

## The length of shifts in the service sector – its relation to scheduling working days

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### Abstract

In the service sector typically strong variations in demand occur affording special consideration of the design of shifts and shift schedules. In designing shifts, issues of starting and stopping times have to be considered as well as the length of shifts. Under the side conditions of (average) weekly working hours and ergonomic recommendations concerning number of days off and length of consecutive work shifts the functional relationship between these conditions and shift length is explored. It is shown that for continuous schedules and typical weekly working hours solutions of the ergonomic side conditions afford increased average shift lengths. The problem is aggravated if within day demand variation is substantial and demand extends substantially beyond average daily working hours. In this case, if adverse costs from overtime or idle time is to be avoided, an inclination exists to solve the problem by introducing (at least a few) very long shifts or split shifts or part-time work.

**Keywords:** shift scheduling, shift design, split shifts

### 1. Introduction

In many industries traditional shiftwork is based on shifts with a length of approx. 8 hours or approx. 12 hours, and many shift schedules apply the same start and stopping times for the different shifts (e.g., morning shifts starting at 06:00, afternoon shifts starting at 14:00 and night shifts starting at 22:00). There are variations (especially between countries, e.g. Mediterranean countries starting a bit later) but they are small.

In some sectors, however, e.g. transport or extramural health services, other shift lengths and shift timings are commonly used. With the growth of service industries and hand in hand with a higher focus on efficiency of personnel planning, as well as the availability of planning tools, untypical shifts become more broadly used. As an example figure 1 shows a demand profile of a police force (number of persons vertical axis) over the first two days of the week (horizontal axis) based on minimal staffing requirements and actual deployments.

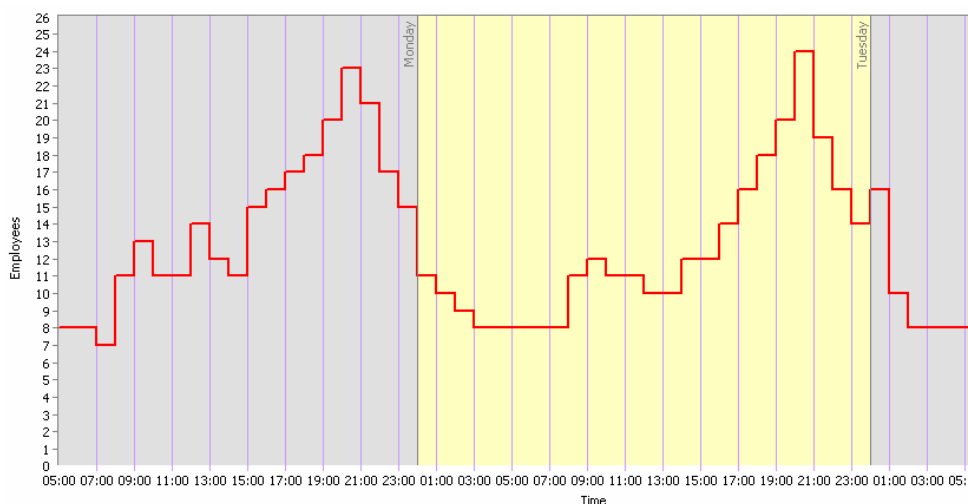


Figure 1: demand profile for a police force over the first two days of the week.

As one can easily see, the demand profile varies strongly over the day and to a lesser extent between days. If one would use traditional 8h shifts, either adverse costs from overstaffing in droughts or understaffing during peak demands (or a combination of both) would be the result.

Consequently, the question of how to design shift schedules is an issue in many organisations. This question can be addressed by quite different approaches:

- One approach would be to rely on the staff working overtime to cover the peaks. From the perspective of employees this often is quite popular (e.g., police force scheduling in Austria). However it often leads to adverse costs and a high number of working hours per employee.
- Another approach would be to use no fixed shifts anymore. Individuals may select time frames of work more or less freely. In regular intervals (e.g., several weeks) remaining inequality of working hours outside given limits is straightened out. This can be accomplished by a prioritisation strategy. Software supporting such a strategy is Timecare (Kreichbergs 2000). This approach is interesting due to the fact that it increases employees' latitude to choose their preferred working time, which is considered positive from a humanistic as well as from an ergonomic point of view (e.g. Smith and Mason (2001) conclude that the shiftwork-specific locus of control is an indicator of better tolerance to shiftwork). However it remains open under which side conditions concerning variability of demand profile ergonomically reasonable solutions can be achieved.
- A third approach stresses the instability of demand curves (they might change from day to day) and predictability might be low and correspondingly the focus might be on mechanisms of short-term adaptation. Taking this approach to the extreme is the concept of 'Vertrauensarbeitszeit' (trust in working hours), where employees are made responsible for deciding to work at proper times and no formal planning is applied (for a discussion see (Adamski 1998; Langecker 1999)). In this case it is even more doubtful whether acceptable and appropriate arrangements result.

The approach explored in this paper is developing working time schedules that are 'as good as possible' from a health and safety perspective while meeting the demand 'to a reasonable degree'. This approach addresses demand profiles that are stable or can be described in terms of a limited number of alternative types and levels of demand (e.g., days with high demand, normal demand, and low demand). To some degree it supports self selection of employees into shifts (e.g., employees choosing their preferred shift out of a set of alternatives). It also assists in the determination of the degree of latitude for the employees the system provides.

The question of designing shifts is a complex task in itself (Musliu, Schaerf et al. 2002). The techniques for shift-design, whether computer supported or manual, are not discussed here (for a review consult (Spurgeon 2003))

What is discussed in the next chapters is the relationship between shift design and schedule design. At first the nature of this relation is introduced and substantiated. Then the consequences are explored giving a small number of real-world examples and, finally, the implications are discussed.

## **2. The relationship between shift design and shift schedule design**

Shift design addresses questions of length of shifts, start- and stopping times, breaks, split or contiguous working hours etc. while shift schedule design is concerned with the arrangement

of shifts within and between shift crews. Although closely related, these tasks have to be distinguished.

A large body of research is devoted to the issue of proper shift design and proper shift scheduling. For a review see (Wedderburn 1991; Popkin, Howarth et al. (in press); Knauth 1993; Nachreiner et al. 2000). Kundi (2003) develops the following principles for the design of shift schedules:

Table 1: Recommendations in (Kundi 2003)

Principle (1):	The total number of night shift hours should be as low as possible.
Principle (2):	The necessary night work should be as equally divided among the respective work force as possible.
Principle (3):	There should be no more than three night shifts in a row, and only occasionally four or at most five if this is justified by a better arrangement of days off or other beneficial conditions made possible by these additional night shifts.
Principle (4):	There should be no more than six working shifts in a row, and only occasionally seven if this is justified by a better arrangement of days off or other beneficial conditions made possible by the additional working shift.
Principle (5):	After each sequence of night shifts there should be at least 32 and preferentially 48 hours off.
Principle (6):	Before each change of shifts differing at least by 6 hours in onset time at least 18 and preferentially 24 hours break should be provided.
Principle (7):	The length of shifts and particularly of night shifts should be balanced against the demands of the working tasks. Very demanding, hazardous or accident prone work should not exceed 8 and only rarely 9 hours, less demanding work might be extended to 12 hours if provisions for sufficient breaks are introduced. If convenient, night shifts should be shorter than other shifts.
Principle (8):	Morning shifts should not begin before 6:00 am, afternoon shifts should not end later than 10:00 pm, and night shifts should not begin later than 11:00 pm.
Principle (9):	Days off should as often as possible include 1 day of the weekend.
Principle (9a):	The sum of days off weighted according to an appropriate weighting scheme should be as high as possible and converge to that of regular day work.
Principle (10):	Number of contiguous days off should as often as possible be 2–3 days and at most 4 days.

Of course, lists of recommendations concerning the design of shifts and shift schedules do not cover everything. Considering recent trends to introduce split shifts, principle 7 should be extended as to avoid split shifts. E.g. a shift starting at 7:00, with a break from 9:00 – 13:00 and an additional spell of work from 13:00 to 19:00 (Sussmann and Coplen 2000) has a nominal overall length of only 8 hours but (together with commuting time) blocks virtually a whole 12 hour period by work related activities. In addition the break of 4 hours can hardly be used by employees for recreation and leisure time activities. In rare cases, especially if commuting can be neglected, split shifts may be a convenient arrangement of working hours for the employee e.g., A single person caring for elderly parents may prefer a split shift so that he or she isn't gone for long periods of time during the day.

There is a direct relation between the design of shifts and the design of shift schedules. It starts from the relation between working hours per week and average shift length shown in formula 1:

$$\text{Working Hours per Week} = \text{Average Length of Shifts} * \text{Duties per Week}$$

Formula 1: The equation connecting shift design and shift schedule.

Working hours per week (or any other convenient time period covering several shifts) are the average working hours of employees. Average Length of shifts is the time paid for the shifts (e.g., a 12h shift with 45 minutes of unpaid breaks would be 11.25h in this calculation) during one week divided by the number of duties per week which is given by the number of shifts disregarding potential splits of a shift into two or more parts (e.g., a shift with an employee working from 07:00–13:00 and another spell of duty from 14:00–18:00 is considered as one shift).

Although appearing trivial at first sight, the importance of duties per week as key issue in the design of shifts was independently noted by (Bourgeois-Bougrine et al. 2001) and our group (Gärtner 2001). Bourgeois-Bougrine et al. used a slightly different formula introducing days off per week. But basically it can be written as given in formula 2.

$$\text{Working Hours per Week} = \text{Average Length of Shifts} * (7 - \text{Days off per Week})$$

Formula 2: Another formulation of formula 1.

Considering the recommendations in table 1 regarding the maximum number of days of work in a row and corresponding days off, the relation leads to the following upper limits for working hours respectively lengths of shifts.

$$\begin{aligned} \text{Min. Nr. of Days of Work in a Row (on Average)} = \\ \text{Weekly Working Hours} * \\ \frac{\text{Min. Nr. of Hours Off in a Row after a Sequence of Duties}}{24 * (7 * \text{Average Length of Shifts} - \text{Weekly Working Hours})} \end{aligned}$$

Formula 3: Relationship between days of work in a row and average length of shifts for a given minimum of days off afterwards and a given number of weekly working hours.

In the following two chapters the following two assertions are substantiated.

1. Depending on average working hours per week, the average length of shifts has to be high to allow for reasonable time off after night-shifts or any sequence of contiguous work shifts
2. It is difficult to design schedules with high average shift-length in many service industries.

### 3. The pressure for long shifts

Applying principle 5 (table 1), recommending 48 hours off after a sequence of working days, for a 40 hours working week the relationship shown in table 2 between shift length and (average) number of working days per week results.

Table 2: The relationship between average shift length and number of work days in a row conditional on 40 working hours per week and a minimum of 48 hours off after each sequence of working shifts.

Average length of shifts	Average number of work days in a	Average number of duties per	Average number of days off per	Dominant rhythm (work
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	row	week	week	days & days off)
12.00 h	1.82 days	3.33 days	3.67 days	2 & 2
10.00 h	2.67 days	4.00 days	3.00 days	3 & 2
9.00 h	3.48 days	4.44 days	2.56 days	3 & 2
8.50 h	4.10 days	4.71 days	2.29 days	4 & 2
8.00 h	5.00 days	5.00 days	2.00 days	5 & 2
7.75 h	5.61 days	5.16 days	1.84 days	6 & 2
7.50 h	6.40 days	5.33 days	1.67 days	6 & 2
7.15 h	7.96 days	5.59 days	1.41 days	8 & 2
7.00 h	8.89 days	5.71 days	1.29 days	9 & 2

Principle 5 (48 h off) and principle 4 (max. 6 or 7 working shifts in a row) taken together imply for a given average number of working hours per week (for a continuous system) a lower limit for the average shift length. For 48 h a week the value is 8.81 h for a maximum of 6 work shifts in a row. It is interesting to note how sensitive the relation is. A change of only 0.28 h in shift length may afford an increase of a whole work shift in the average length of shifts worked in a row.

Table 3: Average shift length in a continuous system in order to achieve a schedule with 4/5/6/7 work shifts in a row and 48h or 72h off after each sequence of work shifts depending on the weekly working hours.

Average weekly working hours	Average number of work days in a row	Average number of duties per week for 48h/72h off	Average number of days off per week for 48h/72h off	Average length of shifts for 48h/72h off
48,0 h	4 days	4,67/4,00 days	2,33/3,00 days	10,29/12,00 h
48,0 h	5 days	5,00/4,38 days	2,00/2,63 days	9,60/10,97 h
48,0 h	6 days	5,25/4,67 days	1,75/2,33 days	9,14/10,29 h
48,0 h	7 days	5,44/4,90 days	1,56/2,10 days	8,82/9,80 h
40,0 h	4 days	4,67/4,00 days	2,33/3,00 days	8,57/10,00 h
40,0 h	5 days	5,00/4,38 days	2,00/2,63 days	8,00/9,14 h
40,0 h	6 days	5,25/4,67 days	1,75/2,33 days	7,62/8,57 h
40,0 h	7 days	5,44/4,90 days	1,56/2,10 days	7,35/8,16 h
36,5 h	4 days	4,67/4,00 days	2,33/3,00 days	7,82/9,13 h
36,5 h	5 days	5,00/4,38 days	2,00/2,63 days	7,30/8,34 h
36,5 h	6 days	5,25/4,67 days	1,75/2,33 days	6,95/7,82 h
36,5 h	7 days	5,44/4,90 days	1,56/2,10 days	6,70/7,45 h
35,0 h	4 days	4,67/4,00 days	2,33/3,00 days	7,50/8,75 h
35,0 h	5 days	5,00/4,38 days	2,00/2,63 days	7,00/8,00 h
35,0 h	6 days	5,25/4,67 days	1,75/2,33 days	6,67/7,50 h
35,0 h	7 days	5,44/4,90 days	1,56/2,10 days	6,43/7,14 h

The figures in table 3 hold for a continuous system with constant staffing. In systems with uneven staffing (e.g. reduced demand in hospitals on weekends) it is not practical to schedule

a constant number of work shifts. Sometimes only a few work shifts can be scheduled in a row. Consequently the number of duties per week goes down and average shift length has to be increased.

The relatively small differences in the average length of shifts are striking. With 40 h per week it is just an hour change of average shift-length that makes the difference between a 4 days two off and 7 days two off rhythm.

In the tables above average shift length in relation to work shifts and time off was computed. Three further issues have to be mentioned that increase the pressure to go for longer shifts:

1. Organisations have to deal with varying demands and/or variations in the number of employees that are available (due to sickness leave, training etc.). Only in rare circumstances these variations are synchronised and predictable. Typically schedules have to be adapted at short notice.  
Correspondingly, with respect to average working hours, average shift length should be higher to allow for changes in the schedule without causing too many work shifts in a row.
2. In the case part-timers are used, an increase of average shift-length for the full-time staff may result. Schedules that allow for a combined employment of part-time and full-time workers tend to introduce longer average shifts for the full-time staff.
3. The calculation was based on Principle 5 to have at least 32 to 48 hours off after a series of night shifts. If the night shifts are a relevant fraction of shifts the situation becomes even more complex. Based on principle 3 there should not be more than three night-shifts in a row. This implies either fast forward rotation with many work shifts in a row ending in a series of night shifts, or separated short series of work shifts. Both alternatives have drawbacks and increase the pressure for high average shift length. 48h off after night shifts may be enough to recover from sleep deficits but the effective leisure time is substantially shortened. Correspondingly employees prefer to have more days off after long series of work shifts that end with night shifts. This leads to similar results as short periods of consecutive work shifts in a row (Tab. 2 and 3).

Summing up, these results indicate a high pressure to go for long shifts. Both reducing the number of work shifts in a row and/or increasing the hours off after a sequence of working shifts results in an increase of shift length to comply with the given number of working hours per week.

#### **4. High average shift length may afford some shifts being very long or split shifts**

In the chapter above it was argued that reasonable time off after several work shifts call for rather long average shift-length. In this chapter it will be suggested that a high average shift-length is difficult to achieve in many organisations of the service sector.

A demand profile as shown in figure 1 is not untypical in the service sector. Demand is not constant over the day and typically is of an immediate type that, though foreseeable, cannot be shifted to equalise the profile. In several branches, however, there are portions of work that can be postponed to some degree. But still the effective variation may be substantial such that all or most shifts have to be designed according to the demand profile.

##### **4.1. Example 1: Police force**

Taking the demand profile for the police force, we optimised allocation and lengths of shifts with the support of a specialised software tool (OPA 2.0 – Operating Hours Assistant © - (Di

Gaspero, Gaertner et al. 2003)). Of course, several side conditions influence such an optimisation process, e.g. how many different types of shifts are feasible, what are reasonable starting and ending times, and - in case there is no optimal solution – how under- and overstaffing should be weighted.

For the example shown in table 5 we introduced only weak restrictions regarding start-times: All times were feasible except start times between 23:00–05:00. We did not limit the number of different shifts and tried to keep overstaffing and understaffing approximately at the same level. Only the shift length's was varied from scenario to scenario, other settings remaining unchanged.

Table 4: Duties per week depending on maximum and minimum shift length for the police force demand profile shown in fig.1 under the restriction of 40 hours weekly working time and 48 hours off after a sequence of work shifts. Shift onset was varied as part of the optimisation process, prohibited were start times between 23:00 and 5:00.

Min shift length	Max Shift Length	Over-staffing	Under-staffing	Sum Over- & Under-staffing	Average length of shift	<b>Average number of duties per week</b>	Average number of work shifts in a row	Dominant rhythm (work shifts & days off)
8,00 h	8,00 h	1,44%	3,42%	4,86%	8,00 h	<b>5,00</b>	5,0	5 & 2
8,25 h	8,25 h	2,44%	3,59%	6,03%	8,25 h	<b>4,85</b>	4,5	5 & 2
8,50 h	8,50 h	2,82%	3,27%	6,09%	8,50 h	<b>4,71</b>	4,1	4 & 2
7,00 h	8,00 h	0,32%	1,22%	1,54%	7,46 h	<b>5,36</b>	6,5	7 & 2
7,00 h	9,00 h	0,50%	0,36%	0,86%	7,80 h	<b>5,13</b>	5,5	5 & 2
7,00 h	10,00 h	0,23%	0,59%	0,82%	7,95 h	<b>5,03</b>	5,1	5 & 2
7,00 h	11,00 h	0,23%	0,36%	0,59%	8,26 h	<b>4,84</b>	4,5	4 & 2
7,00 h	12,00 h	0,00%	0,45%	0,45%	8,33 h	<b>4,80</b>	4,4	4 & 2
6,00 h	10,00 h	0,23%	0,45%	0,68%	7,61 h	<b>5,26</b>	6,0	6 & 2
5,00 h	10,00 h	0,09%	0,27%	0,36%	6,94 h	<b>5,76</b>	9,3	9 & 2
4,00 h	10,00 h	0,14%	0,23%	0,37%	6,16 h	<b>6,49</b>	25,5	25 & 2
4,00 h	9,00 h	0,05%	0,32%	0,37%	5,84 h	<b>6,85</b>	91,6	92 & 2

In all cases the total hours of over- and understaffing decreased if variation of shift length was increased. Effect of average shift length on over- or understaffing depended on the range of working hours per shift. E.g. at a range of 4 hours an average shift length of 8.26 hours was associated with an over- and understaffing of overall 0,59%, while an average of 7.61 hours resulted in 0,68% over- and understaffing. Working with constant shift lengths of 8 h or 8.25 h, deviation from demand increases strongly to 4.8% or even 6%.

If one would go for short shifts a very good fit of staffing and demand can be achieved. The number of duties per week, however, would increase dramatically or split shifts (i.e., combining two short shifts together with a longer break in between) become unavoidable.

## 4.2. Example 2: Laboratory in a hospital

Work in the health services often has a demand profile with a peak in the morning and declining demand in the afternoon. Often nights have to be covered in addition. Typically not all days are equal in their demand; on weekends typically services are reduced.

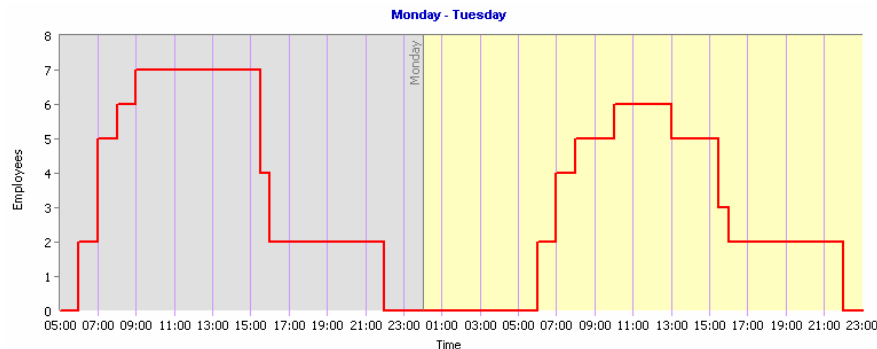


Figure 2: Demand profile of a laboratory in a hospital.

In this case an optimisation under the constraint to have only a small number of different shifts was employed. A difficulty arose because shifts had to include 30 minutes of unpaid breaks.

Table 5: Duties per week depending on maximum and minimum shift length for a laboratory in a hospital under the restriction of 40 weekly working hours and 48 hours off after a sequence of work shifts.

Min shift length	Max Shift Length	Over-staffing	Under-staffing	Sum Over- & Under-staffing	Average length of shift	Average number of duties per week	Average number of work shifts in a row	Dominant rhythm (work shifts & days off)
4,00 h	9,00 h	0,00%	3,29%	3,29%	7,66 h	<b>5,22</b>	5,9	6 & 2
4,00 h	10,00 h	0,00%	2,90%	2,90%	7,87 h	<b>5,08</b>	5,3	5 & 2
4,00 h	11,00 h	0,00%	1,58%	1,58%	7,98 h	<b>5,01</b>	5,0	5 & 2
4,00 h	12,00 h	0,00%	2,90%	2,90%	8,95 h	<b>4,47</b>	3,5	4 & 2

Table 5 shows that duties per week stay high, even if shifts of up to 11h are introduced. After including 12h shifts a slight improvement could be achieved, however, deviation from demand increased.

## 4.3. Example 3: Public transport

Public transport and the corresponding demand vary strongly from town to town and depend, among other factors, on available planning techniques. Legislation typically influences the design of shifts strongly, as minimum requirements for breaks and length of shifts are more specific than for other groups of employees (e.g., Austrian law on working time (1994)).

The problems can be illustrated by schedules for bus-drivers on a route in a small Austrian town. Demand was high from around 06:30 to around 19:30, i.e. for 13 hours.

Such a time span is too long to be covered by one shift and would lead to shifts too short if covered by two shifts. One feasible solution is to work with several split shifts with breaks of several hours.

## 5. Discussion

As implicated by the examples above the design of shifts is not only a difficult problem in itself but also strongly connected to the development of shift schedules, particularly with respect to the number of duties per week. The given number of weekly working hours (that have to be met, according to legal conditions or contracts, on average over an often predefined number of weeks) and the ergonomic and social demand for interspersed days off and a limited number of work days in a row results in limitations on the average number of working hours per shift. For daily duties that exceed average shift length a day and especially for varying demands during the day and across days design of shifts and schedules becomes a laborious task. As a general rule, providing for a reasonable number of days off (especially after sequences of shifts that are strongly interrupting social activities and the human circadian system) and at the same time limiting the number of shifts worked in a row results in increasing average shift lengths. Under varying demand adverse costs due to excessive overtime or idle time can in many cases only be avoided by either varying also shift lengths or by implementing, at least partially, split shifts or part-time work.

Short shifts (e.g. 6h shifts) would be an alternative, although there are severe shortcomings including low number of contiguous days off, unfavourable start and stopping times of shifts resulting, for continuous operation, in an overall increased number of hours that are tied to the schedule. Such schedules, however, have many advantages if overall working time is reduced. Concerning working time the secular reduction over the past one and a half century seems to have come to a stop and a further general reduction seems unlikely in the near future, even though there are interesting examples indicating benefits also for companies (e.g. Karazmann 1998.. On the other hand, pressure for more flexibility concerning arrangement of working hours is increasing. To balance economic costs and ergonomic demands a trade off between different criteria has to be found. Besides reduced working hours, it seems that length of shifts must be increased or shifts must be split to provide sufficient numbers of days off under many given demand profiles.

This raises several questions for research:

- Under which conditions are a few long shifts acceptable from an ergonomic point of view and how is the trade off with respect to the schedule as a whole.
- What are the consequences of split shifts compared to long shifts?
- Is it possible to identify certain patterns of demand that allow for similar solutions?

With long working hours (and/or) unpaid breaks the optimisation process increases in complexity and may result in a no win situation where employees prefer shifts or schedules not recommendable from an ergonomic perspective to keep up their salary (Gärtner 2004).

Principle 1 of the above recommendations by Kundi (2003) already connects working time with work organisation as it calls for a minimisation of night work. Given that the demand profile has such a substantial impact on the design of shifts and schedules, as indicated by the analyses above, trying to improve working time arrangements may be even more strongly related to questions of the organisation of work as such.

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