

A technique to take leave into account in shift-rota design

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Sick leave, vacations, and the like lead to substantial leave factors. Rota design techniques for covering leave are not always feasible. A small company was helped to develop a new rota. The main requirements were an ergonomically better rota, less overtime caused by leave, and a rota that lets employees take their vacation during the summer. The internal evaluation was unanimously positive after 1 year. A prospective leave coverage was used, with different workhours during summer and spring and with a mixture of shift work and flexible day work. Later the rota was further refined, and broader qualifications of the workers made a much simpler rota possible. The experiences of this study indicate that problems with leave can be reduced if expected variations in leave are considered in the rota design by including variations in workhours. A further promising strategy is to mix shift work with other types of work when time is not a critical factor.

Key terms assessment of shift rotas, computer-supported shift scheduling, flexible workhours, leave, shift scheduling.

Sick leave, vacations, and the like lead to substantial leave factors [eg, the Austrian chamber (1) of commerce suggests 15% of total work time as the average]. The amount of leave can vary strongly from company to company, from industry to industry, and from nation to nation. Nevertheless it always has substantial magnitude. In addition to the magnitude of leave, it is only partially known in advance at what times leaves will actually occur.

Companies use the following strategies in dealing with leave:

- In some industries (eg, the automobile industry) the technique of company vacations ("Betriebsurlaub") helps to reduce complications. "Betriebsurlaub" means that the entire work force, or at least the bigger part of it, is on vacation for some weeks. This practice reduces leave during the year and allows time for maintenance work. Still it is only partially feasible (eg, because of the customers' need for continuous supply, technical factors, costs).
- Many tasks can be handled with a work force reduced by leave, if workers can postpone or discard less im-

portant tasks or try to compensate by working harder.

- Workers from other departments, temporary workers and the like can help out. Such additional workers then carry the work load on short notice.
- In cases of shift work the size of each shift group is sometimes increased in proportion to the leave factor (reserve). The advantage of this strategy is that it is fairly simple and does not require additional planning. But this strategy has 2 main drawbacks. First, the number of reserve workers remains constant, whereas leave occurs unevenly (especially the demand for vacation). Second, this strategy is very expensive for small groups as it substantially increases the number of workers. Such small groups not only have to be considered in small plants, rotas for small groups also arise if different qualifications are crucial (eg, if electricians and mechanics are needed, and only a few persons have both qualifications).
- For small groups and for peaks of leave that are not covered by augmented groups 2 other strategies are used. The typical strategies we know are overtime for

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the workers at hand and dedicated reserve workers. Both strategies lead to work on short notice and often to poor workhours.

Some of these techniques are fairly simple and do not need much planning ("Betriebsurlaub", augmented groups, delaying or discarding work). But they do not always cover the peaks of leave, especially not for small groups. In such cases long hours and extra duties occur on short notice. Both are problematic in general, especially in shift work (2). A short example would be 3 shifts M... Morning (8 hours, 0600–1400), E... Evening (8 hours, 1400–2200), N... Night (8 hours, 2200–0600) with the symbols "M" and "E" used as symbols for days off. These symbols are used throughout this article.

Figure 1 shows a simple rota based on the basic series of MMEENN-- with 4 groups and 2 days' difference at the start. The rota is read from left to right starting with the top row. Given 8-hour shifts, it is based on 42 workhours per week.

If people are on leave in this rota, they have to be substituted by members of other teams. The resulting workhours are extremely poor. Assume that a worker of group C gets sick and has to be substituted by a member of another group. Then a possible reaction would be to adapt the rota as shown in figure 2.

A worker of group D is called in, on short notice, and does 2 extra evening shifts (EE). Rest hours are shortened to 8 hours from N to EE and from EE to M. Furthermore, this worker has 14 days in a row of mixed shifts. These are extremely poor workhours. In addition, a worker of group B does 2 morning shifts (EM) on short notice. Given this rota, other solutions are hardly better.

The example highlights the most important problems of this kind of leave management: (i) work on short notice, (ii) long periods of work, (iii) extremely short periods of rest, (iv) overtime, and (v) high costs (overtime payment).

	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2
	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Su
A	M	M	E	E	N	N		M	M	E	E	N	N		
B			M	M	E	E	N			M	M	E	E		
C	N	N			M	E	N	N	N			M	M		
D	E	E	N	N			M	E	E	N	N				

Figure 1. A simple rota for continuous work. (Mo = Monday, Tu = Tuesday, We = Wednesday, Th = Thursday, Fr = Friday, Sa = Saturday, Su = Sunday, M = morning, E = evening, N = night)

	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2
	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Su
A	M	M	E	E	N	N		M	M	E	E	N	N		
B			M	M	EM	EM	N			M	M	E	E		
C	N	N			Sick	Sick	Sick	E	E	N	N		M	M	
D	E	E	N	N	EE	EE	M	M	E	E	N	N			

Figure 2. A simple rota for continuous work with assignments to cover leave. (Mo = Monday, Tu = Tuesday, We = Wednesday, Th = Thursday, Fr = Friday, Sa = Saturday, Su = Sunday, M = morning, E = evening, N = night)

Such problems even accumulate during summertime when most people take their vacations. Sometimes managers may even drop the rota altogether.

In this article we describe a different technique, one developed in a small company. From the beginning we took leave into account in the rota design, using both different workhours and different rotas for spring and summer. The rotas developed were used for a year, internally evaluated, and then refined in the 2nd year. Our experiences indicate that these techniques actually allow substantial improvements in workhours.

Case

First year

A shop steward of a small plant with continuous work asked us to support the company in developing a new rota. The existing rota for spring and summer was built on the series (MMEENN--). Several years ago, they had a slow forward rotating rota. They preferred the quick forward rotation. The average number of workhours was supposed to be 38.0. Four workers were needed from Monday to Sunday, 24 hours a day. In addition, 1 person from Monday to Friday did repairs for 8 hours. Another person was assigned to do extra shifts to cover planned and unexpected leave. People should have extra days off to stay within the number of workhours agreed upon. Overall 18 persons were employed. A "Betriebsurlaub" of the plant in summer would have been the easiest way to facilitate vacations and reduce variations in leave, but it was not feasible due to the technical difficulties of stopping the facility and due also to reasons of capacity.

The main requirements for the new rota were (i) an ergonomically better rota, (ii) less overtime caused by leave, (iii) a rota which lets the employees take their vacations in summertime. The main focus with respect to ergonomics was on reducing differences between the agreed rota and the actual workhours. Sick leave caused a high number of short-term changes (eg, extra duties, switches to other shift groups) with very poor workhours (eg, poor shift changeovers, high number of duties in a row). At the same time, the advantages of the old rota MMEENN-- (eg, quick forward rotation) should also be included in the new rota. Weekends should be improved if feasible. Regarding vacations, people complained that they could not go on vacation. Generally they still had their entire vacation left over from the previous year (5 to 6 weeks).

The task was to design a rota for 32 weeks in the spring and summer. In the autumn again a rota with MMEENN-- was used, but this time on the basis of a 42-hour week and with more work force. In the autumn

no vacations were allowed. In addition there was no reserve for sick leave as the 18 employees and some others were assigned to work only on that facility. If someone got sick, fewer people worked in the plant. This rota should not be changed because it was effective and employees did not want to lose the high salaries they earned for 42 hours per week.

In 3 workshops we developed a new rota using computer support (3). The analysis of leaves showed that 20 workers instead of 18 were needed to take leave fully into account. This change should have substantially reduced the overtime indirectly caused by leaves. The reduction should have led to decreased costs (overtime supplements being 50% to 100% depending on the day of the week). The management agreed to employ these 2 additional workers and also prepared their qualification.

The problem of leave was the most dominant. We therefore analyzed leave data from the previous year. The idea of 2 different rotas emerged in order to prepare for different leaves in the spring and summertime. The hours of leave of the previous year (weeks 6 to 37) and the amount of reserve to be scheduled is illustrated in the figure 3. The hours shown represent the total hours of leave of the whole work force (eg, 280 hours $\approx$ 7 persons on leave). Before the necessary level of reserve was calculated, the decision was made that more maintenance shifts per week should be scheduled and, in exchange, be used both for the nontime-critical repair work and reserve shifts. To establish the level of reserve needed, the average hours of leave were calculated as 166.31 hours per week during springtime and 261.20 hours per week during summer. At least 5 maintenance shifts per week (5 shifts $\times$ 8 hours = 40 hours) were necessary. Only full-time employees with 38 hours per week should be employed.

The first rotas developed had a higher number of workhours in summer (42 hours) and reduced workhours in the spring (about 35.6 hours). Higher workhours in

summer led to more duties per employee and hence to higher reserves. The reserve was very high to allow more vacations than had been taken the year before. The length of these 2 periods (spring = 20 weeks, summer = 12 weeks) reflected early decisions on the basic series of the rota chosen and the aim to meet the number of workhours agreed upon for the full period. Thus the level of reserve (= the number of workhours in maintenance shifts) was set at 208 extra workhours per week during springtime and 336 extra workhours per week during summer. In autumn and in winter no reserve was to be scheduled. Therefore, no leave data for these periods were analyzed.

The working group decided that each worker should do reserve shifts [a concept similar to the flexible shifts discussed earlier by Knauth (4)]. Repairs were not time critical. We therefore exploited maintenance work as a reserve buffer. If workers were not needed to cover leave, they were assigned to do repairs. The name of the maintenance shift was Ma. During the spring 3–4 persons per day did reserve duties (= maintenance duties); during the summer there were 6 persons for this purpose.

The design of the rota varied around 2 basic series and additional parts for the maintenance work: MMEENN---- for spring (a 10-week rota) and MMEENN-- for summer (an 8-week rota).

These series were sometimes replaced by blocks of 3–6 maintenance shifts in a row followed by 2–4 days off. During the summer period the maintenance blocks were inserted in quicker succession. In addition 2 qualification teams, A (12 persons) and B (8 persons), had to be considered, the result being that B had more maintenance shifts than A. Two short parts of the rota for the first weeks of the spring and the summer rota are shown in figures 4 and 5, respectively. Please note that each group's rota is written on a single line.

A lack of appropriately qualified workers also made the design difficult. We had to ensure that sufficient persons of qualification B were scheduled for each day.

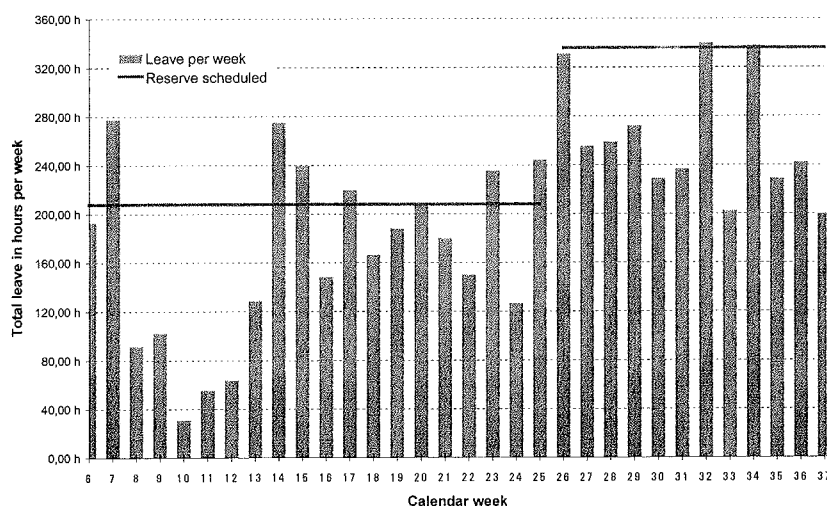


Figure 3. Total hours of leave among the work force in the spring and summer of the previous year and the reserve scheduled (weeks 6 to 37).

	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3	3	3	4	4	4	4	4	4					
	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	
A.1	Ma	Ma	Ma	Ma			Ma	Ma	Ma	Ma			M	M	E	E	N	N			M	M	E	E	N	N			
A.2	Ma	Ma	Ma	Ma			Ma	Ma	Ma	Ma			M	M	E	E	N	N			M	M	E	E	N	N			
A.3	M	M	E	E	N	N							M	M	E	E	N	N			M	M	E	E	N	N			
A.4	M	M	E	E	N	N							M	M	E	E	N	N			M	M	E	E	N	N			
A.5	E	E	N	N									M	M	E	E	N	N			M	M	E	E	N	N			
A.6	E	E	N	N									M	M	E	E	N	N			M	M	E	E	N	N			
A.7	N	N					M	M	E	E	N	N							M	M	E	E	N	N		M	M	E	E
A.8	N	N					M	M	E	E	N	N							M	M	E	E	N	N		M	M	E	E
A.9						M	M	E	E	N	N								M	M	E	E	N	N		Ma	Ma	Ma	Ma
A.10						M	M	E	E	N	N								M	M	E	E	N	N		Ma	Ma	Ma	Ma
A.11						M	M	E	E	N	N								Ma	Ma	Ma	Ma	Ma	Ma	Ma		M	M	
A.12						M	M	E	E	N	N								Ma	Ma	Ma	Ma	Ma	Ma	Ma		M	M	
B.1	M	M	E	E	N	N							Ma	Ma	Ma	Ma			M	M	E	E	N	N		Ma	Ma	Ma	Ma
B.2	E	E	N	N									Ma	Ma	Ma	Ma			M	M	E	E	N	N		Ma	Ma	Ma	Ma
B.3	N	N					Ma	Ma	Ma	Ma	Ma								Ma	Ma	Ma	Ma	Ma	Ma		M	M	E	E
B.4							Ma	Ma	Ma	Ma	Ma								Ma	Ma	Ma	Ma	Ma	Ma		M	M	E	E
B.5							Ma	Ma	Ma	Ma	Ma								Ma	Ma	Ma	Ma	Ma	Ma		M	M	E	E
B.6	Ma	Ma	Ma	Ma			M	M	E	E	N	N							Ma	Ma	Ma	Ma	Ma	Ma		M	M	E	E
B.7	Ma	Ma	Ma	Ma			M	M	E	E	N	N							Ma	Ma	Ma	Ma	Ma	Ma		M	M	E	E
B.8							M	M	E	E	N	N							Ma	Ma	Ma	Ma	Ma	Ma		M	M	E	E

Figure 4. First 4 weeks of the spring rota (rota for each group in a separate row) showing longer periods of days off and maintenance shifts. (Mo = Monday, Tu = Tuesday, We = Wednesday, Th = Thursday, Fr = Friday, Sa = Saturday, Su = Sunday, M = morning, E = evening, N = night, Ma = maintenance)

	21	21	21	21	21	21	21	22	22	22	22	22	22	22	23	23	23	23	23	23	24	24	24	24	24	24	24	
	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
A.1			Ma	Ma	Ma	Ma	Ma	Ma							M	M	E	E	N	N							Ma	Ma
A.2			M	M	E	E	N	N				Ma	Ma	Ma	Ma	Ma				M	M	E	E	N	N		M	M
A.3			M	M	E	E	N	N				M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma		M	M
A.4	Ma	Ma				M	M	E	E	N	N				M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma
A.5	Ma	Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N					M	M	E	E	N	N		Ma	Ma
A.6	M	M	E	E	N	N				Ma	Ma	Ma	Ma	Ma	Ma					M	M	E	E	N	N		M	M
A.7	Ma	Ma	Ma	Ma				M	M	E	E	N	N			M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma
A.8	M	M	E	E	N	N				M	M	E	E	N	N					Ma	Ma	Ma	Ma	Ma	Ma		M	M
A.9	E	E	N	N				M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N
A.10	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma				M	M	E	E	N	N			M	M	E	E	N
A.11	N	N					M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N
A.12	N	N				Ma	Ma	Ma	Ma	Ma	Ma				M	M	E	E	N	N			M	M	E	E	N	N
B.1	Ma	Ma	Ma	Ma			M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N
B.2	Ma	Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N					Ma	Ma	Ma	Ma	Ma	Ma		M	M
B.3	Ma	Ma	Ma	Ma	Ma	Ma				M	M	E	E	N	N					Ma	Ma	Ma	Ma	Ma	Ma		M	M
B.4	E	E	N	N			Ma	Ma	Ma	Ma	Ma				M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma
B.5	N	N				Ma	Ma	Ma	Ma	Ma	Ma				M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma
B.6						M	M	E	E	N	N				Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N
B.7	M	M	E	E	N	N				Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N			Ma	Ma	Ma	Ma
B.8						M	M	E	E	N	N				Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N

Figure 5. First 4 weeks of the summer rota (rota for each group in a separate row) showing shorter periods of days off and maintenance shifts. (Mo = Monday, Tu = Tuesday, We = Wednesday, Th = Thursday, Fr = Friday, Sa = Saturday, Su = Sunday, M = morning, E = evening, N = night, Ma = maintenance)

	20 Mo	20 Tu	20 We	20 Th	20 Fr	20 Sa	20 Su	21 Mo	21 Tu	21 We	21 Th	21 Fr	21 Sa	21 Su
A.1		M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma
A.2		M	M	E	E	N	N	Ma	Ma	Ma	Ma	Ma	Ma	Ma
A.3	Ma			Ma	Ma	Ma	Ma	Ma	Ma	Ma	Ma			M
A.4	Ma	Ma			Ma	Ma	Ma	Ma	Ma			M	M	E
A.5	M	E	E	N	N					M	M	E	E	N
A.6	M	E	E	N	N					M	M	E	E	N
A.7	E	N	N					M	M	E	E	N	N	
A.8	E	N	N					M	M	E	E	N	N	
A.9	N					M	M	E	E	N	N			M
A.10	N					M	M	E	E	N	N			Ma
A.11				M	M	E	E	N	N			M	M	E
A.12				M	M	E	E	N	N			Ma	Ma	Ma
B.1	N												M	E
B.2				Ma	Ma	Ma	Ma	Ma		M	M	E	E	N
B.3	Ma	Ma	Ma	Ma				M	M	E	E	N	N	
B.4	Ma	Ma	Ma							E	N	N		Ma
B.5				M	M	E	E	N	N				Ma	Ma
B.6		M	E	E	N	N				Ma	Ma	Ma	Ma	Ma
B.7	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma	
B.8	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M

Figure 6. Transition between spring and summer rota without adjustments leading to prohibited and unfavorable changeovers. (Mo = Monday, Tu = Tuesday, We = Wednesday, Th = Thursday, Fr = Friday, Sa = Saturday, Su = Sunday, M = morning, E = evening, N = night, Ma = maintenance)

Only 8 persons had qualification B. In every shift at least 1 person with B qualifications was needed. The problems of qualification resulted in several refinements of the rota. Otherwise the design of the rota for each period was not difficult.

Much care had to be taken to plan the transition between these periods to meet the demands for the individual worktime agreed upon and to avoid prohibited or unfavorable shift changeovers. The main technique was to develop the plans separately and then look for ways to assign the rotas to persons that met the requirements as close as possible. Consider the rota at the transition between the 20th and the 21st week. If the rota were to be continued as shown in figure 6, person A.2 would have a prohibited changeover, person A.4 would have 8 duties in a row, and person B.1 would not only have a considerable advantage over all the other workers in team B (10 days off) but would also build up a big difference between the individual worktime agreed upon and the actual workhours.

To reach a more equal distribution of shifts and ensure that each person met the individual worktime agreed upon, rota assignments for weeks 21–32 were changed according to figure 7.

By these adjustments the number of shifts can be distributed more evenly. As the overall rota may look confusing, individual and reordered schedules were compiled.

As rotas were similar in their basic rhythms in the spring, summer, and autumn (all based on MMEENN and some days off), there was finally no changeover with less than 2 days off and no period of work with more than 6

duties. The worktimes agreed upon were met rather closely (overall differences in weeks 1–32 slightly more than 1 duty at most). The differences in worktime were to be balanced by future switches between rotas.

The rota started at the end of January 1996, after extensive discussion between the shop stewards and all the employees. The discussions took a great deal of time, but the prospect of real opportunities for taking vacations was the basis of acceptance for the new rota. The rota was used until autumn. The internal evaluation by both the management and the shop stewards (made in a 1-day workshop in autumn) was unanimously positive. Overtime and extra duties were close to zero. Short-term changes were close to zero. Only in an ill-scheduled week with a lot of further education were some extra shifts needed. People could take their vacation. Sick leave dropped from 7% to 3.31%, people were on vacation for an average of 268 hours.

Second year

The management and shop stewards wanted further improvements, since the workhours and the reserve were considered too high in summertime with respect to the reduced amount of sick leave. The workers did not like to work an average 42 hours and took vacation whenever they could, especially to avoid single maintenance shifts (ie, when the maintenance block was partially used for leave and partially used for maintenance).

We developed a new rota in a 1-day workshop, again using the maintenance shifts as a buffer. The differences in workhours between the summer and spring were reduced. Repair work was grouped more strongly, and broader qualifications made a much simpler rota possible since there were now 10 persons with qualification B instead of 8. It was no longer necessary to build a rota for 2 different groups. Only 1 group (C) with 20 persons (C1, C2, C3, ...) was used. The basic series (both 20 days) for the summer and spring became MMEEEE--NNN---MaMaMaMa- (39.2 h) and MMEEEE--NNN---MaMaMaMa- (36.4 h), respectively.

The group members with the critical qualification were assigned to C1, C3, C5, and so forth. By construction we thereby made sure that, on each day, each shift had at least 1 person with qualification B. The design of the rota was extremely simple. In addition the transition between spring and summer did not impose any problems.

The rota for the autumn was not changed. Transition to the rota for autumn was not difficult since there was a reordering of groups such that they phased into the new rhythm without problematic changeovers.

This time the discussion was easier for the shop stewards. The rota was immediately accepted by the

	20	20	20	20	20	20	20	21	21	21	21	21	21	21
	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
A.1		M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma
A.2		M	M	E	E	N	N			M	M	E	E	N
A.3	Ma			Ma	Ma	Ma	Ma			M	M	E	E	N
A.4	Ma	Ma			Ma	Ma	Ma	Ma	Ma			M	M	E
A.5	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma	Ma
A.6	M	E	E	N	N			M	M	E	E	N	N	
A.7	E	N	N					Ma	Ma	Ma	Ma			M
A.8	E	N	N					M	M	E	E	N	N	
A.9	N					M	M	E	E	N	N			M
A.10	N					M	M	E	E	N	N			Ma
A.11				M	M	E	E	N	N			M	M	E
A.12				M	M	E	E	N	N			Ma	Ma	Ma
B.1	N							Ma	Ma	Ma	Ma			M
B.2			Ma	Ma	Ma	Ma	Ma			Ma	Ma	Ma	Ma	Ma
B.3	Ma	Ma	Ma	Ma				Ma	Ma	Ma	Ma	Ma	Ma	
B.4	Ma	Ma	Ma				M	M	E	E	N	N		Ma
B.5				M	M	E	E	N	N				Ma	Ma
B.6		M	M	E	E	N	N					M	M	E
B.7	M	E	E	N	N			M	M	E	E	N	N	
B.8	E	N	N			Ma	Ma			M	M	E	E	N

Figure 7. Transition between spring and summer rota with adjustments leading to legally and ergonomically acceptable changeovers. (Mo = Monday, Tu = Tuesday, We = Wednesday, Th = Thursday, Fr = Friday, Sa = Saturday, Su = Sunday, M = morning, E = evening, N = night, Ma = maintenance)

employees. The management also liked the much simpler structure.

Concluding remarks

Two issues stand out given our experiences thus far. First, in both design projects, we worked with a prospective leave coverage, with different workhours in summer and spring as well as with a mixture of shift work and flexible day work. These techniques allowed substantial improvements in the actual workhours since we were able to use known differences between the leave caused by demand for vacations in the spring and summer. Still, the difference between the workhours in summer and spring should not vary too strongly. In addition a certain degree of regularity and foreseeability of the vacations was necessary for applying these planning techniques. However, in our experience, typical patterns of leave caused by vacations can be identified in most companies with slight regional, social demographic, and sectoral differences.

Second, qualifications may be crucial in allowing for simpler rota design and a merging of tasks. Not only were plant workers able to do maintenance, which was the basis of the actual design, but also the broader qualification in the 2nd year made it possible to abolish any internal differentiation within the rota. Therefore, a rather simple basic series could be applied. It was enough to distribute the specific qualification evenly.

More generally, the following 4 promising strategies for taking leave into account were devised:

1. Expected leave variations can be considered in the rota design by defining periods of different workhours.

2. Merging shift work with other work regimes may reduce work load and, given that this additional field of work is less time critical, allow a build up of reserve buffers. Qualification, however, is a critical issue in this respect.

3. If leave cannot be covered by other means, rotas can be built upon flexible reserve shifts. Such rotas should work with reduced workhours that take these extra shifts into account on short notice. In such a shift system, these extra shifts are not overtime; instead they are part of the regular workhours. The ergonomic quality of such a rota should be higher, as overall workhours are lower and time-off is increased as overtime is decreased. Still, a bargaining solution might be appropriate to soften the corresponding reduction in income.

4. The times within the rota in which employees can expect to have flexible duties to cover leave should be discussed in advance. This discussion reduces the insecurity the employees feel about their freetime. In addition

possible conflicts with ergonomic requirements (eg, rest hours) can be checked in advance.

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