Rostering in Air Traffic Control

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Contributor: Francesco Di Nocera, Orlando Ricciardi

Most Air Traffic Controllers (ATCOs) must cover uninterrupted work shifts for 24 h a day, seven days a week. The proper planning of a shift schedule requires consideration of at least three elements: the specific characteristics of the controller task, the physiological needs of the operator, and the definition of rest periods within rostering.

Keywords: shift workers ; shift patterns ; night shifts ; night workers ; air traffic controllers ; circadian rhythm

1. Introduction

Most Air Traffic Controllers (ATCOs) must cover uninterrupted work shifts for 24 h a day, seven days a week. In these operational contexts, fatigue can adversely affect performance by increasing response time and the number of errors [1][2][3]. Additionally, shift workers can suffer consequences for sleep quality and job satisfaction [4][5][6]. Properly organized shifts can mitigate the negative consequences of fatigue accumulation. One of the critical elements of a work shift is scheduling rest periods, intended as the time intervals between consecutive turns and as breaks during the single period of service [7][8][9].

Three elements contribute to creating a fit and safe shift planning. The first is related to the specific characteristics of controller tasks, which usually reflect different levels of complexity and, therefore, require varying amounts of effort. The second element is the physiological need of the operator, which varies according to individual differences. Task characteristics and physiological needs greatly affect the third element, which is the organization of rest periods.

2. Shift Patterns Used by Leading Air Nation Service Providers

The shift scheme is one of the most critical features in defining rest periods within a shift cycle. Relevant information on this issue comes from a 2006 report by EUROCONTROL [10], the international organization working to achieve safe and seamless air traffic management across Europe. This document aimed at identifying best practices to help define solutions for the management of shift work in air traffic management (ATM) and other sectors. The study resulted in some recommendations to facilitate the planning and management of flexible working practices to improve safety and productivity. Another major objective of the EUROCONTROL study was also to compare shift workers' management practices of 10 ANSPs from the European Union and three International ANSPs. European Union (EU) suppliers included Austrocontrol (Austria), AENA (Spain), ANS (Czech Republic), Avinor (Norway), DGAC (France), DFS (Germany), LFV (Sweden), Maastricht (EUROCONTROL), NATS (UK), and Skyguide (Switzerland). The comparison revealed that the schedules' features vary from country to country and depend on the presence of the roster organized by a team or by an individual. The prevailing schemes include 4 working days and 2 rest days (4/2), 5 working days and 2 rest days, 6 working days and 3 rest days, or no fixed cycle. As shown in the report, there is an evident heterogeneity in the shift workers' management practices used by the 10 different European ANSPs. Practices vary depending on the different characteristics of shift work, such as the direction of rotation, the duration of shifts, the organization of work individually or in teams, and the distribution of rest days. Differences can be attributed to some extent to factors such as airspace size, culture, or specific national legislation. It is not surprising, therefore, that such differences can also be observed among the extra-European providers considered in the study: Airways New Zealand (New Zealand), Air Services Australia, and the US Federal Aviation Administration (USA). In this case, the adopted rosters present are the 3/3 (Air Services Australia), the 4/2 (Air Services Australia and Airways New Zealand), the 5/2 (USA), and the 6/3 (Airways New Zealand).

3. Shift Duration

Shift duration is a factor that has been studied by several researchers, both in laboratory and in various work settings (e.g., mining, computing, and air traffic control). The durations typically considered vary between 8 and 12 h. Twelve-hour shifts have been shown to have several advantages, including allowing more days off during the week [11][12] and giving more significant opportunities for rest. Some studies also report less absenteeism [13][14] and greater job satisfaction, probably related to the possibility of having more free time [15][16][17]. Furthermore, a 12-h rostering involves fewer handovers, considered a risky time in different work contexts.

Twelve-hour shifts, however, also have disadvantages. Some studies have found increased fatigue in 12-h shifts [18] and decreased performance [19][20][21]. In a review conducted on an initial sample of over five hundred articles, an adverse effect of 12-h shifts on performance was reported, compared to 8-h shifts. This effect is estimated to result in a 100% increased risk of incidents, and is particularly relevant in the case of night shifts, as demonstrated in a study by Rosa and Colligan [22]. Several other studies have confirmed this effect [23][24][25][26]. Another example is provided by Goode [27], who found that even when the duration of the shift is between 10 and 12 h, the incident rate is slightly higher than with a duration of fewer than 8 h. His study included pilots, and the author related the frequency of incidents in operation to the hours of activity.

When choosing between a 12-h shift and an 8-h shift, another aspect must also be considered: while there is no evidence that having more time to rest is sufficient for a full recovery, on the contrary, the long-term adverse effects of fatigue accumulation are well documented [13][28]. In light of these problems, Rosa [29] suggests using shifts lasting more than 8 h only in particular working contexts and after taking a series of measures related to the frequency and duration of breaks. The research conducted by Schroeder, Rosa, and Witt [30] on behalf of the Civil Aerospace Medical Institute (CAMI) specifically concerned ATCOs. The research aimed to compare the effects of 8-h and 10-h shifts on both the vigilance and test performance of ATCOs. Fifty-two highly experienced ATCOs were involved in the research: half of the participants carried out the 10-h program, and the other half carried out the 8-h program (type 2-2-1 rotation: the first two afternoon shifts followed by two morning shifts and, later, a night shift). In the study, the authors used a modified version of the National Institute of Occupational Safety and Health (NIOSH) Fatigue Test Battery to measure eight variables: the quantity of sleep; quality of sleep; mood; physical diseases; perceived workload (indicated by the Task Load Index); response times; arithmetic task performance; and grammar reasoning [30]. The researchers collected these performance data three times during the shift: at the beginning, two hours before the completion of the shift, and at the end of the shift. The results of the study showed an increase in reaction times for both 8-h shifts and 10-h shifts during morning shifts. However, there were no differences between 8-h and 10-h shifts in performance during the day or afternoon shift in the first 4 days of rotation. Additionally, the researchers observed a decrease in performance on the last day of the 8-h rotation, corresponding to the night shift. Data on the amount of sleep reported by controllers were consistent with previous studies. In the first 4 days of rotation, there were no differences between 8-h and 10-h shifts. The maximum hours of sleep were reported on the night before the first day of rotation of the shift (8.3 h), while the minimum number of hours of sleep (5.75 h) was reported earlier on the fourth day. In both groups, the reported sleep hours decreased during the week, to a minimum of 3.75 h before the night shift in the 8-h program.

4. Rest Period between Consecutive Shifts Cycles

A review published by Fischer, Lombardi, Folkard, Willetts, and Christiani [31] considered five studies analyzing the risk of incidents as a function of the number of consecutive working days. The authors analyzed the data reported in these studies and obtained a risk index based on the number of consecutive days of service. The risk of incidents increased by about 2% on the second day, by 7% on the third day, and by 17% on the fourth-day shift compared to the first day. These results indicate the existence of an increased risk in subsequent day shifts. However, the same study shows that the risk is higher in the presence of a succession of night shifts. In an extensive study aimed at defining a Fatigue Index, Spencer, Robertson, and Folkard [32] suggested limiting the maximum number of consecutive working days to no more than six and providing for a minimum of two consecutive rest days.

Despite the relevance of this issue, few studies have considered the distribution of rest periods within a cycle of irregular shifts. Below, researchers present several studies conducted on specific categories of workers other than ATCOs. Interesting results are provided by the work of Folkard and Tucker [33], who conducted a questionnaire-based study involving British aircraft maintenance engineers. The study aimed to provide recommendations for the design of work shifts for staff, linking working hours (e.g., weekly worked hours, shift duration, breaks, annual leave, and notice days) and performance measures, including guidance on vigilance, the likelihood of making mistakes, and confidence in driving home after working hours. In light of their results, the authors recommended a limit of seven consecutive working days before a break of at least 2 days off between two shift cycles.

Åkerstedt and colleagues [34] sought to gather the information that would be useful for defining an optimal balance of working and rest days, in the absence of information presented in the scientific literature. The authors then analyzed data from previous studies on workers in different sectors who were on irregular shifts, or for whom the rest periods and the regularity of shifts were not constant. Subjects were investigated using the Karolinska Sleepiness Scale [35], a self-report measure of sleepiness level on a 9-point scale (9 = the maximum level of drowsiness, and 1 = the maximum level of alertness) validated against electroencephalogram (EEG) parameters. The workers were involved in different kinds of schedules: irregular shift patterns (locomotive train); traditional three-shift work (workers in the chemical industry); 12-h day and night shifts (workers in the chemical industry); rapidly rotating shift system (paper industry); weekly shifts of 84 h (construction workers who have had seven-day shifts in a row of 12 h each between 7.00 and 19.00, followed by a week of vacation); two weeks of consecutive 12-h night shifts followed by three weeks of vacation (workers on an oil production platform in the North Sea from 19:00 to 7:00); irregular and jet-lagged shifts (cabin crews); and a control group (daily shifts, 5 days of work and 2 days off). The data provided by these studies led Åkerstedt and collaborators [34] to conclude that 2 days of recovery appear to be needed after periods involving a sequence of long working hours.

A study by Totterdell and colleagues [36] also sought to identify the time needed to recover energy after a shift cycle. The study compared the levels of activation, pleasantness, tranquility, social and work satisfaction, mental workload, and reaction times in memory tasks, for 1 or 2 days of rest after 3 days of service. For some variables, including mood, job satisfaction, and performance in memory tasks, the results did not find significant differences. In contrast, 2 days of rest were associated with better values of activation, mood, social satisfaction, and mental workload than a single day of rest. In conclusion, 24 h does not seem to be sufficient time for a full recovery, even after a cycle of three service periods. With a similar goal, Rosa and Colligan [16] showed that 2 days of rest are enough to normalize most psychological functions after a 60-h working week. These results indicate the need for a break of at least 48 h following a shift cycle of approximately 60 h.

5. Rest Period between Consecutive Shifts Cycles including Night Hours

A further variable to consider is the presence of shifts that include night hours, with consequent accumulation of fatigue due to changes in biological rhythms. Knauth, Rutenfranz, Herrmann, and Poeppl [37] performed an experimental study by measuring the rhythm of body temperature following several night shifts. The results indicated that when the person was engaged in night shifts for 2 consecutive periods of service, 2 days of rest were required to restore physiological values, but after 21 consecutive nights, 3 to 4 days were necessary for the restoration of body temperature. A subsequent review by Kecklund and Akerstedt [38] cited Kecklund and colleagues [39] reporting that 3 days were needed to recover energy following a cycle of night shifts.

A study by Cruz and Rocco [40] focused on ATCOs, comparing the sleep quality of a group of ATCOs in three different shift programs, two based on a fast and counter-clockwise rotation, and one fixed with the start of the shift in the morning. One of the counterclockwise rotation programs was 2-2-1, with the first two afternoon shifts followed by two morning shifts and, later, a night shift. The minimum duration of the service periods was 8 h. The second roster with quick rotation, instead, consisted of two afternoon shifts followed by a mid-day shift and two morning shifts (2-1-2 type roster). In this case, there were two 12-h shifts and no night shift. The variables analyzed were sleep and wakefulness times, total sleep time, and subjective assessments of sleep quality and drowsiness. The results showed that the roster with the night shift was associated with fewer hours of sleep. The average number of hours of sleep decreased from about 8 h before the afternoon shifts to 5 h before the morning shifts, and to just 2.4 h before the night shift [40]. The results of the study also confirmed what had been previously found [30][40][41], although in these cases, the minimum sleep hours were higher (about 3.5). In addition, in the other roster with fast rotation, there was a reduction in sleep hours, which remained substantially more significant than in the first shift system. In that case, the amount of rest decreased from 8 h of sleep before the first 3 shifts (the two afternoons and the day shift) to 6 h before the last two morning shifts. In this case, there was a substantial difference between the hours of sleep, even where there were no consecutive periods of service that include night hours.

The reduction in sleep hours in conjunction with a service period that includes night hours increases when a roster provides for multiple consecutive night shifts. A study by Härmä and collaborators [42] investigated the relationship between periods of service that include night hours and perceived fatigue during work and on days off. Using a questionnaire, the authors collected information on a sample of more than 7000 hospital employees. Surveys took place at different stages of collection between 2008 and 2015, and the data were associated with daily records of working time in the 3 months preceding each survey. The authors found an association between the performance of several periods of service with night hours and fatigue level (both during work and on days off), altered sleep duration, and difficulty falling asleep. The suggestion resulting from the research was to limit the allocation of consecutive night shifts as much as possible.

The same conclusion was reached by Folkard and Tucker [33] in a review on the same subject. The authors summarized data on the proportion of incidents as a function of various shift characteristics, including the presence of several consecutive night shifts. The studies considered in the review investigated the relationship between incidents and the number of consecutive shifts, night shift time, and consecutive service periods, including night hours. Concerning the latter variable, data on the number of incidents were summed up between seven different studies and subsequently expressed in proportion regarding the first night shift. Authors found that the average risk increased by about 6% between the first and second night, by 17% on the third night, and by 36% on the fourth night.

Despite a moderately pronounced effect, the authors report the absence of data useful to explain this phenomenon. Indeed, the studies analyzed showed a clear increasing trend in the relative risk of incidents following consecutive night shifts, but there is insufficient information to explain this effect. A possible interpretation lies in the loss of sleep associated with the performance of a service that includes night hours, which accumulates when multiple shifts are worked out at night in succession, without the availability of a night to be able to recover from sleep loss. In the same study and using the same methodology, the authors also compared four consecutive daily shifts to determine whether the increased risk was due exclusively to the night shift or, in general, to the succession of shifts. The results showed a slight increase after four consecutive day shifts. The proportion of the incident risk was approximately 2% more on the second day, 7% more on the third day, and 17% more on the fourth-day shift than on the first day.

The comparison of these studies demonstrate that the increase in risk of incidents is greater after consecutive night shifts than when subsequent shifts are daytime. An additional risk in performing consecutive night shifts is the so-called “night shift paralysis”, reported by several ATCOs and described as a short-lived but disabling paralysis that occurs during the night shift, when workers must maintain a state of wakefulness despite the pressure of sleep. This phenomenon was reported by 6% of a group of 435 ATCOs in a survey conducted by Folkard and Condon [43] and was related to sleep deprivation.

6. Minimum Rest Periods following a Day Shift

The results reported so far refer to the rest period available following consecutive cycles of shifts, whether day or night. However, the accumulation of fatigue also depends on the amount of rest available between individual shifts, understood as the time between the end of one shift and the beginning of the next. This interval is typically variable, and its reduction typically results in a corresponding reduction in the duration of sleep. One way to allow the operator to avoid an accumulation of sleep loss is to identify the interval between two shifts necessary for sufficient rest.

A series of studies commissioned by CAMI in 1999 collected information on this issue involving ATCOs. The objective of the research program was to monitor sleep, mood, fatigue, and cognitive performance in a group of controllers to assess the association between these factors and the shift system. As reported by Nealley and Gawron [9], one of these projects consisted of a study involving a 21-day data collection on controllers conducted at a Terminal Radar Approach Control (TRACON) and an Air Route Traffic Control Center (ARTCC). The objective of the study was to assess the effect of shift times and time off between shifts on quality of sleep, mood, fatigue, and cognitive performance inf ATCOs. Both self-reported scales—the Positive and Negative Affect Schedule (PANAS) and the Stanford Sleepiness Scale (SSS)—as well as objective measures (logfile), were collected over the period of 21 days. Results showed a linear relationship between quantity and quality of sleep, highlighting an overall reduction in sleep hours when the interval between two shifts decreased. For example, controllers who had 9 h of rest reported higher scores in terms of affect and sleep quality than controllers who had 8 h of rest. These and other studies confirm the importance of the amount of rest time for the maintenance of adequate performance. It seems that sleeping fewer than 7 or 8 h per night can compromise the ability to maintain prolonged attention on a task [44][45], even if only 2 h of sleep are lost [46], and a continuous and prolonged restriction over time can affect cognitive performance [47].

A shift interval of fewer than 11 h is also called a *quick return*. In a review on the topic, Vedaa and colleagues [48] found a reduction in sleep hours to 6.5 h (or fewer) following a quick return. Härmä and colleagues [42] reported the association between a change in the rate of rapid returns and the fatigue reported during the following workdays and days off, as well as an increase in difficulty falling asleep. Other studies have found associations between quick returns and increased sleepiness [49][50][51] and increased fatigue [49][52][53]. Two studies found that reducing the number of 9-h rapid returns between evening and morning shifts improved sleep and alertness [54] and caused less fatigue than a control group [55]. The study by Costa and colleagues [56] also reported a higher level of drowsiness in an 8-h shift interval compared to a 12-h interval.

Roach, Reid, and Dawson [57], on the other hand, conducted a study to identify the minimum number of hours of break needed for people to sleep for at least 6 h between two shifts. The data refer to a sample of train drivers who had 24-h shifts. The authors reported the results in terms of hours of sleep as a function of the duration of the interval, which could be 12, 16, or 24 h, and of the start of the interval within 24 h. The results showed that participants slept, on average, 5.2 h when they had a 12 h break, from a minimum of 3.1 h for the break that began in the morning (between 08:00 and 10:00) to a maximum of 7.9 h for the break that began in the evening (between 20:00 and 22:00). In comparison, an average of 6.5 h of sleep was obtained in the 16-h intervals, again from a minimum of 4.8 h for breaks beginning in the morning (between 04: 00 and 06: 00) to a maximum of 7.7 h for breaks beginning in the evening (between 18:00 and 20:00). The average sleep time during the 24-h intervals was 8.9, from a minimum of 6.8 h for breaks beginning in the time slot between 14:00 and 16:00 to a maximum of 12.3 h for breaks beginning in the morning (between 06:00 and 08:00).

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