisation consist of many, diverse and interacting elements (complexity definition according to Kastner *et al.*, 1998). A simple procedure like filing a flight plan for example involves a number of international units. Changes over time (dynamics) also happen quicker, e.g. aircraft are moving faster than the trains a station master has to coordinate.

- The traffic flows follow certain daily, weekly and seasonal fluctuations, exposing Air Traffic Controllers (ATCOs) to workload variations. On the employer side, these fluctuations challenge cost-effectiveness.
- Overload (stress) as well as underload (boredom) is an issue. The latter has a special impact on situational awareness during night work as most units have to deal with low nocturnal volumes of traffic.
- ATCOs always have to sustain a high level of performance.
- The hand-over of ATCO positions are critical because the traffic picture has to be quickly taken up (Chapter 4.5).

2.6 Summary

Shiftwork refers to those working-time systems in which work is done at different times over the day or at the same, but at unusual time. The EC Directive 93/104 contains the European regulation for working-time design. There is a great variety of shiftwork systems today with little resemblance to traditional shiftwork systems.

Within in the ATM context, the following aspects are especially important:

⇨ ATM requires round the clock service in many units,

⇨ safety is of critical importance relative to other businesses,

⇨ complexity and dynamics are high relative to other businesses,

⇨ workload varies due to daily, weekly and seasonal fluctuations of traffic,

⇨ overload (stress) as well as underload (boredom) is an issue,

⇨ ATCOs need to sustain a high level of performance.

3. SHIFTWORK AND THE INDIVIDUAL

3.1 Introduction

The impact of shiftwork on the individual can be split into several broad categories as follows:

- human circadian rhythm,
- health-related impacts like fatigue, gastrointestinal and cardiovascular disorders,
- age,
- morning or evening type,
- family and social life.

3.2 Human Circadian Rhythm

The functions of the human organism are linked to a 24-hour rhythm (circadian rhythm) and the change of day to night respectively (Wever, 1979). The **individual circadian cycle** is not exactly linked to a 24-hour period. It varies individually. The cycle is rather longer (Czeisler *et al.*, 1999). This also explains why usually people flying to the **west** adapt more easily than those travelling to the east. Flying to the west means an extension of the day, whereas flying to the **east** shortens the day. In these cases the adaptation is more difficult (Wegmann *et al.*, 1985).

At a first glance external factors could explain the **variation of the circadian rhythm** exclusively. Factors such as day light, activities, meals, and bedtime (as timer) give the day its structure. However, the response to **environmental stimuli** is not the only influence. The human body has its own **autonomous endogenous cycle**. This fundamental finding about the endogenous control of body functions is based upon isolation experiments from the fifties (Wever, 1979). Therefore, a switch of day and night has its limits.

It is considered a proven finding that the change of brightness and darkness serves as a **timer** for the activation of the human body. However, it is assumed that light activates the body during the night only if the light is very bright (Czeisler *et al.*, 1989).

There are reliable scientific findings that working at night causes a de-synchronisation of body functions. Human beings are day-active creatures, who are programmed to perform and be active during the day and to recover during the night. The problem arising from **rotating shift systems**, especially if night shifts are included, is the **activation of the employees against their body clock**. They have to work during the nights and to rest during the day.

To work against the body clock is a stress factor which demands additional effort (Vespa *et al.*, 1998; Costa, 2003).

The increased physical stress by working nights manifests itself in:

- a decrease of performance (Chapters 4 and 5) and
- an increase of tiredness (Chapter 3.3.1).

The reduced efficiency leads to:

- an increased frequency of errors as well as to
- an extension of reaction times (decreased vigilance).

Depending on the field of work **substantial risk** might be a consequence. Caused by the experienced tiredness the employees develop **inadequate coping** strategies. An increased consumption of stimulants such as coffee and cigarettes is often found (Akerstedt & Knutsson, 1997). The use of stimulants activates the cardiovascular system only for a short time, whereas in the long run they are an additional health risk (Rutenfranz & Knauth, 1987).

A day worker's willingness to perform is mainly determined by his actual efficiency, which usually goes along with the stress due to his work. However, working shifts, the **willingness to perform** and the **efficiency** may diverge. This applies to the work situation as well as to the sleep. When the shiftworker is forced to work during the night the activity level is lower, whereas the activity level increases during the following rest time (day sleep). This has consequences on the work as well as on the recreation. However, this does not necessarily prove a connection between capability and actual accidents (Chapters 4 and 5). The task to be performed has a substantial influence (Rutenfranz & Knauth, 1987; Monk, 1990; Wilkinson, 1992; Wedderburn, 1992). The pre-conditions are very unfavourable for recreation as well due to the increased activity level, noise, social and family requirements, sleeping during the day can easily be disturbed and is of minor quality (Chapter 3.3.1).

3.3 Health

Even though the appearing disorders of shiftworkers are rather unspecific, **typical impairments** can be described. The **de-synchronisation** of the diverse body functions is considered the major physiological stress caused by working at night (for a comprising review see Rutenfranz and Knauth, 1987). The most important body functions that depend on the time of day are:

- the rhythm of sleep and activity,
- the physiological preparedness to perform and
- the daily variations of the body temperature.

All body functions are apparently arranged to perform during the day and set to recover during the night (Rutenfranz & Knauth, 1976). The resulting strain for shiftworkers is the consequence of the adaptation the human organism has to perform. In case the body cannot adapt, negative effects of stress become apparent in different ways. Manifested illnesses cannot easily be connected with shiftwork; however, **impairments of well-being**, **sleep** and **performance** show a clear connection to shiftwork (Kiesswetter, 1988).

Night shiftworkers frequently mention troubles with body functions that are related to the circadian rhythm. The following are often expressed:

- sleep deficit / chronic fatigue (Akerstedt, 1988; Kiesswetter, 1988; Smith *et al.*, 1998; Ono *et al.*, 1991);
- gastrointestinal disorders (Angersbach *et al.*, 1980; Tüchsen *et al.*, 1994; Harrington, 1994; Costa 1996);
- cardiovascular disorders (Boggild & Knutsson, 1999);
- reduced well-being (Costa, 1996, 2003).

Because of these impairments some people are totally intolerant to shiftwork. Normally they leave during the first two years. Consequently, shiftwork creates a typical '**healthy worker effect**' (Harrington, 1994; Jansen *et al.*, 2003; van Amelsvoort, 2000), which means that only people resistant to negative shiftwork effects stay at these workplaces in the long run.

Very early in ATM-related research (Baader & Graf, 1958), shiftwork typical **gastrointestinal** and **cardiovascular disorders** were also found in ATC personnel (see also Chapter 6.2).

3.3.1 Sleep and fatigue

Shiftworkers **sleep less** than employees working on day duty and also the quality of sleep is impaired (Beermann *et al.*, 1990; Dekker & Tepas, 1990). Due to missing disposition to sleep during the day, the duration of sleep is usually shorter than that at night. Some shiftworkers interrupt their sleep 'voluntarily' in favour of private matters (e.g. to be with children or friends). Most of the affected persons are not aware of the consequences and impairments they additionally evoke by this 'unhealthy' sleep patterns.

Apart from the quantity, the **sleep quality** constitutes an essential criterion for the effectiveness of sleep. By looking at the brain activity (analysing electroencephalography: EEG-patterns) of night workers a reduction of Rapid Eye Movement (REM)[3] sleep during the day becomes obvious. These **REM-periods** are responsible for the **recreational value** necessary for the physical and psychological regeneration. Experiments have proven that a continuous lack of REM-periods leads to substantial psychological impairments (depression). Naitoh *et al.* (1990) describe in their study even a connection between decreased sleeping time and a decreased life expectancy. The insufficient quality of sleep also contributes to an increased liability for disturbances. At the same time more noise is prevalent during the day and

[3] Orthodox sleep is distinguished from paradox sleep. The latter is characterised by Rapid Eye Movements (REMs). Orthodox sleep can be divided in four phases of different intensity, which recur several times during one night.

therefore interruptions of the day sleep occur more often (Tepas & Caralhais, 1990).

Recent studies reveal that the **degree of fatigue** depends on the kind of **shift system**. Rosa (2001) reports that the experienced fatigue of employees is a result of the number of hours worked, the timing of work within the 24 hours, the number of subsequent shifts and the amount of free time between the shifts (Smith *et al.*, 1998; see also Folkard, 2003).

3.3.2 Gastrointestinal disorders

In association with the physiological de-synchronisation the gastrointestinal disorders have to be mentioned. The **rhythm of the day** influences the **hormonal control** and the **control of secretion** fundamentally. The strain during nights and the wish to structure the night shift make many shiftworkers eat at night. Too many times such night meals are unbalanced and high in calories. This often results in **under-nourishment and/or obesity** (Adenauer, 1992; Cervinka *et al.*, 1984). Additionally, high-caloric meals lead to an increased **digestion activity**, thereby induce changes in cardiovascular function and enhance feelings of fatigue (Musial *et al.*, 1997). A **diet** designed for workers with unusual working times, for example lorry drivers (Nolle, 2002), or a warm meal for night workers (Kuckuck, 1989), can improve the situation (see also Table 6 in Annex 1). However, the influence of nutrition is somewhat overestimated.

3.3.3 Cardiovascular disorders

Epidemiological studies revealed a connection between shiftwork and the occurrence of cardiovascular disorders (Knutsson *et al.*, 1986; Boggild & Knutsson, 1999). The specific causing pathways could not be explained to the full extent. The present results suggest a **complex interplay** of diverse factors, which play a major role (Akerstedt & Knutsson, 1997):

- the sleep contradicting the circadian rhythm,
- problems in social and private life as well as
- unfavourable health behaviour of shiftworkers (smoking, unhealthy diet, lack of exercise, alcohol).

Uehata (1992) studied the correlation of unexpected heart death (*Karoshi*) and working hours beyond sixty hours in middle aged Japanese employees. Within the complex interaction of stress, unhealthy lifestyle, recent critical stress incidents, and extended work hours, the latter had a significant impact. Also Liu and Tanaka (2002) found a twofold risk of acute myocardial infarction (heart attack) compared to normal working weeks of up to forty hours. Sleep of only up to five hours per day and frequent sleep deprivation (two days with less than five hours per week) increased the risk additionally by factor 2-3.

On the basis of these studies, a connection between cardiovascular disorders and extended working hours can be assumed, especially for weeks with more than fifty hours (Spurgeon, 1997).

Moreover, existing ergonomic studies show **specific individual conditions**, which enhance or minimise the development of impairments typical for shiftworkers. These conditions can be of a **dispositional nature** (chronic illness, e.g. depression) or be based upon the **environment** or the **behaviour** (e.g. living conditions or sleeping behaviour) (Vidacek *et al.*, 1993; Ashkenazi *et al.*, 1997; Iskra-Golec, 1993; Parkes, 1994; Akerstedt & Knutsson, 1997).

3.4 Age

A worker's age is another crucial factor. The older employees are, the more difficult is the adaptation to night work. Shiftworkers older than fifty years have increasing **difficulties in adapting** to a change of the sleep-wake cycle. They develop **sleep disorders** more frequently (Nachreiner, 1998; Costa *et al.*, 2000). Female shiftworkers, especially, report a weaker state of health more often (Oginska *et al.*, 1993).

A phase model (taken from EUROCONTROL, 2003b) describes shiftwork throughout a working career:

- **Adaptation Phase** (zero-five years): The shiftworker has to adapt to changes in sleeping and eating pattern, social and family life, and social strain.

- **Sensitisation Phase** (five-twenty years): Tolerance towards shiftwork develops.

- **Accumulation Phase** (twenty plus years): Risk factors, sleep quality and attitudes towards shiftwork accelerate the biological ageing process and have a strong influence on the health and the tolerance of the shiftwork.

- **Manifestation Phase** (twenty plus years): Some workers enter the manifestation phase before but also after retirement, which is characterised by an increase of disorders and diseases related to sustained shiftwork.

Individuals leaving shiftwork can appear at each of the four phases and might display a variation in the ability to cope with shiftwork (see also “healthy worker effect”, Chapter 3.3).

3.5 Morning and Evening Type

The **capabilities to adapt** to shiftwork depend on the individual body clock. Persons with a rather longer rhythm than 24 hours usually are more capable to adapt to a changed **sleep-wake cycle**. In order to investigate the influence of this factor, shiftwork research differentiates ‘morning and evening type’ or ‘**morningness and eveningness**’:

- **morning types** are characterised by a rather shorter rhythm, while
- **evening types** have a longer rhythm.

Existing studies state that evening types cope better with the demands of shiftwork (Horne & Ostberg, 1976). Their rhythm resembles the extension of the day with similar effects of flying to the west. Yet, the results are contradictory. The empirical relevance is restricted as the categorisation in morning and evening type assumes a dichotomy, but it should rather be a continuum (Folkard, 2003). People are more or less a morning or evening type. According to Folkard and Hunt (2000) individual differences in the body clock do not account for more than 10% of the variance.

3.6 Family and Social Life

Apart from the physiological de-synchronisation, the social de-synchronisation as well causes additional demands on the shiftworker. In spite of the intensified deregulation processes in the field of working time (Chapter 2.4; Bauer *et al.*, 1994; Groß *et al.*, 1991) our society still is considered an ‘**evening and weekend society**’. Although the social development and the increased expectations of an active design of leisure time resulted in leisure activities offered to a certain extent throughout the day and the week, the evenings and the weekends are still the highly valued free time (Baer, 1982; Baer *et al.*, 1981; Ernst *et al.*, 1984; Grzech-Sukalo *et al.*, 1989; Garhammer, 1992a & b; Rinderspacher, 1989). These times are used for individual leisure time, for the family or the partner, for contacts with friends and relatives, and for the participation in social and political life.

Due to the alternating or enduring unfavourable working times, shiftworkers only have **restricted possibilities** to take part in the collective leisure time. Even though the amount of leisure time of shiftworkers is equal to that of employees on day duty (Grzech-Sukalo *et al.*, 1989), quality restrictions arise from the position of the free time within the 24 hours of a day (Costa, 2003): Shiftworkers have to work at times when friends and family are having leisure time.

Social life is not only a value in itself; **social support** is also known to moderate the tolerance towards shiftwork substantially and thereby facilitate health and well-being.

3.6.1 Shiftwork and family

Depending on the situation the different time pattern of shiftworkers leads to different demands in the family life. A great amount of the older findings about night and shiftwork are based upon the **traditional family structure**. The typical constellation consists of a sole earner with children and a partner who does not work. In this specific situation the **adaptation** of the partner and the children has an important influence on the successful coping with shiftwork (Bamberg *et al.*, 1986; Cohen & Wills, 1985; Costa, 2003).

Differences in the development of children of shiftworkers occur depending on their age, e.g. the amount of time together depends on the **age of the children**. A negative impact on school success and the development in school was found for children of shiftworkers. The characteristics of the particular shift system have to be considered when analysing the impact of shiftwork on family life. Different **shift patterns** may result in different psycho-social impairments (Grzech-Sukalo *et al.*, 1989; Bonitz *et al.*, 1989; Beermann *et al.*, 1990; Colligan & Rosa, 1990; Hertz & Charlton, 1989).

The existing findings about social impairments take the **new social developments** only partly into account. The amount of single-households has increased substantially in Europe during the last ten years. This goes along with a change in the 'support structure' of the family and the private area. The necessary time to maintain social contacts has increased as well as the time needed for parental investment. Both of these factors lead to a reduction of leisure time (Beermann, 1993). Additional effort to synchronise the schedules has to be made if both partners are working shifts. Especially women with children working shifts have to spend more time in the household compared to their male colleagues in a similar situation (Beermann, 1993).

3.6.2 Participation in social life

Participation in social life can be described in terms of passive as well as active behaviour. It comprises activities such as involvement in social and political issues, duties as a union member, religious and church or voluntary activities as well as activities in clubs and societies. The participation has to be continuous to a certain extent for all of these activities. Shiftworkers often lack this continuity due to their alternating shifts. Yet, it has to be considered that the active involvement of day workers in parties and societies during the free time is decreasing as well. This has to be attributed to general social changes rather than to a specific working-time pattern.

3.7 Summary

Table 2 summarizes the problems faced by shiftworkers in working shift:

- ⇨ Working in a rotating shift system (especially with night shifts) means working against the body clock (circadian rhythm) and leads to a de-synchronisation of the human body functions.
- ⇨ Impairments of sleep, gastrointestinal and cardiovascular disorders can be the consequences. A so-called "healthy worker effect" is found: Only people fairly robust against the negative effects of shiftwork stay at the respective workplaces in the long run.
- ⇨ Individual differences such as age or the classification into morning and evening type determine the effects of shiftwork as well.
- ⇨ Apart from health impairments, shiftwork influences the social and family life. The partner and children have to make an effort in adapting to the shift pattern.

Table 2. Problems of shiftworkers (according to Knauth, 1993a & b, p. 13)

Problems	Morning	Afternoon	Night	Weekend	Daily work > 8 hours	Weekly work > 48 hours	Daily work <= 6 hours	No frequent breaks	Short-term changes of roster
Sleep disturbance	■		■						
Fatigue	■		■		■	■		■	
Appetite disturbance			■						
Gastrointestinal complaints			■						
Gastrointestinal diseases			■						
Coronary heart and blood pressure diseases			■						
Interference with family life		■	■	■		■			■
Interference with meeting friends		■	■	■		■			■
Interference with participation in parties or associations		■	■	■		■			■
Interference with hobbies		■	■	■		■			■
Performance loss and errors	■		■		■			■	
Interference with parallel tasks			■		■	■			
Interference with training		■	■			■			■
Inappropriate ratio of travel and working time							■		

■ = potential problems

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4. SHIFTWORK, AND PERFORMANCE AND SAFETY

4.1 Introduction

Apart from health and social issues, shiftwork and performance especially in safety-critical contexts have been studied. This chapter looks at the effects of shiftwork on the employee's performance. It includes such factors as:

- number of successive shifts and the decreasing performance until the 7th shift;
- shift length and the exponential increase of errors after eight hours;
- time on position and the necessity to allow for a break after four hours at the latest;
- night shifts and their relatively high risk susceptibility.

4.2 Number of Successive Shifts

With the number of successive night shifts the **risk of errors and accidents increases** (summary of studies in Folkard, 2003). In relation to the first night the second night bears an additional accident risk of 13%. In the third night the risk is 25% and in the fourth night 45% higher related to the first night. The re-analysis of several studies by Folkard (2003) showed that the risk for each shift block increases with the duration of the blocks and depends on the number of successive nights. This trend can be found **up to a shift cycle of seven successive shifts**. The results agree with findings about performance reduction due to increasing de-synchronisation and fatigue. Consequently, an improvement of performance could be expected with increasing adaptation – e.g. under the condition of more than fourteen successive night shifts without a day off. However, convincing empirical evidence for this assumption is missing (Folkard, 2003). The effect of an increased risk due to successive shifts is valid for early and day shifts as well, but is most obvious in the night shift.

Schroeder and colleagues (1998) present clear findings in a sample of **ATCOs**. They found a progressive increase of reaction times during five eight-hour working days and during four ten-hour working days.

4.3 Shift Length

Vernon (1921, 1940) was the first to observe an accident risk that was increased by factor 1.5 to 2 when twelve instead of eight hours were worked. Recently, Folkard (1997), Nachreiner *et al.* (2000), Hänecke *et al.* (1998) and Akerstedt (1995) confirmed that the **risk of accident or mistakes increases during the shift**. The effect of the work duration was proven statistically in day shift condition. Based upon present documentations of accidents at work Folkard (1997, Folkard *et al.*, 2000), Nachreiner *et al.* (2000) and Akerstedt (1995) proved the **exponential increase in the risk** of an accident after the 8th hour of work. This effect of an **extended working day** has to be assumed for the night shift condition as well. (Yet, the statistical proof is not possible with the present data for the reasons mentioned in Chapter 4.4.)

In many fields of work, there is a tendency towards a **compressed work week** with more than 48 hours (see also Chapter 2.4). This means a desire to change to a **twelve-hour shift system** which is often due to increased work volume. Therefore, the extension of the working time in many areas is associated with an increase of workload and stress levels. Studies have shown that in extended shifts:

- fatigue and the risk of incidents is increased;
- productivity is decreased (Chapter 5);
- employees are longer exposed to higher stress levels and possibly other harmful circumstances (e.g. radiation).

However, on the one hand, employees especially prefer twelve-hour shifts because they reduce the number of travels to the workplace and therefore can increase their free time. On the other hand, present scientific studies on effects of eight- and twelve-hour shifts respectively cannot confirm that the stress of both shift systems is equal. Some studies reveal marginal negative effects of the twelve-hour shift system (Smith *et al.*, 1998; Axelsson *et al.*, 1998; Lowden *et al.*, 1998). Other studies show a significant increase of fatigue and a decrease of performance due to the extension of the work day (Urgovics & Wright, 1990; Rosa, 1993). Moreover, the numbers of accidents increase with extended working hours (Kelly & Schneider, 1982), health impairments occur (Laundry & Lee, 1991), and disturbances in family life become more distinct (Kogi, 1991; Bourdouxhe *et al.*, 1999). With Knaupp (1983) it can be assumed that extending a shift to twelve hours leads to:

- fatigue;
- more effort to fight attention and concentration problems at the end of the shift (risk of accidents);
- long-term health effects.

In the USA and Canada twelve-hour shift systems are quite common. One of the few controlled longitudinal studies investigated the effect of changing from eight to twelve hours and found even after ten months increased reaction times and decreased self-reported attention (Rosa & Bonnet, 1993). Another study by Rosa (1991) observed effects on reaction time 3.5 years after the change to a twelve-hour system.

Helsegrave *et al.* (2000) investigated the adaptation after a shift extension (eight to twelve hours) in a nuclear power plant. They report a significantly higher reduction of performance towards the end of a shift, increased fatigue, and a decreased vigilance. Employees mentioned sleep disorders, gastrointestinal disorders, and heart sensations more often (Heslegrave *et al.*, 2000). New data identifies **the effect of the timing of work in the 24 hours cycle** as an additional factor besides the shift length. The relation of the circadian rhythm to the shift cycle is of particular importance (see also Chapter 5.2.3).

Following **recommendation** concerning the shift length can be derived from the reviewed results:

The duration of the shifts should not exceed eight hours in fields of work with high physical or mental demands, with exposition to toxic material, with additional overtime, or with an increased risk in case of incorrect behaviour.

These and other recommendations on shiftwork design will be elaborated in Chapter 7.

4.4 Night Shifts

Due to the body clock and the activation level during the day respectively the employees' **motivation** and **capability to work** during the night are restricted fundamentally. Folkard and Tucker (2003) report a significantly lower **efficiency** and **performance** between 7 pm and 7 am (see also Chapter 5.2.3). The reduced performance between midnight and 6 am stands out especially. During this time, also ATCOs reported the most fatigue, stress, and therefore performance and health problems (Vogt & Kastner, 2002; see also Chapter 6.2.3).

Whether this specific course of performance affects safety, is **statistically difficult to prove because of the specific work requirements and the reduced staff during the night**. Frequently, different and sometimes less risky tasks are performed during the night e.g. off-line gate allocating when the airport is closed (for this example see also Chapter 6.5). Moreover, the number of staff is often reduced. Yet, some findings indicate a connection.

4.5 Breaks and Time on Position

The length of time on position before a break should be given and how long the break should last depend very much on the kind of task. ATCOs tasks require sustained vigilance. Since vigilance decreases over time while feelings of fatigue increase, a break every two hours of continuous work should be allowed (Hopkin, 1995; Roske-Hofstrand, 1995). During their breaks ATCOs should have time to (Hopkin, 1995; Meyer, 1973; Roske-Hofstrand, 1995):

- walk away from their working position;
- go to the bathroom;
- spend time in relaxation facilities at the workplace, where they can have something to drink or chat with colleagues.

Active relaxation can accelerate the recovery (Vogt *et al.*, 1999).

Kastner *et al.* (1998) found that estimated break requirements depend on traffic complexity. Heart rate and desired break during and after two hours simulated work were lowest when traffic load shortly faded in – allowing for a warm-up – and slowly petered out with increasing exhaustion. This means that breaks and the necessary hand-over should not be scheduled within or too shortly before traffic peaks.

In his doctoral thesis Hagemann (2000) studied the course of self-reported attention and physiological indicators of vigilance and arousal in connection with traffic changes. One of his main results is of special importance with respect to time on position and break design: after 2.5 to 3 hours of duty, self-report and physiological measures indicated increases of strain and decreases of vigilance.

From this study and many others (e.g. Chapter 6.3), it can be concluded that:

> During day shift a break is due the latest after four hours. Tasks demanding high levels of vigilance should be followed by a break already after two hours. The minimum duration of a break (Chapter 6.3) should be ten minutes plus ten minutes for every hour worked.

Taking a break is very important during night shifts since either:

- low traffic levels induce fatigue resulting from efforts to counter boredom,

or

- high traffic load is prevalent (see Chapter 6.2.3), and
- both conditions meet the de-synchronisation of the body clock.

Kastner *et al.* (1998) quote in their Chapter 10.3.3.1 from the literature: “Within the first third of a night shift, a fifteen-minute break should be granted, after the second third half an hour. Moreover, hourly short breaks of five to seven minutes are recommended (Hahn, 1988)”. In ATC, however, frequent short breaks would expose ATCOs often to the rather stressful situation of hand-over (realising the complexity of a traffic situation in a short time and taking over from a colleague with little warming-up). This issue was already addressed in the Rohmert and Rutenfranz study (1972, 1975) and mentioned by for example Luczak (1982). Therefore, one longer break allowing for a nap and overcoming subsequent inertia is probably more adequate (see also Chapter 6.4.2).

Costa (1993) studied Italian ATCOs on a 1-1-1 backward rotating schedule with a night shift including a four-hour rest period. Apparently, this kind of schedule facilitated psychological adaptation and helped to compensate for sleep loss. This is only one example of many possible night shift schedules that would include a break long enough for napping. However, precautions have to be taken with respect to inertia (Chapter 6.4.2). Break periods could also be shorter for naps of twenty-forty minutes. Research is ongoing to determine the ideal length of a nap.

Unfortunately, too often during night shifts reduced staff makes it difficult for ATCOs to take a break (Rhodes *et al.*, 1994; Roske-Hofstrand, 1995). Staff planning should take breaks into consideration, especially during night shifts (Rhodes *et al.*, 1996).

4.6 Safety Relevant Trends

According to Folkard (2003) studies with constant conditions for all three shifts (early, late, and night) revealed additional risks in the late shift (17.8%) and the night shift (30.6%) relative to the early shift. Besides the general effect of the night work, four consistent safety-relevant trends can be found (Folkard, 2003):

- Fatigue increases, alertness decreases over the course of a night shift.
- The risk of an accident decreases over at least the first few hours of a night shift due to warming-up. This was already reported by Vernon (1923).
- On average, the risk is about 13% higher on the second night, more than 25% higher on the third night, and nearly 45% higher on the fourth night shift than on the first night.
- During a shift a slightly increased risk occurs from the second to the fifth hour, but an exponential increase of the risk develops with time on shift, the main increase occurring after eight hours on duty (Akerstedt, 1995; Folkard, 2003; Nachreiner *et al.*, 2000).

The **type of work** and the **workload** are crucial determining factors in risk assessment, for example the surveillance and controlling activities of ATCOs (Chapter 6.2.6).

4.7 Summary

- ⇨ Present findings on night and shiftwork prove a higher risk of physical and mental impairments for employees working in atypical shift systems compared with employees with regular working hours.

- ⇨ The increased risk of impairments arises from the following factors:

  - The de-synchronisation of working time combined with different working requirements.

  - The capability according to the physiological and social conditions.

  The adaptation to these demands is especially critical if the working time exceeds the regular forty hours per week.

- ⇨ The risk increases from early to late shift and is highest during the night shift.

- ⇨ The risk increases until the seventh successive shift.

- ⇨ The demands for designing rotas for night shift support the European Directive 93/104 which restricts the night shift to eight hours.

- ⇨ The design of night shifts generally should take into account the variability of real life settings compared to laboratory settings – this for example refers to experiments measuring reaction times (laboratory) which do not fully reflect the variability of work demands in the actual night work situation.

- ⇨ During night shift, the risk of fatigue is even more enhanced since the employee works against the circadian rhythm. Special considerations might be taken into account for breaks that may allow napping and enough time to overcome subsequent inertia.

- ⇨ During day shift a break is due at the latest after four hours. Tasks demanding high levels of vigilance should be followed by a break already after two hours. The minimum duration of a break should be ten minutes plus five minutes for every hour worked.

5. SHIFTWORK AND PRODUCTIVITY / EFFICIENCY

5.1 Introduction

This chapter describes the impacts of shiftwork on productivity and efficiency taking into account available research results. The impacts of shift lengths, night work, breaks and roster types on productivity are described. The impact of shiftwork on efficiency discusses the ability to allocate resources to meet varying demand and resource utilisation.

5.2 Shiftwork and Productivity

Productivity in the field of economics is defined as the **ratio of the quantity and quality of units produced to the labour per unit of time**. In ATM, productivity is usually seen in safety, sector utilisation (number of aircraft per sector and time unit), and low amount of delays. ATCO-hour productivity is defined as the number of flight-hours controlled for each hour spent by an ATCO on operational duty.

To increase productivity means to produce more with less. In factories and corporations, productivity is a **measure of the ability** to create goods and services from a given amount of the production factors (labour, capital, materials, land, resources, knowledge, time or any combination of those (Globalchange, 2004)). Another definition explains that productivity is the amount of product created by one unit of a given factor of production over a stated period of time. Moreover, productivity expresses the marginal **relationship of inputs to outputs** and measures the **economic efficiency** of production. Productivity indicators ordinarily relate output to a single factor of production, creating measures like labour productivity, capital productivity, and land productivity. Measures of multifactor productivity, in contrast, combine productivity indicators for multiple factors of production (labour and capital, for example) to produce a single overall measure of productivity growth (Spero & Hart, 2004). Two key factors that can affect productivity are **advances in technology** and **improvements in education and training** (South-Western Economics Resource Center, 2004).

Yerkes' and Dodson's findings from the early twentieth century draw conclusion on the impacts of physiological activation (arousal) on performance and therefore productivity. The authors (1908) investigated the arousal level, which can be seen as the capacity a person has available to work with. Their findings became known as the **Yerkes-Dodson Law** (Yerkes & Dodson, 1908). It predicts an **inverted U-shaped function between arousal and performance**. A certain amount of arousal can be a motivator toward change (with change in this discussion being learning). Too much or too little change will certainly work against the learner. The aim is a mid-level of arousal to provide the motivation to change (learn). Too little arousal has an inert effect on the learner, while too much has a hyperactive affect. Also, there are optimal levels of arousal for each task to be learned. The optimal level of arousal is:

- lower for more difficult or intellectual (cognitive) tasks (the learners need to concentrate on the material);
- higher for tasks requiring endurance and persistence (the learners need more motivation).

Productivity is not only dependent on the right amount of arousal, but also on the **amount of hours worked, night work, allocation of breaks and type of roster**. These issues are discussed in the following paragraphs.

5.2.1 Shift length

A decrease in productivity can be observed in the course of the day shift as reported by Vernon already in 1923 for munitions factory workers. This finding is confirmed by recent publications, which – in the tradition of Vernon's study – focus mainly on productivity losses through accidents (Beermann, 2003a & b). Generally, it can be assumed that performance (quality and quantity), productivity and **efficiency** also of white collar workers decrease with **shift durations** beyond eight hours since:

- accidents and duration of shift correlate,
- accidents disturb production/service and cause a lot of costs.

In terms of shift duration also US studies after World War II recommended the eight hour work day as a general guideline as they found longer working days to cause **productivity losses, absenteeism and accidents** (review by Semmer *et al.*, 1995). This finding was repeatedly acknowledged through the century. Tiffin and McCormick summarised for example in 1965: "...it is quite commonly agreed that as the working day is lengthened, the accident rate increases in greater proportion than the increase in number of hours worked". Moreover, Semmer *et al.* (1995) describe that long working hours especially affect **attention** and **organisation of behaviour**, which again effect productivity. Tucker reports in a more recent study (1998) a decrease of self-reported vigilance with duration of work, especially during twelve-hour night shifts.

Productivity can also be reduced by extended working hours via the **change of free time and sleep time**. A significant reduction of leisure and sleep time due to extended working hours leads to:

- sleep deficits and insufficient recovery,
- dissatisfaction with the work life balance.

Both impair performance (quality and quantity), productivity and efficiency. Knauth and Rutenfranz (1972) for example revealed in their time-budget-studies a significant reduction of free time and sleep time that were associated with increasing safety risks especially in control and surveillance tasks.

5.2.2 Allocation of breaks

A final issue concerning shift length and productivity are **countermeasures** against the problems of extended working hours. The design of breaks determines how fast the incline of productivity is (Graf *et al.*, 1970). Exercise (see Annex 1) or active relaxation during a break can accelerate recovery (Vogt *et al.*, 1999) and thereby prevent productivity losses. Also it was found that napping can increase productivity, creativity and problem-solving skills (Will, 2003).

To sum up, productivity decreases with the duration of work especially beyond eight hours. The design of breaks determines how fast the incline is. Exercise or active relaxation during a break can slow down the productivity loss. Also it was found that napping increases productivity, creativity and problem-solving skills.

5.2.3 Night shift

Besides shift length the position of the shift within 24 hours influences productivity. The factors that enhance or compromise productivity can be different for the day compared to the night. Vernon (1923) reported an indirect measure of productivity, namely the power consumed by a plant, and noted that although this roughly paralleled the injury rate during the day shift, it failed to do so at night. From this observation he concluded that while productivity may have been the major determinant of risk on the day shift, some other factor is prevalent in the night.

In case of a decision for or against the introduction of shiftwork the factors of **safety** and **productivity** are of major importance. Direct studies of safety as well as productivity on shift systems are difficult to conduct as for example productivity measures are confounded with the number of people at work and the nature of work, which often differ from shift to shift. However, Folkard and Tucker (2003) reviewed some well controlled studies. The authors report:

- Significantly **lower efficiency** and **performance between 7 pm and 7 am**, and specify the reduced performance to the time between midnight and 6 am (see also Chapter 4.4).
- A **massive dip of productivity** during the course of the **night shifts** (i.e. ca. 10 pm to 6 am). The trough occurs at 3 am. A second dip around 12:00 hours is generally known as **post-lunch dip**.
- Productivity measures only above average between 7 am and 7 pm.

A recent study revealed the highest overall productivity on the afternoon shift and a **productivity reduction** of 5% during the night shift. Moreover, an **interaction** between the shift type and successive shifts is evident. Whereas morning and afternoon shifts show a constant productivity over successive shifts, productivity on night shifts rises in the course of the first three nights (probably due to warming-up and temporary adaptation) and declines over subsequent shifts. Mathematical models predict variations in alertness and performance relatively successfully (although they are still in the research phase, see Annex 1). The models are based on the assumption of a low productivity and safety at night due to the circadian rhythms in performance being at low ebb. Moreover, the rhythms remain quite unadjusted over successive night duties. The **nature of the task** explains the trend in performance to a certain extent as well. Short-term memory tasks for example have been found to be at their peak in the morning and to decrease in the course of the day. In order to create a safe and productive shift schedule, the influencing factors need to be considered in combination with one another. Folkard and Tucker give an example: “A long night shift that includes frequent rest breaks might well prove safer than a shorter night shift with less frequent breaks.” Finally, Folkard and Tucker seek **further studies on productivity** in order to be able to generalise trends for other work situations.

Knauth and Hornberger (1997) investigated productivity, human errors and product quality in successive night shifts. They report an **increase of productivity but a decrease in quality until the third night** shift and a decline of productivity in the fourth and fifth night shift. This parallels the recommendation to limit the number of successive night shifts as far as possible with a maximum of three (Chapter 7.2).

Nicholls’ study (2003) about the effects of longer working hours in the timber harvesting industry points in the same direction. Longer working hours and shiftwork constitute a common practice in this field of work to meet economic challenges. Yet, the study revealed that for example the afternoon and night shifts took longer to reach their optimal productivity levels. To draw a picture: The night shift production averaged 78% of the day shift productivity. Nicholls found out that in terms of productivity extended working hours appear **counterproductive** unless the issues of alertness and fatigue are well managed.

Another study compared traditional businesses and companies with so-called 24/7 operations (production 24 hours a day, seven days a week). The companies with **24/7 operations** may have lower unit costs and shorter supply chains. However, they also have **lower productivity, greater job turnover, higher healthcare costs** and more on-the-job injuries (Seek, 2004).

To sum up, extending work into the night has a number of negative side-effects that must be subtracted from the production/service achievements which are also reduced relative to the day. In areas where night work is considered only for economic reasons – and not a necessity – managers have to consider these effects to be able to assess whether it is really worth introducing night shifts.

5.2.4 Roster type

Kastner *et al.* (1998) extensively discuss the pros and cons of individual and team rosters with respect to employees´ social and employer's economic requirements. Generally, they raise the question, to what extent a complete individualisation of working times for all employees is feasible. Most of today's working-time models take the level of working groups or teams as a starting point for an individualisation. Büth (1994) reports a good example of time sovereignty for individual employees: Employees decide themselves on the planning of shift assignment, vacation and breaks. Thus, employees can individually change their working time at least to a certain extent.

An individual roster requires the following (Wildemann, 1991):

- equivalent qualification of all employees in the groups;
- flexibility of assignment;
- willingness to cooperate;
- ability to communicate;
- sense of responsibility;
- changed leadership (cooperative and social competence of managers);
- steady monthly salary (salary is paid independently of time worked);
- payment according to the principle of average (neither more nor less productive shifts are considered in payment);
- registration of working time (in order to meet legal and internal conditions, the working time of single employees has to be monitored);
- transparency (all rules have to be obvious for all team members);
- isolation (commitment to all other areas within the company is vanishing).

So-called **capacity-orientated variable working times** (*KAPazitäts Orientierte VAriable ArbeitsZeiten*, **KAPOVAZ**) constitute a good example for flexible working times and combine the elements of stand-by duty and part-time work. KAPOVAZ is defined as a flexible, workload-dependent working-time model: Employers and employees agree on working-time contingencies and thereby both can pursue their economic and social/individual preferences, respectively. Employees can, for example, reduce their total monthly working hours to have more time with their children. The working time that employer and employee have agreed upon is requested by the employer when the workforce is needed. Thus, to stay with the example, the employee can decide **how much** time to spend with the children and the employer can decide **what** times the employee is required to be present (e.g. the middle weeks of a month). At least four days in advance the employee is informed about the working times and can make preparations (see Müller-Seitz, 1996).

Employers have the following **advantages**:

- employees are brought into action according to the work demand,
- less staff costs due to the flexible assignment of employees.

Employees might experience following **disadvantages**:

- little chance for planning working times;
- waiting for the call, uncertainty is stressful;
- due to different working times little contact to other employees within the company.

Advantages and disadvantages of a team shift schedule can be derived from the requirements of **time autonomous working groups** (Büth, 1994). Table 3 highlights the advantages and disadvantages of individual and team rosters.

Table 3. Advantages and disadvantages of team and individual rosters

	Team rosters	Individual rosters
Advantages	▪ Working times adopted to employees' desires ▪ High willingness for cooperation among team members ▪ High ability of the employees to communicate ▪ High sense for responsibility of all team members ▪ Changed structure of leadership within the organisation ▪ Transparent rules and decisions ▪ Economic advantages (this especially applies to production)	▪ Flexible design of working times for the employee as well as for the company; especially the KAPOVAZ-model offers advantages for the company ▪ Employees obtain a high degree of responsibility concerning the organisation of work (time wise); however, responsibility might be perceived as beneficial or as stressful ▪ Due to the high degree of responsibility of all employees managers have to change their leadership; they have to cooperate more with the employees according to their responsibilities ▪ The individualisation prevents negative group processes (e.g. cliques, mobbing)
Disadvantages	▪ Exact registration of the working times of each employee, which is combined with a high degree of control in terms of working times ▪ High responsibility of each team member for the colleagues ▪ Integration difficulties especially for weaker or older persons, disabled, women and introverts ▪ Payments according to the principle of average, increased performance is not fully reimbursed ▪ Isolation from other areas of the company; different working times interfere with contacts between the groups	▪ Isolation of the employees and consequently a diminished commitment to the company ▪ Exact registration of the working times and therefore a high degree of control ▪ The employee has to cope with a high degree of responsibility ▪ Payments according to the principle of average; increased performance cannot be reinforced

The advantages and disadvantages of the team roster mirror the pros and cons of the individual shift schedules. The appeal of an individual working-time schedule lies in the extensive consideration of personal needs and workload requirements. The high degree of responsibility can positively affect motivation. The possible isolation of employees constitutes a serious disadvantage of individual shift schedules. Moreover, the accumulation of unfavourable working times due to individual desires might have negative effects as well.

5.3 Shiftwork and Efficiency

While productivity focuses on what is produced by what, efficiency looks at the losses in that process. The term **efficiency** means an ability to perform well or **achieve a result without wasted energy, resources, effort, time or money**. Efficiency can be measured in physical terms (technical efficiency) or terms of cost (economic efficiency). Greater efficiency is achieved where the same amount and standard of services are produced for a lower cost, if a more useful activity is substituted for a less useful one at the same cost or if needless activities are eliminated (IIME, 2004). In ATM it is a question what shiftwork factors enhance or restrict the flexible deployment of resources (e.g. ATCOs) to match the traffic demand. The following are the main shiftwork impacts on efficiency:

- shift length – varied, contained or extended,
- shift starting time – staggered or rigid, matched to circadian rhythm or not,
- overlapping shifts – single shifts overlap each other,
- break times – fixed or varied according to traffic demand,
- break facilities – exercise, relaxation, meals,
- roster cycle – short or long,
- roster organisation – individual or team,
- advance notice of duty – short or long,
- management of time leakage[4] – see Chapter 5.3.1,
- management of overtime – see Chapter 5.3.1.

The Study "Overtime in Europe" (European Union, 2003) examined the **changing regulation** and **use of overtime** and revealed the relevance of the issue. It is clear that overtime remains a significant issue in working time across Europe, **regarded by many employers as a vital element in achieving flexibility** and by many employees as an important source of income. There are many interlinked issues related to the ways in which overtime is regulated and the levels at which this is done.

These include: the respective roles of rules produced by legislation and collective bargaining, the articulation of the various bargaining levels, and, at

[4] Percentage of perceived working time lost by shiftwork over a period of time due to sickness and other staff absences not evenly spread across a year, breaks not spread evenly across a day, mismatch of regulations and roster.

company or workplace level, the jurisdiction of workers' representatives and works councils.

As overtime is sometimes misused as a 'tool' for flexibility combined with additional costs, models like the mentioned KAPOVAZ seem forward-looking: They offer flexibility without additional costs and are designed especially to enable flexible agreements (see Chapter 5.2.4).

Unfortunately, there has been little research on costs and efficiency of shift issues such as overtime.

5.3.1 Shiftwork and staffing

Looking more at the operational side, the factors that are linked to the planning and management of staff and shiftwork practices that impact efficiency are:

- determining the operational requirement,
- time leakage[4],
- dealing with unexpected absences,
- use of overtime (Chapter 5.3).

The preceding sections have demonstrated that the design criteria for an economic shiftwork practice (productivity and efficiency) are similar to the ones that maintain health, safety, performance and social well-being (Chapters 3 and 4). If the roster does not match adequately the expected workload, **under-staffed** ATC units at peak traffic times as well as **over-staffed** shifts at slack times can occur. Both situations are critical for safety reasons, since most accidents happen either in extremely high or in low workload conditions due to overload or inappropriate relaxation, respectively (Hagemann, 2000). From the economic point of view, over-staffed control rooms are especially undesirable. But also under-staffing can have adverse economic effects in the long run due to losses of work motivation and increases in stress-induced illness of employees.

Probably due to the **dominance of safety** issues in ATM, which restricts decision latitude, other industries could get ahead and long since have workload-related rosters. A practice example is the "*Dienstplanabhängiges Schichtplan management"* DSM of the German police. Experiences are already available from the planning of such a system; for example in case of DSM, police officers were concerned with the loss of the team partner they had become acquainted with for many years. Therefore, standardisation of communication and procedures within teams as well as throughout the organisation is required. Potential economic impacts of shortfalls in communication and participation of the operative staff were also considered in another EUROCONTROL (2006) study.

5.3.2 Efficiency and target hierarchy

Finally, targets are needed as reference points to measure the efficiency of a management process in general and of shiftwork management in particular. Schönfelder and Knauth (1993) suggested a **target hierarchy** for shift management (Figure 2). They weighted the prevention of adverse health effects with 70% and recommended to consider social interests of the employee with 30% (e.g. free time to spend with family or friends at evenings or weekends). While health is sacrosanct, the disposable 30% could be divided between the social interests of employees and the economic interests of the employer.

Main Target 100% safe, healthy and efficient roster		
Sub-Target 1 70% healthy roster	**Sub-Target 2** 15% social roster	**Sub-Target 3** 15% economic roster
35% single night shifts	35% normal working times	100% match of workload and staffing
30% forward rotation	35% predictability of roster	
25% avoid cumulating working times	15% free weekends	
10% begin of morning shift	15% free evenings	

Figure 2. Example of a target hierarchy in shiftwork management (modified according to Schönfelder & Knauth, 1993)

A common sense approach could help in designing shiftwork to sustain safety, health, and social welfare and at the same time be efficient and effective to improve productivity. For any target organisation, one possible way forward could be the development of a target hierarchy and **specifications with respect to**:

- kind of tasks;
- delivering resources, e.g. shift structures, description of rosters, daily shift rotation, break times;
- work and health conditions, e.g. absenteeism rates, sickness patterns, stress responses;
- workload conditions, e.g. peak times, volumes, predictability;

- flexibility, e.g. licence restrictions, distance travelled to work, stand-by;
- social requirements and impacts, e.g. participation of employees and unions in shift planning, facilitating valuable free times;
- cost-effectiveness, e.g. current practices to match traffic and staffing, to improve productivity by considering body clock, biorhythms, fatigue patterns and social requirements;
- tools in use that facilitate planning, e.g. software;
- cultural differences.

It is recognised that improved cost-effectiveness cannot be traded for more safety or health problems. Certainly, health and safety should remain the high priority targets. The negotiable part of shiftwork flexibility needs to be balanced between the social interests of the employees and the economic interests of the employer. Target hierarchies as described in Figure 2 and extended economic efficiency analyses (EUROCONTROL, 2006; Pennig *et al.*, in press) are options among others to help steer organisations to increased safety and enhanced employee health, satisfaction and performance due to optimal shiftwork design.

5.4 Initiatives to Improve Productivity and Efficiency

The following are some of the factors to be considered to improve productivity and efficiency in shiftwork:

- sufficient number of highly skilled employees available;
- willingness to work 'off-hour' shifts; premium or shift differential wage;
- best start and stop times for shifts (see Chapter 7.2);
- shift schedules e.g. five eight-hour days per week or four ten-hour days per week (see Chapters 4.2 and 4.3);
- sufficient management personnel available like superintendents, foremen, sub-foremen;
- extra tools, supplies and materials that need to be stocked to assure their availability;
- management of hand-over of work between shifts to ensure the steady work flow (see hand-over problem described in Chapter 4.5);
- minimise lost time at shift change and the number of shift changes (this may be in conflict with the hand-over problem described in Chapter 4.5 and the restriction of working hours to eight);
- allow enough time – but not too much - for communicating operating conditions (see hand-over problem described in Chapter 4.5);
- use a continuous break coverage system and keep equipment operating through breaks;

- optimise plant equipment - use most productive equipment to its fullest potential;
- match staffing to the workload requirements and fully understand the workload requirements to do this (see Chapter 6.2.6);
- schedule personnel to work when they are most productive (see Chapter 5.2).

5.5 Summary

⇨ Productivity defined as the ratio of the quantity and quality of units produced to the labour per unit of time is affected by shiftwork:

- Productivity is compromised at night.
- Shift type and successive shifts interact with respect to productivity.
- Productivity is lower after eight hours of work.
- The nature of the task influences shiftwork impacts on productivity.

⇨ While productivity focuses on what is produced by what, efficiency looks at the losses in that process. Efficiency is defined as an ability to perform well or achieve a result without wasted energy, resources, effort, time or money. It is measurable:

- either in physical terms (technical efficiency)
- or in terms of cost (economic efficiency).

⇨ Greater efficiency is achieved with the same amount and standard of services produced for a lower cost. Issues of efficiency in shiftwork management are:

- Overtime, which is considered a vital element of flexibility by employers and an important source of income by employees; yet it can cause additional costs and adverse effects.
- Individual roster and KAPOVAZ, which consider personal needs and workload requirements.
- Staffing: Over-staffed control rooms are especially undesirable from the economic point of view, but under-staffing too can have adverse economic effects in the long run, when chronic stress symptoms or safety risks become manifest.

⇨ The guidelines for safety, health and social requirements in shiftwork management can also be applied with respect to productivity and efficiency: reduce night work to the possible minimum, limit the shift length to eight hours and consider interactions with task, quality and quantity of breaks.

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6. RESEARCH EXAMPLES

6.1 Introduction

The following chapter depicts aviation-specific issues and delineates exemplary European studies concerning shiftwork and atypical working hours in the field of aviation. The reports are based on research of the authors (Denmark, Germany) or available publications from other countries. In this chapter studies outside Europe are only briefly outlined while details are given in Annex 1. The main studies involved:

- German Air Traffic Controllers (ATCOs) and Air Traffic Service Assistants (ATSAs) (Kastner *et al.*, 1998, 2000; Hagemann, 2000; Vogt & Kastner, 2002);
- British aircraft maintenance (Folkard, 2003);
- French aircrews (Cabon *et al.*, 2003; Bourgeois-Bougrine *et al.*, 1999, 2003);
- Copenhagen Airport stand allocation service case study;
- stress and workload study for Austrian ATCOs;
- research outside Europe (FAA McCallum *et al.*, 2003; Australian studies).

6.2 German ATCOs and ATSAs

6.2.1 Introduction

General scientific findings and recommendations in terms of work schedules and shiftwork were described structurally within Chapters 2 to 5. The following section will additionally give a short overview of results obtained from the German air traffic control services *Deutsche Flugsicherung GmbH (DFS)*. During 1998-1999 the research group of Michael Kastner at Dortmund University carried out a study on the impact of shiftwork on Air Traffic Controllers (ATCOs) (Kastner *et al.*, 1998) and Air Traffic Service Assistants (ATSAs). Contents of the study were:

- impacts of shiftwork on health;
- impacts on private partnership / family, attitude of the private partners and children towards shiftwork;
- impacts on behaviour during recreation time.

Apart from these general issues, two specific projects revealed results about shiftwork and certain diseases on the one hand (Vogt & Kastner, 2002) as well as responsiveness to traffic demands, physiological and subjective exhaustion on the other (Hagemann, 2000).

6.2.2 Finding 1: impacts on self-reported health complaints

Based on a literature review, significant negative impacts on the controllers' and assistants' health were expected (Chapter 3). The following complaints were obtained through questionnaires:

- exhaustion (drowsiness, fatigue);
- rheumatic pains (feeling of heaviness within the legs, feeling of pressure, arthralgia, headache, backache);
- stomach troubles (feeling of pressure, stomach ache, heartburn, nausea);
- significant impairments with respect to the self-reported occurrence of these diseases were found in both samples.

Relative to the self-reported rheumatic pains and stomach troubles, the exhaustion troubles were more important. Especially fatigue and the exceeding need to sleep together with weariness were reported by ATCOs as well as ATSAs.

Also **headache, rheumatic pains and backache** due to the lack of motor activity were reported. Though stomach troubles were less important in the view of the subjects compared to exhaustion and rheumatic pains, both samples reported some gastrointestinal complaints.

Comparing young versus older employees in the DFS, the **older group reported** significantly **more health impacts**. The older colleagues felt more exhausted, had more rheumatic pains, and more stomach troubles. Especially the employees over 41 years bemoaned more stomach troubles compared to their younger colleagues. This is perfectly in line with the general findings reviewed in Chapter 3.

6.2.3 Finding 2: impacts on specific manifest diseases

Apart from these self-reports on health, Vogt and Kastner (2002) investigated the accumulation of manifest ***tinnitus aurium*** (ringing in the ear) in the former licence group 03 of Düsseldorf centre. This licence group covered the sectors Nörvenich (including military operations) and Cola (Cologne, especially busy during the night). From 35 colleagues working in backward rotating shifts, nine had developed a tinnitus. This incidence was significantly higher than the probability in the West German population at that time (0.01 to 0.02% according to Michel, 1994). The DFS very quickly and professionally took action with several studies, changes in the workplace, and support for the affected colleagues. A stress-coping training with the controllers concerned relieved most of them and even healed some of them.

Vogt and Kastner extensively studied seven of the nine tinnitus patients with medical assessment, interviews and ergonomic checks of the workplace, although, due to the small number of subjects, the empirical evidence of this clinical study is limited. Some results are interesting with respect to the research question at issue.

The authors identified the backward rotating shift system in combination with the high workload during day (Nörvenich, Düsseldorf) and especially night (Cologne) as one of the main factors that probably contributed to the accumulation of the disease. Three aspects of the shift system were especially stressful:

- In a split-shift, morning and night duty could be worked within 24 hours.
- The night shift hours exposed the controllers to extremely high workload between 11 pm and 3 am due to night operations in Cologne.
- Following this stressful period the controllers reported it was especially difficult to overcome the fatigue around 6 am when Düsseldorf opened again.

Six of the seven interviewees criticised this shift system and some of them saw a connection to their disease. They regularly tried to avoid these shifts by changing duties with colleagues. As stated before, DFS sustainably resolved these problems.

6.2.4 Finding 3: impacts on family life

As Chapter 3 has shown, the negative effects of shiftwork do not only refer to the workplace and the affected persons themselves, but also affect their private life. In the German study, the majority of controllers and assistants reported different problems within their partnership and family. The shiftworkers are absent during common leisure times – especially in the evening and at the weekend. These times have the highest quality for **partnership, family and friends**; shiftworkers cannot share these times very often. ATCOs as well as ATSAs complained that the occasions of being together with the partner and the children are rare. Especially if the partners themselves were employed on day duty, the shared time was rated as insufficient. Asked for the partners' attitude towards their shiftwork, the assistants appraised that the partners did not like the work conditions but got used to them. If the partners themselves were employed on day duty their attitude towards the work schedule of the DFS employees was quite negative.

Referring to the possibility to spend time with their children, the distribution of answers was bimodal and **depended on the age of the children**: The majority of persons with children over the age of six was disaffected or even very disaffected. Asked for the children's attitude towards the work schedule, the controllers and assistants reported it was neutral or minted by customisation.

6.2.5 Finding 4: impacts on behaviour during leisure time

It is well known from the literature, that shiftworkers are significantly less dedicated in clubs, political parties, or comparable organisations. Also the number of friends outside the work setting who can be met regularly is smaller (Beermann *et al.*, 1990; Garhammer, 1992a & b; Wolf, 1985). Compared to non-shiftworkers these results were also found for both samples within the DFS.

Asked for membership in clubs, political parties, etc., the DFS personnel reported due to time constraints even less participation in organisations than workers in industry.

Nevertheless compared to shiftworkers in other industries, controllers and assistants from DFS reported to have more friends whom they meet regularly.

6.2.6 Finding 5: impacts of traffic responsiveness

During 1996 to 1998 the DFS (Kastner *et al.*, 1998) carried out a number of studies on traffic load, subsequent stress response and necessary countermeasures. Radar and tower simulations revealed that self-reported experienced **stress and desired break time increased nearly linearly with traffic complexity**, which was in the en-route setting defined as high-low combinations of the number of aircraft under control (twelve vs. six), the number of potential conflicts (twelve vs. two), the portion of climbing and descending traffic (two thirds vs. one third) as well as pilot errors (two vs. zero). Physiological responses showed more variance but also depended significantly and systematically on the **number of aircraft under control and the number of potential conflicts**.

The study found that estimated break requirements depended on traffic complexity. Active relaxation accelerated recovery. Heart rate and desired break during and after two hours simulated work were lowest when traffic load shortly faded in – allowing for a warm-up – and slowly petered out with increasing exhaustion. This means that breaks and the necessary hand-over should not be scheduled within or too shortly before traffic peaks.

In his doctoral thesis, Hagemann (2000) studied the course of self-reported attention and physiological indicators of vigilance and arousal in connection with traffic changes. Two of his main results are of special importance to the designing of shiftwork:

- After **2.5 to 3 hours** of duty, self-report and physiological measures indicated increases of strain and decreases of vigilance.
- During the fade-off period of traffic peaks, attention was over-proportionally decreased. The author interpreted this phenomenon as an '**overshooting relax**' response.

From this study, shift plan managers might derive the consequence that after 2.5 to 3 hours of duty at busy ATC workplaces a break or relocation to less stressful positions is due. Moreover, ATCOs should be informed, sensitised, and trained with respect to the typical human ‘overshooting relax’ response after stress peaks.

6.2.7 Summary

- ⇨ The expected negative impairments of shiftwork reviewed in Chapter 3 were confirmed also for German ATCOs and ATSAs. Health, partnership, family, and leisure time were negatively affected.
- ⇨ Subjective health impairments were especially found with respect to exhaustion and rheumatic pains. Older colleagues (> 41 years) in both samples reported significantly more impairment than younger ones (< 32 years). An unusual high incidence of the clinically manifest disease tinnitus was found at workplaces with backward rotation, split-shifts and very high workload during the night.
- ⇨ Impairments of private partnership were especially bemoaned, if the partner was employed but not as shiftworker him- or herself.
- ⇨ Satisfaction in terms of having time for the children was dependent on the children’s age. If the children were older than six years, the shared time was assessed insufficient.
- ⇨ Psycho-physiological studies have shown that after 2.5 to 3 hours of duty at busy ATC workplaces a break or relocation to less stressful positions should be offered (see also Chapter 4.5). Moreover, ATCOs should be informed, sensitised, and trained with respect to the typical human ‘overshooting relax’ response after stress peaks.
- ⇨ The time on duty and the subsequent desired break depend on traffic complexity. Active relaxation can accelerate recovery.

6.3 British Aircraft Maintenance Engineers

6.3.1 Introduction

Folkard (2003) conducted a questionnaire study on British aircraft maintenance engineers. The focus of the study lies upon the investigation of the working hours (e.g. weekly hours, shift length, breaks, annual leave, days notice of schedule) on the one hand, and on outcome measures on the other. Outcome measures include safety questions relating to alertness, the likelihood of making mistakes and confidence in driving home after the different shifts. Moreover, outcome measures relate to questions concerning health and satisfaction with the shift schedule.

Folkard derives recommendations for shiftwork design for aircraft maintenance personnel. Moreover, he examined whether it is possible to predict outcome measures on the basis of various variables including demographic ones, ratings of circadian type, the individual's control over the work schedule and various specific features of the shift systems concerned.

6.3.2 Findings

Folkard found over hundred different work patterns and grouped them into five main categories:

(1) 32.49% of his subjects worked rotating shifts involving nights.
(2) 30.24% of his subjects worked rotating shifts without nights.
(3) 9.13% of his subjects worked permanent nights.
(4) 1.43% of his subjects worked permanent afternoons.
(5) 26.71% of his subjects worked permanent mornings.

The five groups differed with respect to demographic variables:

- Engineers working rotating shifts with nights were significantly **younger** than those working permanent mornings or rotating shifts without nights. This is in line with the age-induced increase of strain and the subsequent healthy worker effect described in Chapter 3.3.

- Employees working rotating shifts with nights had less **experience as engineers** than the other groups.

- The groups also differed in terms of the **experience with the present job**:
  - People working in rotating shifts without nights having the greatest and permanent morning workers having the least experience.
  - As far as the overall shiftwork experience is concerned those working rotating shifts without nights had the greatest experience, whilst permanent morning workers had the least.
  - Both permanent morning and afternoon shiftworkers had less experience of their present shift pattern than those working permanent nights or rotating shifts.

- In terms of **commuting time** there was a slight difference between the groups: Those working rotating shifts with nights travelled on average five minutes longer to work than those who did not work during nights. Rotating shifts with nights involved the highest number of hours schedule wise. As far as actual work hours are concerned, the group of those working in rotating shifts without nights worked the fewest hours.

From his findings Folkard derived several recommendations for aircraft maintenance personnel.

- ⇨ A limit on scheduled hours per week of 48 hours, as well as a limit on scheduled hours per shift of twelve hours.
- ⇨ A maximum of four hours work before a break, and a minimum break length of ten minutes plus five minutes for each hour worked.
- ⇨ A limit of seven successive work days before a break of at least two rest days.
- ⇨ The start time of the morning/day shift should not be earlier than 6 am, and it should be delayed until 7 or 8 am whenever possible.
- ⇨ The end of the night shift should be no later than 8 am.
- ⇨ At least 28 days notice should be given of the shift schedule.

Concerning the outcome measures Folkard established three factors: The four health measures constitute as the first factor ‘poor health’. Factors 2, 3, and 4 comprised the alertness, likelihood of making a mistake, and confidence in driving home for the night, morning and afternoon shifts, respectively. Folkard refers to them as the ‘**perceived risk**’ **outcome measures**.

Examining whether it is possible to predict these outcome measures on the basis of a range of variables including demographic ones, ratings of circadian type, the individual’s control over the work schedule and various specific features of the shift systems revealed following findings:

- As far as the perceived risk on night shifts is concerned the demographic variables for neither group were significant predictors.
- Morningness (Chapter 3.4) was positively related to perceived night shift risk, i.e. **morning types perceived the night shift as riskier than evening types**.
- Permanent night workers associated **increased control** over which specific shifts they worked with **reduced perceived night shift risk**. This relation was not found for rotating shiftworkers.
- The rotating group associated greater control over the start and finish times of their shifts, and **greater notice of their shift schedule**, with a **reduced perceived night shift risk**.
- As far as the perceived risk on morning/day shifts is concerned the demographic variables were significant predictors. In most cases **greater experience** was associated with **greater risk**.

Folkard reports that the most reliable finding is that increased experience of the present shift was associated with decreased perceived risk in the permanent workers. He states that this may reflect an increased adjustment of their circadian system to morning or day shifts. Rotating morning types perceive morning/day shift as less risky than evening types. Yet, this effect was not present in the permanent workers.

- As far as the perceived risk on the afternoon shift is concerned, the data suggest an association between increased experiences in the present job and increased perceived risks during afternoon risks. Folkard interpreted this result as reflecting an **increased awareness of risk with experience**, rather than a genuine increase in risk with experience. Again, morningness was significantly related to perceived afternoon shift risks: Morning types rated the risk higher than evening types. Moreover, later start, but not finish, of the afternoon shift was associated with an increased perceived risk.

- Concerning the factor ‘poor health’, Folkard emphasised that the only predictors approaching significance were the length of experience as engineer (**greater experience – poorer health**) and perceived control (**greater control – better health**). Moreover, Folkard delineated that the factor dissatisfaction can be reliably predicted with shiftwork experience (**less dissatisfaction with greater experience**), morningness (**less dissatisfaction as morning type**), control over shifts worked and start times (**less dissatisfaction with greater control**), and greater notice of the schedule (**less dissatisfaction with greater notice**).

- Concerning features of the work schedule Folkard found **increased hours** scheduled per week and **increased numbers of successive work days** associated with **increased dissatisfaction** and increased scheduled rest days and annual leave with decreased dissatisfaction. However, the inclusion of night shifts and the length of the shift were no reliable predictors of dissatisfaction.

- Folkards concluded “with respect to perceived risk, in most cases the trends observed in this study are reasonably consistent with established trends in either performance capability or accident and injury frequency”.

- As most obvious discrepancy Folkard quoted the lack of any increase in perceived risks as the span of successive night shifts increased from two to four. Due to this unexpected result Folkard **questioned the validity of the questionnaire based assessments of risk**. Consequently, he concluded that individuals’ assessments of risk are not always accurate, and therefore he suggests educational programmes designed to alert engineers to the times at which they are most likely to make mistakes.

6.3.3 Summary

- ⇨ Scheduled hours per week should be limited to 48 hours.
- ⇨ Scheduled hours per shift should be limited to twelve hours.
- ⇨ At latest after four hours work a break is due.
- ⇨ The minimum break length is ten minutes plus five minutes for each hour worked.
- ⇨ At latest after seven successive work days a break of at least two rest days are due.
- ⇨ The morning/day shift should not start earlier than 6 am and should be delayed until 7 or 8 am whenever possible.
- ⇨ The night shift should end no later than 8 am.
- ⇨ At least 28 days notice should be given of the shift schedule.
- ⇨ Experience, subjective control over the roster, morningness and eveningness influence the outcome measures health and risk perception.

6.4 French Aircrews – Atypical Working Hours

6.4.1 Introduction

Three French studies concerning atypical working hours of flight crews are summarised in this section. The studies go beyond the investigation of shift patterns as such and focus on the influence of napping, diverse aspects of fatigue in the view of pilots, and recommendations for flight crews.

6.4.2 Napping during transatlantic flights

Cabon, Bourgeois-Bougrine, Mollard and Speyer (2003) conducted a study on sleep patterns of cockpit crew members. The study investigated the effects of pilot napping during transatlantic flights. It was investigated whether napping had positive effects on alertness and performance as suggested by Rosekind *et al.* (1994) or whether the negative effects on safety due to sleep inertia are predominant. Negative effects can occur especially during the awakening phase after a deep sleep stage (Naitoh, 1981). Therefore, the duration of the pilots' sleep was restricted to 45 minutes in the study at issue. This limitation of sleep was supposed to avoid the mentioned deep sleep stage. Twenty pilots were subjected to physiological monitoring of brain activity

(ElectroEncephaloGraphy [EEG]), eye movements (ElectroOculoGraphy [EOG]), and cardiovascular responses (ElectroCardioGraphy [ECG]) during ten round trips Brussels-New York.

The authors found out that **sleep inertia occurs even after this limited rest period of 45 minutes**. They attribute this effect to the influence of the time of the day and the cumulative sleep loss. The authors state that airlines already recommending this rest period should take the new findings into account: Airlines could for example **provide enough time after the nap** to avoid the negative effects of sleep inertia.

6.4.3 Fatigue: point of view of French pilots

Fatigue in aviation depicts the focus of the second study mentioned in this chapter. The study on French pilots was conducted by Bourgeois-Bourgrine, Cabon, Gounelle, Mollard, Coblentz and Speyer (1999). The questionnaire survey focused on the pilots' perception of fatigue. Factors generating fatigue, striking physiological and operational symptoms, and strategies or countermeasures involved in facing fatigue were investigated.

Pilots on **long-haul** flights mainly mention the **loss of sleep, the night flight** and **jet-leg** as causes of fatigue, whereas pilots on **short-haul** flights attribute fatigue to the **high workload, multi-leg flights**, and the **compliance with time constraints**. The most important factors generating fatigue during climb and descend are sleep deprivation, high workload and the density of verbal communication. As far as flight events are concerned the authors report that performing an additional leg, which was not planned originally, has a significant impact on pilots' fatigue. This especially refers to crew members flying long haul, because of the previous long duty time. The results thereby confirm the negative effects of excessive shiftwork described in Chapters 3 and 4 and the importance of the predictability of shifts for the individual employee. On the other hand, compliance with time constraints has a high impact for short-range flights.

Another result of the study refers to the manifestations of fatigue. The authors distribute the **manifestation of fatigue in three main categories: mental, verbal and sleep-loss-related** manifestations. The pilots themselves describe the sleep-loss-related manifestation of fatigue as a reduction of alertness and attention and a lack of concentration. For the other crew members, however, they refer to mental manifestations, such as the increase of reaction time and minor mistakes, and verbal manifestations, such as the reduction of social communications and bad message reception. The authors conclude that pilots have a different self and peer perception. They are not aware of the consequences of fatigue on their own quality of performing flight tasks.

Results on the impact of fatigue on flying tasks do **not suggest a difference between short and long-haul flights**. Generally, the flying tasks are experienced significantly more difficult when pilots are tired, especially supervisory activities, manual flying, selection and entering data.

Moreover, the authors analysed the relation between the level of fatigue and the duty time performed over the last seven day period. The results confirm a **higher fatigue for nocturnal duty** time and a greater importance of fatigue in short-range flights than in long-range flights if the diurnal duty time is the same.

6.4.4 Coping with long-range flying

Another study of Bourgeois-Bougrine, Folkard, Cabon, Mollard, and Speyer (2003) revised an earlier recommendations booklet for crew rest and **alertness on long-range flights** (Cabon *et al.*, 1995; Mollard *et al.*, 1995). The revision takes into account for example the **time when aircrew members have to leave their home or hotel** instead of basing the recommendations upon the scheduled flight. The time when the crew has to get up determines when they can take a nap. Moreover, the authors plan to develop a software programme which makes it easy for crew members to get individual recommendations and an individual sleep schedule. The software considers **external conditions** (e.g. flight details) as well as **individual characteristics** such as morningness-eveningness (see also Chapters 3.5 and 6.3, and Annex 1). With respect to the diversity and the various influencing factors in the field of shiftwork and irregular working hours, the effort to develop a comprising software programme needs to be made and depicts a step in the right direction. By doing so the individual differences (personal and schedule wise) are taken into account and adequate recommendations are the result.

6.4.5 Summary

The authors sum up and emphasise "the need to introduce chronobiological rules in aircrew scheduling to prevent fatigue or to reduce its impact on flight safety; second, flight and duty time limitations have to take into account the flight categories; third, crew members have to be informed of the negative impact of fatigue on the quality of flight tasks performing for themselves also."

6.5 Stand Allocation Service – Copenhagen Airport

6.5.1 Introduction

The following section describes the Stand Allocation Service at Copenhagen Airport. The section consists of a description of the workplace and the workload of the traffic coordinators. The development of the shift system is delineated as a case study and lessons learned are summarised.

6.5.2 The workplace

At Copenhagen Airport, Stand Allocation Service is performed by 16 airport employees called traffic coordinators situated in the apron tower. The ground control is sited at the front of the same tower to facilitate coordination between ground controllers and the traffic coordinators (placed at a podium at the rear of the tower). The traffic coordinators are placed in three workstations from where the stand allocation is performed with the aid of a computer system. The employee at workstation No. 1 is supervisor for the day, the employee at No. 2 is assistant coordinator, and the employee at workstation No. 3 is monitoring the automatic landing information system, which includes observing landings at the runways and subsequently checking the information system to correct possible errors. During lunch breaks the traffic coordinator at workstation No. 3 is standing in for employees at workstations Nos. 1 and 2. The stand allocation is manned 24 hours a day, apart from working station No. 3, which is only worked from 7 am to 11 pm.

6.5.3 Distribution of workload over 24 hours

The workload changes during the day. The highest workload occurs during the peak hours of approx. 8 am to 10 am, 2 pm to 4 pm, and 6 pm to 9 pm. At night the heaviest workload is found from midnight to 3 am, partly because stand allocations for the next day's traffic is planned during this time span. From 3 am to 5 am the workload is at its minimum with almost no landings or take-offs. Both employees at night duty are expected to stay awake all night.

6.5.4 The shift system procedure

The Stand Allocation Service operated by the airport was implemented in 1993, and it thereby relieved Scandinavian Airlines System (SAS), which had been in charge of the stand allocation operation until then. Sixteen employees where hired from different companies situated at the airport. At the beginning no shift system was available, and the roster was prepared by clerical staff. However, after some time this work was allotted to the traffic coordinators themselves, and hereafter one of the traffic coordinators was regularly assigned to some hours of office work to draw up a draft for the roster. When completed, the draft must be approved by the management.

One of the problems that arose when the roster was prepared by clerical staff was a problem of adjustment. When the traffic coordinators wanted to make adjustments to their individual rosters because of personal preferences for free time, the clerical staff tried to please everyone in planning the roster (see social requirements in Chapter 3.6), but since not all employees could be absent at once, some wishes for adjustments were turned down and others not. This inconsistent granting of the more valuable free time caused serious conflicts among the traffic coordinators, and it was decided to change the procedure. Instead the management allowed the traffic coordinators to swap duties among themselves after the roster had been published, emphasising that Danish law on working time had to be maintained at all times. According to Danish legislation (*Bekendtgørelse af lov om arbejdsmiljø §51*) an employee is for example entitled to one day off (lasting at least 24 hours) every seven work days.

After a couple of years experience with this procedure, it was decided by the management in agreement with the traffic coordinators, to try initiating a more formalised shift system.

The traffic coordinators had by then made a local agreement with the management on working hours. This agreement included rules on yearly and monthly norms, minimum number of successive free days and how long prior to the coming into force the roster had to be presented to the employees.

6.5.5 The current shift system

The traffic coordinators were presented three shift systems, and by a **democratic vote** they decided on a **forward rotated** system (morning, evening and then night duty). Hence, the benefits of participation and a forward rotating shift system were utilised (Chapters 2 to 4). Since only two traffic coordinators were needed during the night time, the **number of night duties was reduced** compared to the numbers of morning and evening duties. Each duty period was followed by a **minimum of 59 hours free time** (an eleven-hour rest period and 48 hours free time), except for periods of under-staffing during which free time less than 59 hours could be scheduled occasionally but never more than once a month.

Only three successive identical duties were allowed, and night duties were restricted to two successive duties apart from weekends where three night duties in a row were scheduled. This was due to a wish to keep the weekends as free as possible for those employees having the weekend off, so they should **not have to work neither Friday night nor Sunday night**. The rule on maximum number of successive identical duties was decided upon according to the wish of the traffic coordinators as a majority of these complained about being fatigue due to longer periods of identical duties. This operational observation again matches the scientific research results reviewed in Chapters 3 and 4.

Since the Stand Allocation Service is manned 24 hours a day, one of the issues concerning the traffic coordinators in the making of the roster was to get at least some weekends and national holidays off. Therefore, a yearly account of these **free weekends and holidays** was made for each employee, keeping in mind that these days were **distributed equally** among the traffic coordinators.

At Christmas time, a special roster was made for the period approx. December 20th to January 2nd to secure that working Christmas Eve and New Year's Eve was equally distributed among the traffic coordinators in an eight-year rotation schedule (every traffic coordinator working Christmas Eve or New Year's Eve once every four years). During the Christmas holidays, manning the workstations was reduced when possible in accordance with the reduced traffic flow at the airport.

6.5.6 Summary

The case study described in this section demonstrates the application of some of the recommendations derived from the literature review (Chapter 3). It illustrates the importance of including employees in the decision-making when planning the roster. The conflicts ceased when the traffic coordinators were allowed to take part in preparing the roster. Not only because they could participate in planning their own working hours, but also because they consequently realised that making a good roster is not an easy task as many things have to be considered i.e. rules on working hours, local agreements, traffic load and employee/management preferences.

With only sixteen people in the shift system it should not be impossible to make a roster that pleases the majority of the employees. The conflicts that did however arise between the traffic coordinators and the management, and among the traffic coordinators themselves, in making the roster show how difficult the job would be making a roster for fifty to hundred employees. An example to illustrate this is the Danish Railways S-Train Division (DSB S-Tog) where rosters are made and daily supervised for 500 engine drivers by no less than four full-time staff and one full-time employee from the railway union.

In conclusion, considering the human factor is important for the management in making a good roster. This can be achieved by considering the wishes and issues of the employees as far as possible. Failing to do this will, in spite of all other measures taken, cause lack of motivation and health decrements among the employees and thereby reduce effectiveness in the work and the company itself.

6.6 Stress and Workload Study for Austrian ATCOs

The Austrian study conducted by the Social Sciences Department of the Vienna Chamber of Employment gives a good overview of requirements and problems of ATM.

The Department carried out this study on stress and workload of Austrian air traffic controllers (ATCOs) in 1990/91 (Austrocontrol, 1990/91). 202 ATCOs participated from all six provincial air traffic control units (provincial airports) and the Air Traffic Control Centre (ATCC) in Vienna District 3. The study included flight progress strips as well as video analysis and expert ratings because of the anticipated air traffic growth and because of the staggered liberalisation of European air traffic. The impacts on stress and workload of ATCOs were to be investigated.

6.6.1 Specific areas of stress within the air traffic control service

Specific areas of stress ATCOs highlighted in the study were the following:

- Decisions ATCOs have to make are complicated.
- Difficult situations occur fairly often.
- The work of an ATCO requires quick reactions and decisions; therefore ATCOs work under enormous time pressure.
- Other stress factors are monotony, mental fatigue and mental saturation in periods with less traffic or fewer problems. ATCOs find it problematic during these phases to react quickly to an incident which occurs suddenly and threatens safety.

Separation losses are the most stressful situations for ATCOs. 70% of the participating ATCOs find complex traffic mixes (large numbers of aircraft with different specifications), short radio outages, high-density traffic, and emergency situations just before the end of a shift very stressful or stressful. Around 60% found a hectic working environment resulting from radar image disruptions or outages, bad weather or slow colleagues, or the fact that they had not taken the best possible decisions very stressful. Finally, 50% found noise, heat, radio interference and also unjustified criticism from their superiors very stressful or stressful.

6.6.2 Results of the control strip analysis, expert ratings and video analyses

The results highlight the **traffic volume** as a significant predictor for ATCO workload. The ‘ideal workload value’ was the simultaneous control of three aircraft in ten minutes. If the ideal value is constantly exceeded, there is a drastic deterioration in the ATCOs' mental state towards the end of their shift. If the workload falls considerably below the ideal level, this manifests itself in monotony and mental saturation. The ‘ideal’ workload curve across the shift for ATCOs is a slow but constant rise in workload to the level of three aircraft every ten minutes which is not exceeded during the rest of the shift.

The number of **radio communications** per aircraft also constitutes an important stress factor. How many aircraft the approach controllers could handle in a thirty-minute period before reaching their maximum workload proved to be primarily dependent on how many radio communications issuing instructions were required per aircraft.

Whenever a large volume of traffic was anticipated, an increase in tension was to be observed in ATCOs. **Methodical planning and organisation** by air traffic coordinators as well as a good **cooperation** between radar controller and air traffic coordinator can alleviate **peak workloads**. Controllers and coordinators of widely different ages and working methods had problems dealing with peak workloads.

6.6.3 Work satisfaction and sensitivity to stress

Work satisfaction constitutes an important factor in determining employee stress levels. Therefore, it was assessed in the Austrian study as well as its potential impact on the stress felt by ATCOs. Three main job satisfaction factors were identified, i.e. organisation, social relations and work content.

Basically, almost all ATCOs rated their colleagues as ‘fairly good’ (in terms of satisfaction with the level of cooperation). Around 80% gave the same rating to their work. Only around 50%, however, gave the same rating to their immediate superior. Somewhat fewer - around 40% - rated their working conditions as ‘fairly good’. The lowest level of satisfaction related to the management. Only just under 10% of ATCOs rated these as ‘fairly good’, whilst 90% rated them as ‘fairly poor’, with 40% expecting an improvement in this regard in the future.

The factor of little satisfaction with ‘organisation and management’ combines several aspects which scored low on work satisfaction and subjective importance: personal development and promotion prospects, organisation/ management, and external working conditions.

Work satisfaction proved to have a major impact on the development of health problems and the deterioration in the subjective mental state via interpersonal stress management.

Increased work satisfaction contributes to a more effective stress control: increased work satisfaction and decreased health problems coincide. The subjective mental state as well as the health state is highly dependent on the degree of burnout.

6.6.4 Mental and physical effects of air traffic control work

At the end of a shift ATCOs suffered from more physical pains (pain in the limbs, back, neck, headaches, etc.) and experienced less efficiency, motivation, well-being, ability to concentrate on a mental level. Speaking in social terms, ATCOs showed reduced social initiative and increased social withdrawal. As a consequence these phenomena also caused stress to families or partners.

Mental and physical effects were also studied **during a shift**. The focus was laid upon mental fatigue, monotony, mental saturation and stress. These phenomena were examined using Plath and Richter's BMS procedure (questionnaire for measuring stress in control and surveillance work).

Even though the work of ATCOs is one of the most stressful jobs, periods with relatively little stress occur as well. In such periods, stress phenomena such as **monotony and mental saturation** develop.

Factors that influence monotony and mental saturation are the following:

- repetitive work,
- environment (e.g. monotonous background noise),
- lack of stimulation (e.g. social isolation),
- individual emotional evaluation,
- motivational factors.

Towards the end of a shift there was a tendency of the participating ATCOs to show signs of a significant increase in mental fatigue. Exertion, effort, loss of concentration and tiredness were more salient at the end of a shift than half an hour after the beginning of their shift. Partly, they suffered from increased monotony towards the end of their shift and showed a substantial change in the 'mental saturation' feature of the mental state.

As further results of the study show, these phenomena became more pronounced as

- the number of aircraft to be controlled increased,
- the number of conflicting aircraft increased,
- the total number of overflights in a given period of time increased.

As far as **burnout** is concerned, the study revealed that generally speaking ATCOs proved to be at little risk of burnout.

Even though these results indicate a significant deterioration in the ATCOs' mental state, ATCOs themselves assessed their level of activity and performance after the end of a shift as good. They reported to be happy with their work and to feel well-balanced. This paradox might be risky: since the health consequences are identified late, they can in certain circumstances be chronic and thus require long-term treatment.

6.6.5 Main problems of the ATCOs

The main problems of Austrian ATCOs in the data collection period were as follows:

1. High statutory retirement age under the Austrian General Social Insurance Act (ASVG).

2. Lack of health prevention measures, such as preventive cures.

3. Lack of ongoing further training.

4. Inadequate staffing.

6.6.5.1 The retirement age of ATCOs

The retirement age of Austrian ATCOs is 60 or 65. This retirement age is questionable from the gerontopsychological viewpoint and with regard to air traffic safety. The results of psychological research show that with age, the mental and physical abilities required for the job diminish. Affected are e.g. reaction time, concentration, hearing and sight, and cognitive flexibility. This decrease and the increased strain on ATCOs were confirmed in the interviews.

At the age of 40-45 on average, the ATCOs noticed their abilities starting to diminish. This has consequences on the working methods. About 60% of the ATCOs were ‘very considerably’ or ‘considerably’ hampered by colleagues working slowly. Older ATCOs criticise the limitation of opportunities for personal development. Add to that the profession is highly specialised, therefore ATCOs find it difficult to change jobs.

The retirement age of 60 or 65 still applicable under the ASVG is no longer justifiable. Since the retirement age of Austrian ATCOs is not in line with the international norm, it would be useful to bring it into alignment.

6.6.5.2 Preventive health programmes

The lack of health-specific prevention measures such as those available for ATCOs in many European countries is most regrettable, especially under the assumption that ATCOs in their forties or fifties are not able to cope as easily in what is a stressful profession as the younger colleagues.

To ensure air traffic safety, the mental and physical fitness of the ATCOs has to be maintained at an appropriate level. Generally speaking, 20-30% of the ATCOs interviewed, chronic complaints included stress, shoulder-arm syndrome (stiff neck), problems with eyesight, intervertebral disk disorders, minor headaches, head colds, tension/cramp, general tiredness/fatigue/ exhaustion. The complaints specified are typical for shiftwork and screen work and for stressful activities placing a great strain on the immune system.

Preventive health measures in many European countries contribute considerably to enhanced air traffic safety. With regard to the most frequently cited chronic complaints, preventive **cures** (including spinal training, relaxation training and ocular training) as ongoing preventive health programmes should be introduced from the age of thirty. Experience shows that the people most in need of these programmes are the very ones who do not use them.

Also there is considerable need for **psychological counselling**. This could help reduce work- and performance-related anxiety, which is caused by traumatic experiences while on duty and subsequently influences the ATCOs’ working methods.

Additionally, more thorough **eye tests** should be introduced, as many ATCOs complained of problems with their eyesight on finishing their shift. **Ergonomic**

analyses of the working positions should also be carried out, as they could provide more accurate information on these complaints.

6.6.5.3 Ongoing and further training for ATCOs

ATCOs both criticised the initial training provided and the lack of opportunities for ongoing and further training (lack of instructors, suitable equipment and premises).

The impending changes in European aviation and the associated technical innovations (both in aircraft and in ATC) and innovations in ATC procedures make this lack of measures highly problematic. As a consequence, ATCOs learned the new procedures and regulations by themselves without the appropriate material. This makes it very difficult to improve the quality standard achieved.

Further the study revealed that ATCOs often have traumatic experiences (which are not properly dealt with, e.g. through psychological counselling) which affect their working methods for years to come.

Many ATCOs also criticised the relatively short induction period when new software is introduced. ATCOs called for training in the event of changes to procedures, briefings and emergency training.

Further training programmes not only ensure that the ATCOs preserve their high levels of expertise until retirement, but to encourage self-assuredness in their control and supervisory functions, and to promote a positive working environment and teamwork.

Further training programmes should provide the following:

a) Training for mental capacities (reaction speed, spatial visualisation, flexibility in solving problems in critical air traffic situations, etc.).

b) Training in social skills essential for teamwork and safety in ATC (conflict resolution abilities, empathy and communication).

c) Intensive induction of new procedures and software systems.

d) Introduction of new processes and technical innovations in both aircraft manufacturing and ATC to help ensure air traffic safety and encourage the ATCOs to identify with aviation.

e) More intensive exchange of information between the ATCOs and pilots (joint events to make the activities of the other partner transparent and to encourage effective cooperation). Cockpit flights for ATCOs as minimal solution.

6.6.5.4 *The staffing situation*

In the 1990 there were **considerable staff shortages**. The effects were felt particularly in summer, when the number of staff off sick rose considerably. As a result, ATCOs had to replace sick colleagues and hence were on duty for more than three consecutive days (up to five or six days). This is all the more problematic since the results of the study show that the psychological attributes ‘sensitivity’ and ‘anxiety’ prior to coming on duty increase as the number of days worked increases. Moreover, it was not possible to relieve the ATCOs from their working positions for a considerable period of time (up to three hours in extreme cases).

ATCOs are now tested by the psychologists of the Austrian traffic safety board. Most candidates recruited are supposed to be 23 or under (their active ATC career falls within an age of 25 to 35 when their physical and mental capacities are at their peak).

The growth in air traffic, which has been under way for some years now, requires a flexible allocation of breaks, and hence the availability of stand-by staff. This appropriate organisation of work, with a need for shorter sector working hours and the measures in turn require more personnel.

6.7 Studies and Experiences from Outside Europe

A number of studies outside Europe are outlined in this section with the details provided in Annex 1.

6.7.1 FAA: operational fatigue risk factors

The FAA together with other transportation organisations ordered an extensive review of shiftwork problems and solutions which was prepared by McCallum *et al.* (2003). The operational fatigue risk factors discussed in this paper are the same as those mentioned in the previous chapters:

- extended work and/or commuting periods,
- split-shiftwork schedules,
- sleep/work periods conflicting with circadian rhythm,
- changing or rotating work schedules,
- unpredictable work schedules,
- lack of rest or nap periods during work,
- sleep disruption,
- inadequate exercise opportunities,
- poor diet,
- environmental stressors.

The conclusions and recommendations are compatible with the ones given in Chapter 7.

6.7.2 FAA and NAV Canada: fatigue management programmes

NAV Canada describes a managed approach to fatigue in the annual report 2001. Their organisation's philosophy is that the company, its employees and their bargaining agents share the responsibility of managing fatigue. Together with Alertness Solutions, a scientific consulting firm, a Fatigue Management Programme was implemented. According to the report, the programme's long-term objectives are to help employees better manage fatigue, and to incorporate scientific principles of fatigue management into NAV Canada's practices. Especially a comprehensive information and training programme is provided and existing shift scheduling practices in Edmonton and Gander Area Control Centres are analysed.

Also McCallum *et al.* (2003), discuss key components of fatigue management programmes:

- organisational commitment,
- employee-employer partnership,
- education and training,
- employee health screening,
- programme evaluation and refinement.

More details and examples of fatigue management programmes and fatigue countermeasures are given in Annex 1.

6.7.3 Australia

Australian governmental and research organisations can offer a great amount of shiftwork research. Some of the more recent work is mentioned in Annex 1.

6.8 Summary

From the extensive research results reviewed above, which are not at all exhaustive, following aspects should be kept in mind for shift management in ATM. Grouping of the results follows the different national subjects that were studied considering that other kinds of tasks might reveal different results and require modification of the recommendations. However, a certain extent of generalisation is acknowledged for the following aspects:

German ATCOs and ATSAs: The predicted impacts of shiftwork on health, performance, social life, and family were confirmed in this context. The avoidance of backward rotating shift systems and concentrated working time in combination with high workload can prevent the occurrence of manifest diseases like tinnitus. Especially older colleagues prefer balanced workloads.

British aircraft maintenance engineers: Weekly work should be limited to 48 hours and no shift should exceed twelve hours. After a maximum of four hours work, a break is due which should last ten minutes plus five for each hour worked. A maximum of seven days should be worked in a row and than be followed by at least two days off. Notice should be given 28 days prior to these arrangements.

French aircrews: Napping can help coping with fatigue but enough time has to be given to overcome potential inertia. Short- and long-haul flights expose fatigue problems for different reasons. Chronobiological rules and flight categories should be considered in fatigue management and the crew must be informed.

Danish gate allocators: The general recommendations for shiftwork management were successfully applied in this context, e.g. participation of the employees, equal distribution of valued free time at weekends and holidays, forward rotation, restriction of night duties and sufficient free time afterwards.

American transportation operators: The reviewed research results and practical experiences are confirmed by US studies. Moreover, the US transport organisations provide extensive knowledge on fatigue management techniques and programmes which involve organisational commitment, employee-employer partnership, education and training, employee health screening, programme evaluation and refinement.

Australian organisations: These also have extensive research and application experience which confirm the European view. New aspects are added like the amplification of adverse shiftwork effects in precarious employment and under intensified market conditions (e.g. low-cost carriers). These will be of growing importance in future work settings generally and also in aviation particularly.

Despite this extensive knowledge, many questions remain open which have to be addressed in future research and development for example cultural differences within Europe. Especially matching manpower with workload variations will be of increasing importance due to the need for cost-effective shift management.

7. SHIFTWORK DESIGN

7.1 Introduction

The design of shift systems demands a high degree of competence, skills, and experience of the designer. The design of shift systems aims at a working-time organisation that considers interests of the company (safety, productivity and efficiency), health affecting factors, social impairments as well as individual preferences.

It is also stressed that a best shift system in ATM cannot be defined. The specific conditions of the work situation, the workload, its spatial and temporal distribution, the individual conditions such as age, attitude, and social support as well as the organisational frame play a vital role in the design of shift systems. However, taking into account the findings from existing research (mentioned in the previous chapters) the following guidelines are provided for shiftwork design.

7.2 Guidelines for Shiftwork Design

Guideline 1: Successive Night Shifts

> The number of successive night shifts should be as low as possible; it should not exceed three night shifts in a row.

Explanation: Even though many shiftworkers having a schedule of five or more successive night shifts feel that their body has adapted, there is no genuine adaptation of the body functions to working at night. Adaptation can only occur partially and one single day off between the night shifts extinguishes the partial adaptation easily. Working nights means working against the body clock (circadian rhythm). That is why the night shift periods should be **as short as possible**, so the adaptation does not start in the first place. Moreover, sleeping in the morning time leads to a reduction in length and quality of sleep compared to sleeping at night. Working successive night shifts causes an accumulation of **sleep deficiency with reduced sleep quality**. Additionally to health damages the risk of accidents is increased due to the increasing fatigue.

The number of night shifts does not only affect health, but also social relations. Apart from physiological aspects **social consequences** of night and shiftwork play a vital role for the employees. Traditional long-rotated shift schedules with early, late, and night shifts and a weekly change result in the employees' separation from free time activities. Especially the evenings with family and friends are affected for a period of at least two weeks. This separation from free time in the evening, which is highly socially valued, leads to social isolation of many shiftworkers. The time for a shared family life is reduced. The families' effort to adapt to the shift schedule is considerable. Shift schedules with only a few early, late, or night shifts enable employees to join family life in the evening after four to six days only – depending on the schedule.

Working at night means working against the body clock. Therefore, night shift periods should be as short as possible. The number of successive night shifts should be as low as possible to avoid an accumulation of sleep deficiency and negative social consequences respectively.

Guideline 2: Rest Period between Night Shifts

> After a night shift, the rest period should be as long as possible. The resting time should not be less than 24 hours.

Explanation: This demand arises from scientific findings, that **working night shifts** is an **additional risk** besides the job activities themselves. Consequently, employees should be granted **more resting time** after their night shift period. Most desirable is a resting time of 48 hours. Unfortunately it is hardly possible to consider this recommendation at all times when putting it into practice. The extended resting time after a night shift period might result in a reduction of the coherent free time which is also highly desired. This problem especially refers to systems with a lot of night shifts, very short night shift periods, and many standard weekly hours.

Working night shifts is considered an additional risk. Therefore, the resting time after a night shift should be extended. The aspect of coherent free time needs to be considered.

Guideline 3: Coherent Blocked Free Time at the Weekends

> Coherent, 'blocked' free time at the weekend is to be preferred to single days off during the weekend.

Explanation: Even though the design of working hours is becoming more and more diverse, the **weekend** still takes up a **high status**. Most of the employees value free time at the weekend clearly higher than during the week. Coherent free time at the weekend means two continuous free days at the weekend, including at least the Saturday or Sunday. **Possible combinations** would be for example: Friday and Saturday, Saturday and Sunday, or Sunday and Monday.

<u>Guideline 4</u>: Number of Free Days

> Shiftworkers should have more free days per year than employees on day duty.

<u>Explanation</u>: Even with a continuous way of production working weekends and on holidays should be compensated with free time. Moreover, the additional burden resulting from working night shifts has to be compensated, as for example demanded by German law (*Arbeitszeitgesetz* § 6, Abs. 5). The **compensation** should be granted as **free time**. Depending on the number of night shifts additional free days are to be given.

<u>Guideline 5</u>: Shift Rotation Pattern

> Unfavourable shift sequences are supposed to be avoided. Forward rotation is preferable.

<u>Explanation</u>: Ergonomic studies shows that on average employees working in a **forward-rotated shift pattern** (early, late, night shift) develop less health impairments than employees working in backwards rotated shift systems (night, late, early shift). Resting times between the shifts (when changing shifts) within forward-rotated systems are usually longer. Employees however do not always appreciate the forward-rotated shift system as it reduces the coherent free time (see No. 9).

<u>Guideline 6</u>: Early Shift

> The early shift is not supposed to start too early.

<u>Explanation</u>: The early shift is not meant to be half a night shift. It is because of long drives to work, which are very common for many employees nowadays, that they have to get up at 3:30 am in order to start their shift at 5:30 am. Experience shows that employees do not go to bed a lot earlier when working the early shift. In addition many fear not to wake up in time. This leads to a considerable **sleep deficit** – especially within long-rotated systems.

<u>Guideline 7</u>: Night Shift Length

> Night shifts should finish as early as possible.

<u>Explanation</u>: This recommendation is based upon the finding that sleeping times during the day are related to when the sleep was started. The earlier the sleep begins the higher the probability of a

longer sleeping period. Most workers wake up around noon because of their body clock. Depending on when they have fallen asleep the sleep time varies. Within continuous productions or a 24-hour service company this demand contradicts recommendation No. 6.

Guideline 8: Individual Preferences

> Individual preferences are to be taken into account instead of rigid starting times.

Explanation: Shiftwork employees are increasingly interested in an **individual flexibility** of starting times (see also Sections 3.5, 3.6, and 5.2.4). It is possible – and some companies have already put it into practice – to offer starting times between 6 and 7 am. Shiftworkers can choose according to their individual preferences and conditions (e.g. driving times to work).

Guideline 9: Concentration of Working Hours Restriction

> The concentration of working days or working hours on one day is supposed to be restricted.

Explanation: Experience shows that shift schedules with a **large free time period** are very attractive to the employees. This especially applies to younger shiftworkers. Yet, long periods of free time can only be won at the **expense of working-time concentration**. In order to gain long free time periods, many shifts have to be worked without interruption by days off. The nursing service in hospitals often uses this system: Their shift schedule shows cycles of twelve days or nights without a day off. The concentration of working time on one day constitutes the possibility to get long periods of free time. This arrangement refers especially to e.g. police, fire service, and partly to the chemical industry. Working twelve-hour shifts results in a working time of 36 hours within three days only. The resulting free time periods are the reason why twelve-hour shifts are assessed positively, especially by young and healthy employees. A change of this assessment occurs with **increasing age**: Older workers prefer a balanced workload.

There is good **reason against the concentration** of working hours: The **accumulation of stress** without the necessary rest time. The average daily working time of eight hours per day and 48 hours per week is the result of scientific findings about the effects of workload including the demands arising from shiftwork. Work induced stress leads to a continuous increase of strain. Depending on the kind of work this can result in (as demonstrated in the studies of Folkard, Akerstedt and Nachreiner quoted in the previous chapters):

- Physical or mental strain reflected as:
  - exhaustion,
  - tiredness,
  - reduced vigilance,
  - monotony and
  - increased risks of accidents.

Free time should allow a complete regeneration from stress responses. If there is not enough rest time to recover from the effects of stress, **health impairments** will be the consequences. When they occur depends on the specific type of work, the individual fitness and pre-dispositions. The arrangement of an eight hour day represents a limit that can of course be exceeded in single cases. Being aware of the stress curve during the shift constitutes a premise before exceeding the eight hour day: An increase in tiredness and in stress responses respectively develops not only over the time of a shift, but **also accumulates during a work week, month, and year**. That is the reason why not only the daily but also the monthly and yearly working time has been restricted.

Shift schedules should consider the type and also the difficulty of work concerning the set of the shift length. An **extension of the work days requires** that:

- there is only a minor stress level (physical, mental) caused by the type of work;
- no additional overtime arises;
- the risk of errors is limited;
- there is enough staff available;
- there is no exposition to toxic substances;
- the working time consists partly of stand-by duty.

Shift schedules with long free time periods are very attractive to employees. Yet, it needs to be considered that these periods are won at the expense of working-time concentration. There is good reason against the concentration of working time: Accumulation of stress and consequently of strain which may be reflected by tiredness, exhaustion, reduced vigilance and an increased risk of accidents. An extension of the work day requires certain preconditions for example minor stress levels and limited risks of errors.

Guideline 10: Transparency of Shift Schedules:

Shift schedules should be transparent and foreseeable.

Explanation: As mentioned above shiftworkers have limited possibilities to arrange their free time compared to colleagues on day duty. This **limitation** should not be enhanced by unforeseeable additional duties. The employees have to be able to **plan their free time**. Individual wishes and **preferences** are to be taken into account when designing the shift schedule. Also, motivation and satisfaction are positively influenced by granting the highest possible degree of **autonomy** to the employees. These aspects should be considered when undertaking flexible practices.

Table 4 gives an overview of the recommendations on shiftwork.

Table 4. Ten recommendations on shiftwork

No. 1	The number of successive night shifts should be as low as possible; it should not exceed three night shifts in a row
No. 2	After a night shift, the rest period should be as long as possible. The resting time should not be less than 24 hours
No. 3	Coherent, ‘blocked’ free time at the weekend is to be preferred to single days off during the weekend
No. 4	Shiftworkers should have more free days per year than employees on day duty
No. 5	Unfavourable shift sequences are supposed to be avoided. Forward rotation is preferable
No. 6	The early shift is not supposed to start too early
No. 7	Night shifts should finish as early as possible
No. 8	Individual preferences are to be taken into account instead of rigid starting times
No. 9	The concentration of working days or working hours on one day is supposed to be restricted
No. 10	Shift schedules should be transparent and foreseeable

7.3 Shiftwork Redesign

Unfortunately, experience shows substantial conflicts between affected employees and management and the personnel department respectively when changing shift systems; these conflicts may arise in spite of the positive convictions of all persons involved. The necessity and importance of an intensive discussion of the advantages and disadvantages of different rotas especially concerning health impairments in a long run before implementing new shift systems is often underestimated. The following criteria should be taken into account when implementing new shift systems:

- **Employee orientation**: A shift system is considered employee oriented when it a) takes into account the social requirements that are generally preferable (Chapter 3.6), and b) gives the workers a vote in the design of the roster (for example Chapter 6.5). Employees should participate in the design of working time. The importance of each design criteria must consider their assessment, especially with respect to valuable free time and social requirements. When working time has to be changed at an internal level, the employees define which criteria are most important for them. Previous experience has shown that these wishes vary considerably. Employer and employees ideally agree upon a target hierarchy (Figure 2).

- **Employees' age:** Older workers more often desire a balanced workload.

- **Traffic conditions:** This refers to long drives to work. It is of considerable importance if an employee has to drive to work only three times a week working a twelve-hour shift or four to five times working an eight-hour shift. Moreover, car pools play an important role as well.

- **Free time:** In centres of population as well as in rural areas with many leisure amenities employees like to use their time off as short holidays. 'Blocked' spare time is also often used to pursue a second job. In rural areas for example farming depicts such a second job. The second job might as well be a more or less systematic (approved or unapproved) activity.

- **Employees' family situation:** Especially women are restricted as far as the variation in working-time systems is concerned because they have additional family engagements. The desire for permanent night shifts in the field of nursing serves as a typical example for women with family.

- **Team composition**: The team composition can play a vital role for employees depending on the company's culture. A shift schedule which leads to a mixture of teams may be rejected considerably in some work areas (e.g. police, Chapter 5.3) whereas in other areas this criterion may not be of any importance at all.

- **Guarantee of income:** Employees usually reject changes in working time fundamentally if they cause financial losses.

- **Information:** Before employees actually can assess particular design criteria, they have to be informed about health and social restrictions or damages caused by these criteria. Therefore, short- and long-term effects of stress due to shift and night work are to be presented and discussed in information meetings.

Furthermore, it is stressed that some design factors are required and therefore cannot be discussed, for example legal conditions such as maximum working hours.

7.4 Summary

⇨ Some of the recommendations are contradictory and therefore cannot be implemented all at the same time. This is most obviously the case for recommendations Nos. 6 and 7. Conflicting aims require a target hierarchy (Figure 2).

⇨ It is an optimisation task, the demand for 48 free hours after a night shift and free weekends whenever possible requires particular premises. These premises refer to the assessment of the particular criteria when compared directly.

⇨ Which criterion is more important in order to diminish health risks for the employees: The optimum regeneration after a shift or the possibility to spend as much time with friends and family? In particular cases these criteria have to be discussed with the respective employee.

⇨ Even though it is hardly possible to put the criteria in a particular order, specific aspects take priority concerning the health risk reduction. Some of these criteria are protected legally by the European guidelines concerning working hours.

8. CONCLUSIONS AND INSIGHTS

The following conclusions and insights gained from this literature review are as follows:

1. There is a great variety of shiftwork systems today with little resemblance of traditional shiftwork systems. Shiftwork, especially night shifts, can have a number of adverse effects with respect to health, social life and work efficiency and performance quality. These problems occur in any industry that makes use of shiftwork. ATM differs in some respects in that:

   - Safety is of critical importance relative to other businesses.
   - ATCOs always have to sustain a high level of performance.
   - Complexity and dynamics are high relative to other businesses.
   - Overload (stress) as well as underload (boredom) is an issue. The latter has a special impact on situational awareness during night work as most units have to deal with low volumes of nocturnal traffic.
   - Workload varies substantially during the day (inbound and outbound rush), during the week (workday vs. weekend) and during the year (holiday and fare season, summer vs. winter traffic). On the employer side, these fluctuations challenge cost-effectiveness. The slopes down of traffic peaks can be critical times due to overshooting relax responses (Chapter 6.2.6).
   - The hand-over of ATCO positions are critical because the traffic picture has to be quickly taken up (Chapter 4.5).

2. Research reveals that a common sense approach to good shiftwork management is required. Different features of a shift system like the number of successive shifts, the length of a single shift and the effect of a certain time of day (early, late, night shift) need attention with respect to their implications on individual health, performance and safety.

3. The shiftwork guidelines for safety, health and social requirements in shiftwork management can also be applied with respect to productivity e.g. reduce night work to the possible minimum, limit shift length to eight hours and consider interactions with task, quality and quantity of breaks.

4. In terms, efficiency research indicates that there is growing trend towards individual rostering in the planning and allocation of staff. Also attention needs to be given to the allocation of breaks and the hand-over of positions.

5. Although there are general guidelines for good practice on shift design it is obvious that not all recommendations can be matched to full extent at the same time. To cope with conflicting guidelines for shiftwork

management, one suggestion is that employer and employees should define their respective targets within the shift system and agree upon a target hierarchy (Figure 2).

6. Studies on German air traffic controllers (ATCOs) and air traffic service assistants (ATSAs), British aircraft maintenance engineers, French aircraft crews, Danish gate allocators showed that the general shiftwork issues also apply to ATM. Although these studies in themselves have produced extremely valuable knowledge, they are only single investigations of specific samples of employees in some countries.

7. The quality and quantity of individual health and performance decrease with shift durations beyond eight hours and the probability of errors increases exponentially after this time. The studies reviewed in this document also indicate that the number of successive shifts, the time on position, night work, and shift rotation affect performance and thereby bear certain risks. While these are issues in all shiftwork settings, the hand-over of ATCO positions and workload variations are typical risk times in ATM. Table 5 gives an overview.

This literature review has demonstrated that despite considerable knowledge on shift management many questions remain open and need to be specified for the particular situation faced by ANSPs. Especially the issues of cost-effective shift management and productivity were rarely investigated, and if so they were secondary to the study of accident prevention and health promotion.

This review also highlighted that a best shift system in ATM cannot be defined. The specific conditions of the work situation, the workload, its spatial and temporal distribution, the individual conditions such as age, attitude and social support as well as the organisational frame play a vital role in the design of shift systems.

One option to obtain European best shiftwork practices for given circumstances and target hierarchies in delivering resources, work and health conditions, flexible practices, social relations, and matching traffic variation, is to study the range of different shift systems in European ATM. Thus, cultural differences could be revealed and lessons learned from each other beyond the ‘hard factors’ like shift length or average daily duty hours described in this review.

Table 5. Impact of shiftwork features on health, performance, safety, productivity, efficiency and recommended countermeasures

Features of Shift Systems	Impacts on Health	Impacts on Performance	Impacts on Safety	Impacts on Productivity	Impacts on Efficiency	Countermeasures
Shift system: - permanent, - alternating, - continuous, - semi-continuous, - non continuous.	Continuous shiftwork requires work at unusual times (nights, weekends), is thereby against the body clock and/or prevents sufficient recovery.	Working against the body clock and insufficient recovery can impair performance; this depends on the nature of task – short-term memory tasks have been found to be at their peak in the morning and to decrease in the course of the day.	Working against the body clock and insufficient recovery can compromise safety if no countermeasures are taken.	Working against the body clock and insufficient recovery can impair productivity.	Working against the body clock and insufficient recovery can impair efficiency.	Non-continuous or semi-continuous shiftwork is preferable. If continuous shiftwork is necessary, permanent systems should be matched to individual preferences (e.g. morning/evening type) and alternating systems should have short and forward cycles.
Direction of rotation: - forward, - backward.	Forward rotating shifts are more tolerable by the body. Backward rotation causes fatigue and sleep problems but often also more coherent free time.	Due to fatigue and sleep problems performance is impaired in backward rotation.	Due to fatigue and sleep problems the safety risk is probably higher in backward rotation compared to forward rotation.	Due to fatigue and sleep problems productivity is impaired in backward rotation.	Due to fatigue and sleep problems efficiency is impaired in backward rotation.	Forward rotating shift systems are preferable.
Shift change cycle: - short (e.g. daily change), - long (e.g. weekly change).	Short cycles are generally more tolerable by the body.	Due to increasing de-synchronisation and fatigue, performance decreases until the seventh successive shift; this trend is most obvious for night shifts.	Due to increasing de-synchronisation and fatigue, safety risks increase until the seventh successive shift; this trend is most obvious for night shifts.	Due to increasing de-synchronisation and fatigue, productivity decreases until the seventh successive shift; this trend is most obvious for night shifts.	Due to increasing de-synchronisation and fatigue, efficiency decreases until the seventh successive shift; this trend is most obvious for night shifts.	Short cycles are preferable.

Features of Shift Systems	Impacts on Health	Impacts on Performance	Impacts on Safety	Impacts on Productivity	Impacts on Efficiency	Countermeasures
Roster type: - team, - individual.	Both types – if operated successfully – can have health promoting aspects: - individual control and fulfilled personal preferences; - team coordination, social support and corporate identity.	Both types – if operated successfully – enhance work motivation and thereby performance.	Individual rosters require highly standardised operations to prevent misunderstandings that naturally do not occur in established teams.	Both types – if operated successfully – enhance work motivation and thereby productivity.	Individual rosters cause less staff costs due to flexible assignment of employees according to workload demand. On the other hand: - costs for individual roster management are higher; - qualification costs can be higher since all employees need the same, highest qualification.	Influencing factors need to be considered in combination.
Split-shifts	> eight hours work within 24 hours cause health impairments (see shift length).	Depending on workload and position of split-shifts within the 24 hours performance decreases (see shift length and night shifts).	Depending on workload and position of split-shifts within the 24 hours safety risks increase (see shift length and night shifts).	Depending on workload and position of split-shifts within the 24 hours performance decreases (see shift length and night shifts).	Depending on workload and position of split-shifts within the 24 hours efficiency decreases (see shift length and night shifts).	Avoid split-shifts. Design breaks (see time on position).
Shift length: - eight hours, - twelve hours (concentration of working time).	> eight hours work per day cause health impairments via: - fatigue and sleep problems; - effort to fight attention and concentration problems at the end of the shift; - accumulated stress; - missing recovery.	Performance decreases after eight hours of work: - errors exponentially increase; - quality and quantity of production/service decrease.	Risk of accidents and mistakes increases during the shift, especially after the eighth hour of work.	Productivity is lower, absenteeism and accident rate higher, especially after the eighth hour of work.	Efficiency decreases after the eighth hour of work: - accidents cause costs and disturb production/service; - absenteeism decreases productivity while labour costs remain unchanged.	Daily work should generally not exceed eight hours.

Features of Shift Systems	Impacts on Health	Impacts on Performance	Impacts on Safety	Impacts on Productivity	Impacts on Efficiency	Countermeasures
Night shift	Increasing de-synchronisation and fatigue with respect to: - rhythm of sleep and activity; - physiological preparedness to perform; - daily variations of body temperature; - impaired well-being; - decreased motivation and capability of work.	Performance decreases due to: - working against the body clock; - increased tiredness; - extension of reaction times (vigilance decreased).	Risks of errors and accidents increase especially in the beginning, the second half and in successive night shifts (see shift change cycle).	Productivity is lower between 7 pm and 7 am; massive dip between 10 pm and 6 am with trough at 3 am.	Efficiency is lower between 7 pm and 7 am; massive dip between 10 pm and 6 am with trough at 3 am.	Influencing factors need to be considered in combination. Number of night shifts should be limited as far as possible with a maximum of three. Plan for more controllers to allow for napping and overcoming inertia. Match with individual preferences (evening types).
Breaks at night	Low workload induces fatigue and stress resulting from efforts to counter boredom. High workload meets reduced staff. Both conditions meet the de-synchronisation of the body clock.	Performance is reduced due to underload, overload and de-synchronised body clock.	Underload, overload and de-synchronised body clock can compromise safety if no countermeasures are taken.	Productivity is reduced due to underload, overload and de-synchronised body clock.	Efficiency is reduced due to underload, overload and de-synchronised body clock.	Plan for more staff to: - allow for napping and overcoming inertia; - socially activate.
Time on position and breaks	> eight hours work per day cause health impairments (see shift length).	Depending on workload vigilance decreases after two-three hours while fatigue increases; in night shifts, performance increases during the first few hours (warming-up).	Safety risk increases after maintaining high levels of vigilance for two hours; in night shifts, safety risk decreases during the first few hours (warming-up) and increases in the	Productivity decreases depending on workload and accumulating stress; in night shifts, productivity increases during the first few hours	Efficiency decreases depending on workload and accumulating stress; in night shifts, efficiency increases during the first few hours (warming-up) and decreases in the second half (see night shift).	Design breaks: - break after two hours where high levels of vigilance have to be maintained; - after four hours on other positions; - break length ten minutes

Features of Shift Systems	Impacts on Health	Impacts on Performance	Impacts on Safety	Impacts on Productivity	Impacts on Efficiency	Countermeasures
			second half (see night shift).	(warming-up) and decreases in the second half (see night shift).		+five for each hour worked; - hand-over should not be scheduled within or too shortly before traffic peak; - exercise or active relaxation can accelerate recovery; - napping can increase productivity, creativity and problem-solving skills.
Hand-over	Handing over positions is especially stressful: - if workload is high; - the predecessor worked a long time and is eager to go; - if the free-time period was too short (insufficient recovery) or too long (warming-up takes longer). Health can be affected by hand-over stress in the long run.	Performance can be reduced due to hand-over stress, insufficient warm-up, and insufficient recovery before hand-over.	Safety risk is especially high after a break, in the thirty minutes following a hand-over (Della Rocco, 1999) and shortly after a traffic peak (Hagemann, 2000).	Productivity can be reduced due to hand-over stress, insufficient warm-up, and insufficient recovery before hand-over.	Efficiency can be reduced due to hand-over stress, insufficient warm-up, and insufficient recovery before hand-over.	Inform and train controllers; hand-over outside peak times; give sufficient time; design breaks.

ANNEX 1: RESEARCH STUDIES OUTSIDE EUROPE

1. USA, FAA: Operational Fatigue Risk Factors

The FAA together with other transportation organisations ordered an extensive review of shiftwork problems and solutions which was prepared by McCallum *et al.* (2003). The operational fatigue risk factors discussed in this paper are the same as those mentioned in the previous chapters:

- extended work and/or commuting periods,
- split-shiftwork schedules,
- sleep/work periods conflicting with circadian rhythm,
- changing or rotating work schedules,
- unpredictable work schedules,
- lack of rest or nap periods during work,
- sleep disruption,
- inadequate exercise opportunities,
- poor diet,
- environmental stressors.

The conclusions and recommendations are compatible with the ones given in Chapter 7. The main issues will be quoted in the following from the McCallum *et al.* (2003) paper.

- Extended work and/or commuting periods

  According to McCallum *et al.* (2003) over-extended working periods and repeated inadequate sleep periods can result in accumulated sleep debt and associated operator fatigue. Among the primary aspects of extended work and/or commuting periods that have been cited as contributing to operator fatigue are:

  - long commutes to or from work on a daily basis;
  - long waits after reporting for work before duty begins;
  - forced interruptions in work that extend the duty day;
  - long commutes from home to report for work prior to beginning a multi-day work period.

  McCallum *et al.* (2003) mention as an aviation example that a minimum of eight- or nine-hour rest period for crew members might only allow for a sleep opportunity of less than five hours. Especially long commutes to and from home bases contribute to the problem.

- Split-shiftwork schedules

  These make it difficult to obtain adequate sleep during the normal sleep period. Among the primary factors that commonly occur in conjunction with split-shift schedules contributing to operator fatigue are:

  - early morning start of shift,
  - late evening end of shift,
  - high-paced operations during the work period,
  - limited time at home during the awake period,
  - difficulty in taking advantage of mid-day sleep opportunities.

  These points were already mentioned in Chapter 3. The aviation examples given by McCallum *et al.* (2003) are cargo, commuter and other operations which result in split-shifts, with off-duty rest available only at an airport rest area or at offsite accommodations. In these cases, non-use of the rest facilities by crew members, facility conditions like noise, and the time of day can compromise obtaining rest and thereby contribute to fatigue.

- Sleep/work periods conflicting with circadian rhythm

  As Beermann also pointed out (see Chapter 3), McCallum *et al.* (2003) see the quality and quantity of sleep suffering when work schedules require people to obtain their sleep during times that are normally awake periods. More specifically, work during 'low' periods of the circadian rhythm (roughly 1 am – 4 am and 1 pm – 4 pm) can be associated with drowsiness and a low level of alertness.

  According to McCallum *et al.* (2003) inappropriate times to obtain sleep for those adjusted to a night time sleep schedule are:

  - late morning,
  - afternoon,
  - early evening.

  Moreover, for time zone travelling employees any time is suboptimal for sleep which is day time in the circadian rhythm. As an aviation example, McCallum *et al.* (2003) mention international and transoceanic flights that commonly have a domestic departure in the evening, resulting in all-night flights, followed by early morning return flights after a disrupted sleep period. Early wake-up times for departures (e.g. 3 am wake-up for a 6 am departure) lead to fatigue problems that are difficult to compensate for by an earlier bedtime, because the bedtime will be prior to a normal sleep period.

- Changing or rotating work schedules

  Many commercial transportation operations require frequent changes or rotations in schedule. As outlined by McCallum *et al.* (2003) these schedule shifts lead to relatively quick changes in the time of day at which operators can obtain sleep, making it difficult to adapt to a certain sleep time or at least anchor sleep (see below). Changing or rotating work schedules can be characterised as follows:

  - changes in work and rest schedules that do not have a fixed pattern and thereby result in fatigue management challenges that are extremely difficult to address;
  - rotating schedules that have fairly systematic shifts in the work start and stop times.

  McCallum *et al.* give the example of crew members who work for supplemental operators (i.e. cargo carriers) often at night; then, when off duty, they might revert to a night-time sleep schedule.

- Unpredictable work schedules

  As recommended in Chapter 6.3, the amount of advance notice that employees have regarding their work schedule should be at least 28 days. However, McCallum *et al.* found a substantial variation of this time. They, like Beermann in Chapter 3, argue that an unpredictable schedule can lead to forced changes in sleep times and therefore in low-quality sleep and a sooner than necessary wake-up in order to check in with dispatchers. Conditions commonly associated with unpredictable work schedules include according to McCallum *et al.* (2003):

  - being ‘on call’ for work without a fixed schedule,
  - first-in, first-out work pool scheduling,
  - schedule delays resulting from equipment, weather, or traffic problems.

  As aviation examples they mention weather, traffic, and mechanical problems that can result in unexpected delays. Moreover, on-call crew members have limited advance notice regarding their schedules.

- Lack of rest or nap periods during work

  Taking a brief rest or nap during a work period is a controversial topic in some transportation settings, while it is considered the norm in others (for pros and cons of naps see also Chapter 6.4). According to McCallum *et al.* (2003), research has demonstrated the value of planned napping to supplement sleep and to temporarily restore alertness. Lack of nap periods can result from:

  - company policies that restrict or prohibit napping,
  - federal regulations that restrict or prohibit napping,
  - unwillingness of operators to take naps.

The aviation-specific examples given by McCallum *et al.* (2003) are the FAA regulations that forbid on-duty crew members from taking naps on domestic flights and the rest breaks of two to three hours that are scheduled on long-haul international flights having three or four crew members. Among these, the first rest period is least desirable and the middle most.

- Sleep disruption

  In accordance to Chapter 3, McCallum and colleagues mention as sources of disturbances:

  - noise, vibration, movement, uncomfortable temperature, poor light shading and air quality in sleeping quarters;
  - unfamiliar environments away from home with suboptimal conditions;
  - attempting to sleep de-synchronised with circadian rhythm.

  Examples from airlines operations are unpredictable aircraft movement, turbulence, vibration, and/or noise which disrupt crew member rest.

- Inadequate exercise opportunities

  People who exercise regularly have fewer sleep difficulties. While exercise cannot be seen an effective countermeasure for immediate fatigue, it can improve sleep quality by promoting smoother, more-regular transitions between sleep phases. McCallum and colleagues recommend moderate exercise lasting twenty to thirty minutes, three or four times a week. Exercise in the morning or afternoon is preferred in order not to interfere with the onset of sleep. However, operational requirements often limit exercise opportunities; McCallum and co-authors (2003) mention crew members whose workdays are extended and thereby prevent adequate exercise well in advance of the sleep period.

- Poor diet

  Corresponding to the findings reported in Chapter 3.3.2, McCallum and colleagues mentions dietary behaviours that can disrupt sleep:

  - Eating heavy or spicy foods just prior to bedtime.
  - Alcoholic drinks that can make sleepy, but can also fragment sleep; therefore, and for many other reasons (dehydration, next day performance problems, addiction), they are not at all an option.
  - Consuming caffeine within four to six hours before bedtime can delay the onset of sleep as well as disrupt sleep.

  For example, meals provided in flight might not be appropriate for a crew member’s work schedule. In the context of ATC, Kastner *et al.* (1998) criticised the limited possibilities to get appropriate meals at the workplace especially during night and in ATC towers. They quote Kuckuck (1989) with the following recommendations:

Table 6. Recommended time and energy intake (percent) during night shifts (Kuckuck, 1989)

Meals	Percent	Time
1. Lunch	25	14:00
2. Vesper	10	17:00
3. Dinner	20	20:00
4. First nocturnal meal	25	00:30
5. Second nocturnal meal	10	04:00
6. Breakfast	10	07:00

- Environmental stressors

  As also described in Chapter 3, especially noise can adversely affect employees sleep and levels of alertness. Apart from noise, McCallum *et al.* (2003) also mention heat, humidity, cold, altitude and vibration as relevant environmental stressors.

2. FAA and CAMI, USA: Transitioning Research Results to the Workforce

Della Rocco and Nesthus (draft) describe in a book chapter how the shiftwork issues and fatigue countermeasures can be transferred from the laboratory to the workforce.

They describe several studies including the Civil Aerospace Medical Institute (CAMI)'s program of research on shiftwork in the FAA's ATC facilities. Different shift schedules were compared regarding performance, sleep, stress, mood and circadian rhythms. Based on the studies' findings Della Rocco and Nesthus outline different countermeasures for the effects of sleep loss and shiftwork. The goal is twofold: to manage alertness and cognitive resources, and to develop strategies for managing times when alertness is decreased.

- Napping

  Napping is considered the only effective countermeasure for sleep deprivation. Therefore, strategic and prophylactic naps are suggested as very effective at maintaining alertness during circadian rhythm troughs, as well as under conditions of sleep loss.

  Napping addresses:

  - sleep loss,
  - tiredness,
  - maintenance of performance, and
  - support for the drive home from midnight shift,

  and serves as 'anchor' sleep to stabilize circadian rhythms.

CAMI conducted a study on the effectiveness of napping in terms of performance and alertness (three conditions: two-hour nap, 45-minute nap, no nap during the midnight shift). Both cognitive performance and subjective measures of sleepiness supported the use of naps during the midnight shift. The long nap resulted in better performance than the short nap. Sleepiness increased across the midnight shift for all groups, but ratings were lower for the long nap condition.

Napping during night shift can be used as effective countermeasure to performance decrement and sleepiness. Yet, some problematic issues remain:

- Sleep inertia: It is defined as "period of grogginess experienced upon awakening" (see Chapter 6.4). While napping, deeper stages of sleep might be reached that cause a period after awakening in which performance and alertness might be compromised.
- Logistical problem: The facility needs to provide sleep accommodations.
- Policies: Policies need to ensure that there is no sleep inertia prior to returning to work.

- Scheduling

Another available countermeasure is the instrument of scheduling. Areas for improvements are:

- longer times between shifts on quick-turn-arounds,
- stability in scheduling patterns.

General guiding principles:

- minimization of midnight shift exposure,
- provision of a rest day after midnight shifts,
- rotation of shift start times in a clockwise rotation,
- provision of long intervals between cycles (at least two days),
- avoidance of quick-turn-arounds,
- avoidance of early morning start times,
- provision of weekend days off,
- schedule of eight-hour shifts instead of twelve-hour shifts,
- predictability in scheduling for the employees.

The following four recommendations were identified as the highest priority:

1. Feedback of the survey results to the workforce.
2. Education of the workforce on shiftwork, its effects on performance, and management of fatigue.

3. Napping during break periods (to increase alertness and maintain performance).
4. Evaluation of facilities' current schedule (application of ergonomic principles).

In order to transfer the research result to the workforce, brochures as well as an educational multimedia CD-ROM ("Shiftwork Coping Strategies") were developed.

From the experience of this long-matured process of surveys following aspects can be highlighted. It is important to consider different operational communities. Afterwards specific countermeasures can be targeted for this specific context. Add to that it is important to understand and acknowledge the issues that arise in transitioning scientific results to the field. The extent of understanding the issues in the operational environment will greatly influence the transitioning process of scientific findings from the laboratory to the field.

3. FAA, USA and NAV, Canada: Fatigue Management Programmes

NAV Canada describes a managed approach to fatigue in the annual report 2001. Their organisation's philosophy is that the company, its employees and their bargaining agents share the responsibility of managing fatigue. Together with Alertness Solutions, a scientific consulting firm, a fatigue management programme was implemented. According to the report, the programme's long-term objectives are to help employees better manage fatigue and to incorporate scientific principles of fatigue management into NAV Canada's practices. Especially a comprehensive information and training programme is provided and existing shift scheduling practices in Edmonton and Gander Area Control Centres are analysed.

Also McCallum *et al.* (2003), discuss key components of fatigue management programmes:

- organisational commitment,
- employee-employer partnership,
- education and training,
- employee health screening,
- programme evaluation and refinement.

McCallum and colleagues recommend that senior executives should be involved in the formulation and support of their organisation's fatigue management policy. These should be established through a joint effort by all organisational stakeholders and include:

- goals and objectives,
- responsibility and authority definitions,
- documentation,
- programme evaluation and refinement.

McCallum *et al.* (2003) mention the following best practice examples:

- After the introduction of the **NASA Ames Fatigue Management** Training Module, organisational involvement among airlines generally grew. Thus, most US airline carriers have established some form of a fatigue management programme.
- **British Airways** after two years evaluated its Alertness Management programme that consists of an Alertness Management Manual and trip specific advice cards. Satisfaction with the programme was generally high with regard to presentation, readability, and ease of use of the manual.

4. USA, FAA: Fatigue Countermeasures

McCallum *et al.* (2003) extensively review fatigue countermeasures. These are grouped in those measures that

- clearly work,
- are still investigated,
- need supervision of a physician,
- clearly not work, have minimal effects or undesired side-effects.

In this chapter only categories one and two will be quoted.

The countermeasures that clearly work included both the **prevention** of fatigue by getting enough sleep, and the **mitigation** of fatigue through countermeasures applied when employees are getting tired. Individual countermeasures will need to be combined, based on the specific operational circumstances:

- adequate sleep,
- caffeine,
- napping,
- anchor sleep,
- trip planning,
- good sleeping environment.

To facilitate <u>adequate sleep</u> McCallum *et al.* recommend:

- having a regular routine for sleep,
- obtaining sufficient sleep,
- ensuring an appropriate sleep environment,
- starting new shift schedules with minimal sleep debt,
- obtaining compensatory sleep before new schedule,
- matching work schedules with morning (‘lark’) or evening type (‘owl’).

McCallum *et al.* (2003) count caffeine among the countermeasures that clearly work. However, from a nutrition point of view this recommendation must be given with some precautions: Coffee as well as black teas do not substitute normal drinks that provide the body with water. On the contrary, caffeine contributes to dehydration. However, if sparingly used and supplemented by watery drinks, caffeine use makes sense (according to McCallum *et al.*, 2003):

- in the middle of a night shift on the first or second day of the work week;
- during mid-afternoon when the alertness dip after lunch is greater due to missing sleep;
- prior to an early morning commute following a night shift, but at least four hours before sleep is planned.

Taking a nap should be timed to obtain the maximum benefit. This will vary quite a bit depending on the circumstances, but in general the following guidelines are applicable (McCallum *et al.*, 2003):

- Avoiding the general high-alertness periods like 10:00 to 12:00 hours.
- Napping should be kept to a maximum of 45 minutes, allowing at least fifteen minutes to get fully awake at the end (Chapter 6.4.2).
- Napping during the lunch break can take advantage of the mid afternoon alertness dip and postprandial sleepiness.
- Napping for a couple of hours prior to the start of a night shift.
- Ten-twelve minute ‘power naps’ can refresh for a short period of time almost any time.
- Napping is part of a duty period and should not extend it.
- Potential occurrence of inertia should be considered (Chapter 6.4.2).

According to McCallum *et al.* (2003), anchor sleep refers to a regular sleep period of at least four hours duration, obtained at the same time each day, which can stabilise the circadian rhythm to a 24-hour period. It might also be possible to time the anchor sleep period so that circadian rhythm high and low points correspond to work and sleep periods. Meals should be taken at the times the employee normally eats. He or she should make sure that the meals are not so close to the anchor sleep period that they might interfere. The same applies for caffeine consumption. Anchor sleep should be used as a coping mechanism for situations where a full eight hours of sleep is not possible. It **should not be a routine**.

The predictability of rosters was already mentioned as an important health and social issue in the previous chapters. McCallum *et al.* (2003) see the primary advantage of trip planning in the fact that the employee can **anticipate times** at which he or she **will be feeling fatigued**, and do something about it before performance is lowered to unsafe levels. However, trip planning is often outside the control of the employee, and depends on shift start, the availability of rest areas, and the pace of operations.

A good sleeping environment, i.e. a silent, shaded, well-temperatured and -ventilated room, is a precondition for restorative sleep. However, the ability to control the physical elements of the sleep environment is restricted especially in travelling professions. For example, some hotels do not provide room darkening shades, or outside traffic noise may be unavoidable. McCallum recommend carrying earplugs and eye shades in these cases and not to invest too much psychologically in the need for certain sleep environment characteristics, because this can lead to stress-induced insomnia.

The **countermeasures that are still in the research phase** according to McCallum and colleagues (2003) are:

- models of alertness,
- fitness for duty testing,
- alertness maintenance monitoring.

Alertness models use knowledge of the underlying physiological processes to predict levels of alertness on the job. Gundel (2001) for example presented a software tool for the trip planning of inner-European flights, which highlights critical time periods on the basis of for example circadian rhythm, time since awakening, wake-up process, turn-round times, etc. Using this knowledge can help to anticipate fatigue at certain points in time, and to think about potential countermeasures, such as caffeine or a nap. Although alertness models give advice in this way, McCallum *et al.* (2003) do not believe that software tools can be used with precision by the layman. They recommend model predictions as guidelines rather than absolute predictions of alertness.

Fitness-for-duty tests determine if an employee is fit to perform the job at the moment of testing. This testing can take place when the worker arrives at the workplace to begin an assigned work shift. It can also mean periodically testing in the middle of a work shift to determine if the employee is still performing with a satisfactory level of alertness. Finally, testing prior to being permitted to work an additional work shift or doing overtime can be a useful application. According to McCallum *et al.* (2003) many of the fitness-for-duty tests have not been validated and none operationally used on a regular basis. Therefore, the authors concluded that such tests are still in the research stage and need to overcome a variety of issues related to practical implementation, for example, that most tests do not reliably predict whether a worker will perform adequately some number of hours into the future, after passing the test. Also, there is no agreement on an acceptable performance level.

Alertness maintenance monitoring involves tracking the performance (e.g. steering-wheel variability) or physiological data (e.g. eye-blink frequency and latency) of operators to determine if they are approaching drowsiness or impairment. McCallum and colleagues (2003) judge that virtually all of the monitoring devices are in the research stage and there is not yet sufficient evidence about their reliability and validity to warrant routine use.

5. Australia

Australian governmental and research organisations can offer a great amount of shiftwork research. Some of the more recent work is very briefly mentioned in this annex.

Australian Safety Bureau‘s (2001) survey showed that most of 340 occurrences of error in the maintenance operations of high capacity airlines (airlines that operate aircraft with more than 38 passenger seats) occur during the early morning. The survey is consistent with the studies reviewed in the previous chapters which also identified the **early morning as a high-risk period** next to the third night shift in a row.

Bohle (2003) compared normal shiftworkers with those in **precarious contracts** and found the adverse effects of shiftwork even worse in the latter group.

DiMilia (2003) concluded that whilst there was no significant change in total sleep time of a group of shiftworkers, a **faster rotation** intended to reduce **chronic** sleep loss can also have negative effects like **acute** sleep loss. In terms of shift design, strategies that seek to reduce the impact of acute sleep loss need to be carefully examined. It is also suggested that repackaging the total number of night shifts into smaller blocks does not reduce the overall night shift exposure.

Fletcher and Dawson (2003) review example components of a **practical fatigue risk management system** like organisational fatigue policy, alertness models, risk management frameworks, communication strategies including training and education. Most of these options are supported by scientific evidence and could be incorporated into management and regulations. However, future workplace-based validations should further clarify those tailored components that best reduce the risk in the given operations of the specific target organisation.

Knowles and Bull (2003a) studied 135 subjects from two Australian Police Local Area Commands and found an **active coping strategy** to have beneficial effects with respect to individual psychological and physiological symptoms, including chronic fatigue.

Knowles and Bull (2003b) confirm the **nutrition problems** associated with shiftwork that were already mentioned in Chapters 3.3.2 and 6.7.1. Their 67 subjects (police officers) reported lower than the recommended average daily intake of five servings of vegetables, two servings of dairy products, two servings of fruit, and four servings of cereal or grains.

Petrilli, Jay, Lamond, Vickers and Dawson (2003) found fatigue significantly affecting performance in an inspection time and psychomotor vigilance tasks as well as subjective ratings of alertness, but not in a travelling salesman task. They concluded that when individuals are suffering from fatigue, erroneous decision-making may be due to **performance deficits at the initial stage of situation awareness** during the stage of lower-level perceptual processing.

Popkin and Coplen (2003) compared a functioning prescriptive (i.e. US.) and non-prescriptive management-based approach (i.e. Australia) to fatigue mitigation. They conclude that if properly implemented, a **tailored non-prescriptive fatigue management provides quicker, more sustainable and substantial progress**.

Phipps-Nelson, Redman, Dijk and Rajaratnam (in press) report that **bright light** is an effective countermeasure for sleep-deprivation induced decrements in vigilance performance.

Smith and Wedderburn (1998) give emphasis to **unplanned and excessive working of overtime** hours due to increased labour flexibility and market driven production. The need for flexibility to meet both work and life demands highlights according to Smith and colleagues the **importance of fatigue management** (Smith & Cross, 2001) that brings together roster design, work hours policy, support arrangements, and the ongoing monitoring of the impact of shiftwork on employee well-being (Queensland Government, 2001).

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GLOSSARY

For the purpose of this document, the following definitions shall apply:

Accumulation Phase	Risk factors, sleep quality and attitudes towards shiftwork accelerate the biological ageing process and have a strong influence on health and tolerance towards shiftwork (twenty plus years; ref. EUROCONTROL, 2003b)
Adaptation Phase	The shiftworker has to adapt to changes in sleeping and eating pattern, social and family life and social strain (zero-five years; ref. EUROCONTROL, 2003b)
Alertness maintenance monitoring	Monitoring performance (e.g. steering-wheel variability) or physiological data (e.g. eye-blink frequency and latency) to assess whether operators are approaching drowsiness or impairment
Alertness models	Alertness models use knowledge of the circadian processes to predict levels of alertness on the job
Alternating shiftwork	Continuous shiftwork at different times, e.g. the conventional system of one week early, late, and night shift
Anabolic	Referring to construction; originally used in biology to label constructive tissue change (opposite of catabolic)
Anti-clockwise	See rotating shiftwork
Arthralgia	Pain in joints
Backward rotating	See rotating shiftwork
Body clock	See circadian rhythm
Cardiovascular	Referring to the heart (*cardio*) and blood vessels (*vascular*)
Catabolic	Referring to destruction; originally used in biology to label destructive tissue change (opposite of anabolic)

Change-over	A work position is handed over to a colleague for a break or at the end of a shift
Chronobiology	Sub-discipline of biology that deals with circadian (daily), circa lunar (monthly), circa annual (yearly) and other time-based organisation of organisms
Circadian rhythm	The rhythm the functions of the human organism are following; usually slightly more than 24 hours
Circadian type	See circadian rhythm, morning and evening type
Clockwise	See rotating shiftwork
Complexity	System state that comprises number, diversity and interaction of elements
Compressed working week	Weekly working time beyond 48 hours
Commuting	Refers to the distance and time workers travel to their regular (usually daily) duties
Condensed working hours	Daily working time beyond eight hours
Continuous shiftwork	Shiftwork 24 hours a day, seven days a week (168 hours operational time); can be organised in permanent or alternating shifts
Daily resting time	Should be 11 subsequent hours in each 24-hour period
De-synchronisation	Refers to activity or sleep against the circadian rhythm
Dynamics	System changes over time; see also complexity
Efficiency	Achieve a result without wasted energy, resources, effort, time or money
Electrocardiography (ECG)	Electrical deduction of the heart contractions
ElectroEncephaloGraphy (EEG)	Electrical deduction of the brain activity from the scalp
ElectroOculoGraphy (EOG)	Electrical deduction of changes in position or polarisation of the eyeball, which is a dipole

Epidemiology	Epidemiology is the study of the demographics of disease processes, including the study of epidemics and other diseases that are common enough to allow statistical tools to be applied. Besides contagious diseases it also focuses on e.g. diabetes, coronary heart disease, high blood pressure
Evening and weekend society	Refers to the fact that social activities take place mainly at evenings and weekends
Evening types	People with a rather longer circadian rhythm
Eveningness	See evening type
Fatigue management	Collective term for all measures taken against operator fatigue
Fitness-for-duty tests	Fitness-for-duty tests determine if an employee is fit to perform the job at the moment of testing; see also alertness maintenance monitoring
Forward rotating	See rotating shiftwork
Gastrointestinal	Referring to the stomach (gastro) and the bowels (intestines)
Hand-over	A work position is handed over to a colleague for a break or at the end of a shift
Healthy worker effect	Only people resistant to the adverse effects of shiftwork stay at shiftwork jobs in the long run
Individual roster	Shiftwork is planned for individuals; thus most of the subjective preferences can be considered
Inertia	Feeling of laziness and unwillingness to move especially after sleep
Insomnia	Sleeplessness
Karoshi	Japanese word for death at work; refers mainly to the unexpected heart death of young and middle-aged managers
Lark	See morning type
Long-cycle shiftwork	Slow shift changes, e.g. every seventh day

Manifestation Phase	Some shiftworkers (see “healthy worker effect”) enter the manifestation phase, before but also after retirement, which is characterised by an increase of disorders and diseases related to sustained shiftwork (twenty plus years; ref. EUROCONTROL, 2003b)
Maximum weekly working time	Should be 48 hours
Mid-afternoon dip	See post-lunch dip
Morning types	People with a rather shorter circadian rhythm
Morningness	See morning type
Myocardial infarction	Destruction of heart tissue resulting from obstruction of the blood supply to the heart muscle
Non-continuous systems	Shiftwork with a weekly working time of up to 120 hours
Overshooting relax response	ATCOs reduce their attention after a traffic peak faster than traffic decreases (Hagemann, 2000)
Owl	See evening type
Participation	Refers to the involvement of employees in management processes such as shiftwork organisation
Permanent shiftwork	Continuous shiftwork at always the same time, e.g. permanent night shift
Postprandial	Refers to the time after food intake; see post-lunch dip
Post-lunch dip	Within the circadian rhythm, alertness and productivity are decreasing at about 12:00 hours; this can be enhanced by a heavy lunch
Productivity	Ratio of the quantity and quality of units produced to the labour per unit of time
Rapid Eye Movement (REM)	In deep sleep stages, sleepers rapidly move their eyes under closed lids; these periods are responsible for the recreational value of the sleep

Rotating shiftwork	Sequence of separate shifts in alternating systems; can be early, late, night (forward or clockwise rotation) or *vice versa* (backward or anti-clockwise rotation)
Semi-continuous shiftwork	Shiftwork 24 hours a day, five days a week
Sensitisation Phase	Stage at which tolerance towards shiftwork develops (five-twenty years; ref. EUROCONTROL, 2003b)
Shift change cycle	Number of shifts of the same type that have to be worked in a row; can be short e.g. every day or long cycles e.g. every week
Shift length	Number of working hours within one shift
Shift type	Position of the shifts within the 24 hours of a day e.g. morning (early) shift
Shiftwork	Work that is done at different times over the day or at the same, but unusual time
Short-cycle shiftwork	Fast shift changes, e.g. every day
Situational awareness	Perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future (definition by Endsley, 1988)
Sleep-wake cycle	See circadian rhythm; humans usually are day-active and sleep at night
Social requirements	Refer to the prevention of social life impairments by shiftwork
Split-shift	A day of work divided into periods with some hours off between them
Standard working hours	6 am to 6 pm five days a week
Strain	Refers to the effects of stress in the individual e.g. heart rate increase or fatigue
Stress	Refers to the external (situational, organisational) conditions for example task complexity that make a person strain

Team roster	Plan the shiftwork on the basis of teams
Time leakage	Working time lost by shiftwork over a period of time due to sickness and other staff absences not evenly spread across a year, breaks not spread evenly across a day, mismatch of regulations and roster
Tripartite division of the day	Eight hours work, eight hours leisure, eight hours sleep; suggested by Rutenfranz *et al.* (1976)
Tinnitus aurium	Disease of the ear that manifests in the perception of a usually high pitch noise (ringing in the ear)
Vigilance	State of alertness in which small and/or rare events are detected e.g. at a radar screen and adequately responded to; can be maintained only a couple of hours
Yerkes-Dodson Law	The inverted U-shaped function between arousal and performance

ABBREVIATIONS AND ACRONYMS

For the purpose of this document, the following abbreviations and/or acronyms shall apply:

ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATCO	Air Traffic Controller *(US)*
ATM	Air Traffic Management
ATSA	Air traffic Service Assistant
CAMI	Civil Aerospace Medical Institute *(US)*
CHAMP	Collaborative and Harmonised ATCO Manpower Planning *(EUROCONTROL process developed under EATM, HRS, MSP)*
DAP	Directorate ATM Programmes *(EUROCONTROL, EATM Service Business Unit)*
DAS	Directorate ATM Strategies *(EUROCONTROL, EATM Service Business Unit)*
DFS	Deutsche Flugsicherung GmbH *(German air traffic control service provider)*
DSB	*Danish State railway*
DSM	Dienstplanabhängiges Schichtplanmanagement *(workload-related rosters of the German police)*
EAAP	European Association for Aviation Psychology
EATM(P)	European Air Traffic Management (Programme) *(EUROCONTROL), today known as the* "European Air Traffic Management Performance Enhancement Programme"
ECG	ElectroCardioGraphy
EEG	ElectroEncephaloGraphy
EOG	ElectroOculoGraphy

FAA	Federal Aviation Administration *(USA)*
FUGS e.V.	Eingetragener Verein zur Förderung des Umwelt-, Gesundheits- und Sicherheitsverhaltens *(German public utility organisation for the advancement of environmental, healthy and safe behaviour)*
HF	Human Factors
HFRP	Human Factors and/or Resource Programme
HPM	Human Resources Performance Model *(by Pennig et al., in press)*
HPTE	Human Performance and Training Enhancement
HR	Human Resources
HRS	Human Resources Programme *(EATM)*
HUM	Human Factors Management Business Division *(EUROCONTROL, EATM Service Business Unit, DAS)*
IIME	Institute for International Medical Education *(US)*
KAPOVAZ	KAPazitätsOrientierte Variable ArbeitsZeiten *(German capacity-orientated variable working times)*
LAMPS	Long-Term ATCO Manpower Planning Simulation *(EUROCONTROL tool developed under EATM, HRS, MSP)*
MSP	Manpower Sub-Programme *(EATM, HRS)*
NAV	Canadian air navigation service provider
PRC	Performance Review Commission *(EUROCONTROL)*
PRU	Performance Review Unit *(EUROCONTROL, PRC)*
REM	Rapid Eye Movement
SAS	Scandinavian Airlines System