Quality in fives

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APPENDIX A

QUESTIONNAIRE

This appendix shows the translated questionnaire referred to in the third, fourth and fifth chapter. The Dutch version of the questionnaire was sent to the nurse schedulers who participated in this research. For ease of answering, most of the questions of this original version were multiple choice questions (including ‘None of the above, namely ...’). This appendix only shows the questions.

A.1 General questions

1. Which type of health care organization are you working at?
2. What is the name of this health care organization?
3. Which type of ward are you working on?
4. Which type of nursing unit are you working in?
5. What is your function?

A.2 Characteristics of the task performance

6. Is your nursing unit continuously operational?
7. Are shifts assigned to individuals or to teams of nurses?
8. Do you arrange completely new nursing schedules or do you start with a basic schedule?
9. What is the length of the schedule period?
10. Do you arrange a nursing schedule all by yourself, or do you cooperate with others?
11. If your scheduling task involves cooperation, is there a conflict of interests?

A.3 Characteristics of the task domain

12. Does your scheduling task involve different types (functions) of nurses? If so, what are these types?
13. How many different types of qualification are relevant for your scheduling task?
14. Do you take the working experiences of the nurse into account while arranging a nursing schedule?
15. Which percentages of full-time equivalent are present in your nursing unit?
16. How many different types of working days are relevant for your scheduling task?
17. Is your nursing unit devided into different locations? If so, how many? If not, go to question 9.
18. Do these locations differ according to work load?
19. Does the work load per location change in time?
20. Does your nursing unit use so-called call-up shifts?
21. What types of shifts are used in your nursing unit? At what time do these shifts start and end?
22. What are the quantitative staffing demands per type of shift and type of working day?

A.4 Policy and planning

23. Does your health care organization have a (written) staffing policy?
24. Does your ward have a (written) staffing policy?
25. Does your nursing unit have a (written) staffing policy?
26. Is there nursing staff planning at the level of the whole organization? If so, what is the length of the planning period?
27. Is there nursing staff planning at ward level? If so, what is the length of the planning period?
28. Is there nursing staff planning at nursing unit level? If so, what is the length of the planning period?
29. Does your health care organization have a (written) admission policy?
30. Does your ward have a (written) admission policy?
31. Does your nursing unit have a (written) admission policy?
32. Is there admission planning at the level of the whole organization? If so, what

is the length of the planning period?

33. Is there admission planning at ward level? If so, what is the length of the planning period?
34. Is there admission planning at nursing unit level? If so, what is the length of the planning period?
35. Does your health care organization have a (written) nurse scheduling policy?
36. Does your ward have a (written) nurse scheduling policy?
37. Does your nursing unit have a (written) nurse scheduling policy?

A.5 Nursing schedules

38. How would you define nursing schedule quality?
39. To what extent can nursing schedules differ in total nursing salary?
40. What is the average percentage of illness at your nursing unit?
41. To what extent do these illness percentages fluctuate?
42. How would you define continuity in nursing care?
43. How do you maintain this continuity?
44. To what extent do the number of available nurses differ per schedule period?
45. To what extent do the types and numbers of admitted patients differ per schedule period?
46. To what extent do you take the distribution of the types of shifts per nurse into account when arranging a nursing schedule?
47. To what extent do you take the length of consecutive shifts into account when arranging a nursing schedule?
48. To what extent do you take the amount of rest between shifts into account when arranging a nursing schedule?
49. What is the average length of the period between the time a nursing schedule is given to the nurse and the starting date of this schedule?
50. Are the nurses of your nursing unit allowed to specify preferences and special requests?
51. Are the nurses of your nursing unit allowed to exchange shifts?
52. Can the nurses of your nursing unit negotiate about changes in the scheduled working hours?

A.6 Method of scheduling

53. How many months of scheduling experience do you have?
54. How did you learn to arrange nursing schedules?
55. To what extent do you keep up with the latest developments in the domain of nurse scheduling?
56. Do you know the latest scheduling regulations by heart? Or do you have to look them up?
57. What is the average total amount of time that you spend on arranging a new nursing schedule?
58. Do you find nurse scheduling difficult? Or easy? To what extent?
59. Do you follow a (written) method of scheduling to arrange a nursing schedule?
60. Do you use special techniques to arrange (parts of) the nursing schedule? If so, what are they?
61. Do you make calculations of available and required nursing time before you start to arrange the schedule?
62. How do you cope with ‘extra’ nursing time?
63. Do you sometimes have to reschedule parts of the nursing schedule? How often can this occur?
64. Do you use certain tools to arrange nursing schedules? If so, what are they? If not, then this questionnaire ends here. If these tools do not include a computer program, then the next question is your last question.
65. What are the benefits of these tools?
66. What is the name of the computer program you use to arrange nursing schedules?
67. Who developed this program?
68. Would you please list the main functions of this program?
69. What is your opinion of this program?

APPENDIX B

RANKINGS OF THE SHIFT PATTERNS

This appendix shows the results of the ranking experiment per decision aspect. In total, this experiment used thirty decision aspects. Below, each of these thirty decision aspects will be discussed by describing the alternative shift patterns and each pattern's position in the rankings given by the nurse schedulers. Both the shift patterns and the rankings will be shown in one table. In these rankings (*i.e.* the lower part of each table), the letters (*i.e.* a, b, c *etc.*) represent the corresponding shift pattern described in the upper part of each table. The numbers 1 to 10 represent the nurse schedulers who participated in this experiment. Furthermore, the capitals refer to the codes of the shifts (see table 5.10).

The numbers within the ranking part of each table represent the position of the corresponding shift pattern in the ranking given by the corresponding nurse scheduler. In the case of tied ranks, the average of the positions these shift patterns would have had if they had been distinguishable is given to each of these 'tied' shift patterns. Furthermore, the ranking part of each table also shows the mean position of each shift pattern over all the given rankings ($?_i$).

Each of the following tables represents the corresponding coefficient of concordance (W). Whenever these coefficients of concordance are marked with an asterisk (*), this means that the given rankings are significantly similar using an error tolerance of one percent.

B.1 Decision aspect of completeness on normal working days (C-1)

The upper part of table B.1 shows three shift patterns. Shift pattern C-1a represents a shortage of one day shift on a normal working day (*i.e.* 4 scheduled day shifts instead of the required 5 day shifts). Shift pattern C-1b represents a shortage of one evening shift (*i.e.* 2 scheduled evening shifts instead of the required 3 evening shifts). The third alternative shift pattern (C-1c) represents a shortage of one night shift (*i.e.* 1 scheduled night shift instead of the required 2 night shifts).

The lower part of table B.1 shows the rankings of these three alternative shift patterns given by the ten nurse schedulers. Apart from nurse scheduler number one, most nurse schedulers (*i.e.* 9 out of 10) ranked a ‘night shortage’ as the most important to avoid.

B.2 Decision aspect of completeness on special working days (C-2)

The upper part of table B.2 shows three shift patterns. Shift pattern C-2a represents a shortage of one day shift on a special working day (*i.e.* 3 scheduled day shifts instead of the required 4 day shifts). Shift pattern C-2b represents a shortage of one evening shift (*i.e.* 2 scheduled evening shifts instead of the required 3 evening shifts). The third alternative shift pattern (C-1c) represents a shortage of one night shift (*i.e.* 1 scheduled night shift instead of the required 2 night shifts).

The lower part of table B.2 shows the rankings of these three alternative shift patterns given by the ten nurse schedulers. Apart from nurse scheduler number one, most nurse schedulers (*i.e.* 9 out of 10) ranked a ‘night shortage’ as the most important to avoid.

B.3 Combination decision about completeness per type of working days (C-3)

The upper part of table B.3 shows both ranking objects of the combination decision about completeness per type of working day (*i.e.* normal versus special working days).

The lower part of table B.3 shows the rankings of these two alternative ranking object given by the ten nurse schedulers. These rankings do not show a significant coefficient of concordance. About half of the nurse schedulers ranked incompleteness on special days as being more important to avoid, while the other half ranked incompleteness on normal days as being more important to avoid.

B.4 Decision aspect of day shift optimality on normal working days (O-1)

Optimality has to do with the distribution of nursing expertise over the different shifts. This distribution concerns the proportion of registered nurses in relation to the nursing assistants. Table B.4 shows three shift patterns with different proportions, all concerning the day shifts on normal working days.

Six nurse schedulers ranked shift pattern O-1b as the best; three chose O-1a; and nurse scheduler number 10 ranked O-1c as the best. The corresponding coefficient of concordance was not significant when using an error tolerance of one percent.

B.5 Decision aspect of evening shift optimality on normal working days (O-2)

Table B.5 shows three shift patterns with different proportions, all concerning the evening shifts on normal working days.

The rankings of these three shift patterns given by the ten nurse schedulers show a significant coefficient of concordance when using an error tolerance of one percent.

B.6 Decision aspect of night shift optimality on normal working days (O-2)

Table B.6 shows three shift patterns with different proportions, concerning the night shifts on normal working days.

The rankings shown in the lower part of table B.6 show a significant coefficient of concordance when using an error tolerance of one percent. Apart from one nurse scheduler, all nurse schedulers ranked shift pattern O-3b as the best.

B.7 Combination decision about optimality on normal working days per type of shift (O-4)

The upper part of table B.7 shows three ranking objects, each representing one of the three previously-discussed decision aspects related to optimality.

The lower part of table B.7 shows a wide variation in the rankings, which resulted in an insignificant coefficient of concordance when using an error tolerance of one percent.

B.8 Decision aspect of day shift optimality on special working days (O-5)

Table B.8 is almost similar to table B.4. The difference between both tables is that B.8 concerns special working days instead of normal working days.

The rankings shown in the lower part of table B.8 show a significant coefficient of concordance when using an error tolerance of one percent. The average ranking has O-5b as the best, then O-5a, and finally O-5c.

B.9 Decision aspect of evening shift optimality on special working days (O-6)

Table B.9 concerns the evening shifts on the special working days. The upper part of this table shows three shift patterns.

The lower part of this table shows the given rankings of these shift patterns. These rankings show a significant coefficient of concordance when using an error tolerance of one percent.

B.10 Decision aspect of night shift optimality on special working days (O-7)

Table B.10 concerns the night shifts on the special working days. The upper part of this table shows three shift patterns.

The lower part of this table shows the given rankings of these shift patterns. These rankings show a significant coefficient of concordance when using an error tolerance of one percent.

B.11 Combination decision about optimality on special working days per type of shift (O-8)

Table B.11 is almost similar to table B.7. The difference between both tables is that B.11 concerns optimality on special working days instead of normal working days.

The lower part of table B.11 shows a wide variation in the rankings, which resulted in an insignificant coefficient of concordance when using an error tolerance of one percent.

B.12 Combination decision about optimality per type of working day (O-9)

Combination decision O-9 combines combination decisions B.7 and B.11. This decision forces nurse schedulers to decide whether optimality on normal working days is more important than optimality on special working days.

The given rankings of both ranking objects show a light preference for optimality on normal working days. However, when the given rankings are re-interpreted by introducing a third virtual ranking object (*i.e.* ranking object O-9b is copied to O-9c), the insignificant coefficient of concordance when using an error tolerance of one percent becomes clear.

B.13 Decision aspect of proportionality concerning the numbers per type of shift (P-1)

The upper part of table B.13 shows seven distinct shift patterns, all related to proportionality concerning the numbers per type of shift. For instance, shift pattern P-1b consists of 13 day shifts, 7 evening shifts and 4 night shifts.

The lower part of table B.13 shows that the ten nurse schedulers differed strongly in the rankings of these seven shift patterns. As a result, the coefficient of concordance when using an error tolerance of one percent was not significant.

B.14 Decision aspect of proportionality concerning the distribution of days off (P-2)

The upper part of table B.14 shows seven distinct shift patterns, all related to proportionality concerning the distribution of days off. For instance, shift pattern P-2a consists of a pattern of several days on, followed by 2 days off, followed by several days on, followed by 3 days off, followed by several days on, followed by 2 days off, followed by several days on, followed by 3 days off, followed by several days on, followed by 1 day off, and ends with several days on.

The lower part of this table shows the given rankings of these seven shift patterns. These rankings show a significant coefficient of concordance when using an error tolerance of one percent. In the average ranking, shift pattern P-2c is the best, followed by P-2d, while P-2e is the worst.

B.15 Decision aspect of proportionality concerning the distribution of week-ends off (P-3)

The upper part of table B.15 shows four distinct shift patterns, all related to proportionality concerning the distribution of weekends off. For instance, shift pattern P-3a represents an alternating pattern of a weekend on always followed by weekend off.

The lower part of table B.15 shows that all ten nurse schedulers ranked these four shift patterns in the same way, which resulted in a coefficient of concordance with the maximum value.

B.16 Combination decision about the importance per decision aspect concerning proportionality (P-4)

The upper part of table B.16 shows three ranking objects, each representing one of the three previously-discussed decision aspects related to proportionality.

As the lower part of table B.16 shows, the ten nurse schedulers differed strongly in the ranking of these three ranking objects. As a result, the coefficient of concordance when using an error tolerance of one percent was not significant.

B.17 Decision aspect of healthiness concerning the number of consecutive night shifts (H-1)

The upper part of table B.17 shows seven distinct shift patterns, all related to healthiness concerning the number of consecutive night shifts. For instance, the nurse schedulers had to decide whether they believe that four night shifts in a row (*i.e.* shift pattern H-1d) is healthier or unhealthier than five night shifts in a row (*i.e.* shift pattern H-1e). There were no shift patterns of eight or more consecutive night shifts, because these shift patterns are not allowed by Dutch law.

Most nurse schedulers did, in fact, believe that four night shifts in a row is healthier then five night shifts in a row. In the average ranking, four and three nights in the row are the healthiest shift patterns of consecutive night shifts. The corresponding coefficient of concordance when using an error tolerance of one percent is significant.

B.18 Decision aspect of healthiness concerning the number of consecutive evening shifts (H-2)

Table B.18a is almost similar to table B.17. The difference between both tables is that B.18a concerns evening shifts in a row, instead of night shifts. There were no shift patterns of eleven or more consecutive evening shifts, because these shift patterns are not allowed by Dutch law.

In the resulting average ranking, three, four and two evening shifts in a row are the three most healthiest shift patterns of consecutive evening shifts, respectively. Furthermore, the lower part of table B.18a also shows that six or more evening shifts in a row are the least healthy shift patterns of consecutive evening shifts. The corresponding coefficient of concordance when using an error tolerance of one percent is significant. As shown in table B.18b, this significance is still present when the shift patterns representing seven evening shifts or more (*i.e.* shift patterns H-2g, H-2h, H-2i and H-2j) are clustered into a single ranking object *(i.e.* shift pattern H-2g).

B.19 Decision aspect of healthiness concerning the number of consecutive day shifts (H-3)

Table B.19a is almost identical to table B.18a. The difference between both tables is that B.19a concerns days shifts in a row, instead of evening shifts. There were no shift patterns of eleven or more consecutive day shifts, because these shift patterns are not allowed by Dutch law.

In the resulting average ranking, four, three and five day shifts in a row are the three healthiest shift patterns of consecutive day shifts, respectively. Furthermore, the lower part of table B.19a also shows that six or more day shifts in a row are the least healthy shift patterns of consecutive day shifts. The corresponding coefficient of concordance when using an error tolerance of one percent is significant. As shown in table B.19b, this significance is still present when the shift patterns representing seven day shifts or more (*i.e.* shift patterns H-3g, H-3h, H-3i and H-3j) are clustered into a single ranking object *(i.e.* shift pattern H-3g).

B.20 Decision aspect of healthiness concerning the number of consecutive working days (H-4)

Just like the three previously-discussed decision aspects, the upper part of table B.20 shows shift patterns that represent shifts in a row. These seven shift patterns show different numbers of consecutive days on. There were no shift patterns of eleven or more consecutive days on, because these shift patterns are not allowed by Dutch law.

As shown in the lower part of table B.20, the resulting rankings show a significant coefficient of concordance when using an error tolerance of one percent. In the resulting average ranking, seven, six, and five consecutive days on are the three healthiest shift patterns of consecutive days on.

B.21 Combination decision about the importance per decision aspect concerning healthiness of consecutive shifts (H-5)

The upper part of table B.21 represents four ranking objects related to a combination decision. This combination decision concerns the importance per decision aspect concerning healthiness of consecutive shifts. It combines the four previously discussed decision aspects of healthiness. These decision aspects H-1, H-2, H-3 and H-4 are represented as the ranking objects H-5a, H-5b, H-5c and H-5d, respectively.

The lower part of table B.21 shows that eight of the ten nurse schedulers ranked ‘not too many consecutive days on’ as the most important. The corresponding coefficient of concordance when using an error tolerance of one percent is significant.

B.22 Decision aspect of healthiness concerning the amount of rest after a period of night shifts (H-6)

The six shift patterns shown in the upper part of table B.22 represent different amounts of rest after a night shift period. These patterns differ from 47.5 hours of

rest after a night shift period for the ‘shortest’ pattern (H-6a) to 103.5 hours of night shift recovery time for the ‘longest’ shift pattern (H-6f).

As shown in the lower part of table B.22, the resulting rankings show a significant coefficient of concordance when using an error tolerance of one percent. The average ranking shows that healthy working schedules involve at least about eighty hours of night shift recovery time.

B.23 Decision aspect of healthiness concerning the amount of rest between a change of shift without days off (H-7)

The four shift patterns shown in the upper part of table B.23 represent different amounts of rest between a shift change without days off. These patterns differ from eight hours of rest for the ‘shortest’ pattern (H-7c) to thirty-two hours for the ‘longest’ shift pattern (H-7b).

The lower part of table B.23 shows that all but one nurse scheduler rank shift pattern H-7a is the healthiest of these four. The corresponding coefficient of concordance when using an error tolerance of one percent is significant.

B.24 Decision aspect of healthiness concerning the amount of rest between a change of shift with days off (H-8)

The six shift patterns shown in the upper part of table B.24 represent different amounts of rest between a shift change with days off. These patterns differ from thirty-two hours of rest for the ‘shortest’ pattern (H-8d) to fifty-six hours for the ‘longest’ shift pattern (H-8c).

Although the given rankings shown in the lower part of table B.24 seem to differ strongly, the corresponding coefficient of concordance when using an error tolerance of one percent is significant.

B.25 Combination decision about the importance per decision aspect concerning healthiness of scheduled rest (H-9)

The upper part of table B.25 represents four ranking objects related to a combination decision. This combination decision concerns the importance per decision aspect concerning healthiness of scheduled rest. It combines the three decision aspects H-6, H-7 and H-8. These decision aspects are represented as H-9a, H-9b and H-9c, respectively.

In the resulting average ranking, 'the amount of rest after a period of night work' is ranked as the most important. The corresponding coefficient of concordance when using an error tolerance of one percent is significant.

B.26 Combination decision about the importance of healthiness of consecutive shifts versus healthiness of scheduled rest (H-10)

Both ranking objects represented in the upper part of table B.26 represent the importance of decision aspects H-5 and the importance of decision aspects H-9, respectively. This combination decision concerns the importance of healthiness of consecutive shifts (H-10a) versus healthiness scheduled rest (H-10b).

As the lower part of table B.26 shows, the ten nurse schedulers differed strongly in the rankings of these three ranking object. As a result, the coefficient of concordance when using an error tolerance of one percent was not significant.

B.27 Decision aspect of continuity during night shifts (T-1)

The upper part of table B.27 shows five distinct shift patterns, all related to continuity during night shifts. Shift pattern T-1a represents two blocks of four night shifts in a row assigned to two nurses, followed by three night shifts in a row assigned to two other nurses (*i.e.* twice '(4,3)'). Shift pattern T-1b represents two blocks of five night shifts in a row assigned to two nurses, followed by two night shifts in a row assigned to two other nurses (*i.e.* twice '(5,2)'). Shift pattern T-1c represents a repetition of two blocks of three night shifts in a row assigned to two

(other) nurses (*i.e.* twice '(3,3)'). Shift pattern T-1d represents a repetition of two blocks of seven night shifts in a row assigned to two (other) nurses (*i.e.* twice '(7)'). Finally, shift pattern T-1e represents a mixture of the shift patterns T-1a and T-1b (*i.e.* '(4,3)' and '(5,2)').

The lower part of table B.27 shows that all but one nurse scheduler rank shift pattern T-1a as the one with the highest continuity of these five. The corresponding coefficient of concordance when using an error tolerance of one percent is significant.

B.28 Decision aspect of continuity during evening shifts (T-2)

The upper part of table B.28 shows five distinct shift patterns, all related to continuity during evening shifts. All five shift patterns contain blocks of two, three or four consecutive evening shifts. However, these patterns differ in the numbers per type of length, and also in the order in which these different blocks are scheduled. As a consequence of this distribution, the pattern with the highest continuity (T-2d) involves the scheduling of seven nurses a week, while the pattern with the lowest continuity (T-2e) involves the scheduling of nine nurses a week.

The given rankings shown in the lower part of table B.24 differ strongly. The corresponding coefficient of concordance when using an error tolerance of one percent is not significant.

B.29 Decision aspect of continuity during day shifts (T-3)

The upper part of table B.29 shows five distinct shift patterns, all related to continuity during day shifts. All five shift patterns contain blocks of two, three, four or five consecutive day shifts. However, these patterns differ in the numbers per type of length, and also in the order in which these different blocks are scheduled. As a consequence of this distribution, the pattern with the highest continuity (T-3a) involves the scheduling of ten nurses a week, while the pattern with the lowest continuity (T-3e) involves the scheduling of fourteen nurses a week.

The lower part of table B.29 shows that all but two nurse schedulers rank shift pattern T-3a as the one with the highest continuity of these five. The corresponding coefficient of concordance when using an error tolerance of one percent is significant.

B.30 Combination decision about the importance of continuity per type of shift (T-4)

The upper part of table B.16 shows three ranking objects, each representing one of the three previously-discussed decision aspects related to proportionality. These decision aspects T-1, T-2 and T-3 are represented as the ranking objects T-4a, T-4b and T-4c, respectively.

The lower part of table B.30 shows that all but two nurse schedulers rank ‘continuity during day shifts’ as the most important. The corresponding coefficient of concordance when using an error tolerance of one percent is significant.

Table B.1 DECISION ASPECT OF COMPLETENESS ON NORMAL WORKING DAYS (C-1)

C-1	D	E	N	
C-1a	4	3	2	(a shortage on a day shift)
C-1b	5	2	2	(a shortage on an evening shift)
C-1c	5	3	1	(a shortage on a night shift)

C-1	a	b	c
1	1	2	3
2	3	2	1
3	2	3	1
4	3	2	1
5	3	2	1
6	3	2	1
7	2	3	1
8	3	2	1
9	3	2	1
10	3	2	1
$\bar{S}_i$	2.6	2.2	1.2

W = 0.52*

Table B.2 DECISION ASPECT OF COMPLETENESS ON SPECIAL WORKING DAYS (C-2)

C-2	D	E	N	
C-2a	3	3	2	(a shortage on a day shift)
C-2b	4	2	2	(a shortage on an evening shift)
C-2c	4	3	1	(a shortage on a night shift)

C-2	a	b	c
1	2	1	3
2	3	2	1
3	2	3	1
4	3	2	1
5	3	2	1
6	3	2	1
7	2	3	1
8	3	2	1
9	3	2	1
10	3	2	1
$\bar{S}_i$	2.7	2.1	1.2

W = 0.57*

Table B.3 COMBINATION DECISION ABOUT COMPLETENESS PER TYPE OF WORKING DAY (C-3)

C-3a	incompleteness on normal working days
C-3b	incompleteness on special working days

C-3	a	b
1	1	2
2	2	1
3	1	2
4	1.5	1.5
5	2	1
6	2	1
7	1	2
8	2	1
9	1	2
10	1	2
$\bar{S}_i$	1.45	1.55

W = 0.11

Table B.4 DECISION ASPECT OF DAY SHIFT OPTIMALITY ON NORMAL WORKING DAYS (O-1)

O-1	registered nurses	nursing assistants
O-1a	3	2
O-1b	2	3
O-1c	1	4

O-1	a	b	c
1	2	1	3
2	1	2	3
3	2	1	3
4	3	1	2
5	2	1	3
6	2	1	3
7	2	1	3
8	1	2	3
9	1	2	3
10	3	2	1
$\bar{S}_i$	1.9	1.4	2.7

W = 0.23

Table B.5 DECISION ASPECT OF EVENING SHIFT OPTIMALITY ON NORMAL WORKING DAYS (O-2)

O-2	registered nurses	nursing assistants
O-2a	2	1
O-2b	1	2
O-2c	0	3

O-2	a	b	c
1	2	1	3
2	1	2	3
3	1	2	3
4	2	1	2
5	2	1	3
6	2	1	3
7	2	1	3
8	1	2	3
9	1.5	1.5	3
10	2	1	3
$\bar{S}_i$	1.65	1.35	3

W = 0.77*

Table B.6 DECISION ASPECT OF NIGHT SHIFT OPTIMALITY ON NORMAL WORKING DAYS (O-3)

O-3	registered nurses	nursing assistants
O-3a	2	0
O-3b	1	1
O-3c	0	2

O-3	a	b	c
1	2	1	3
2	1	2	3
3	2	1	3
4	2	1	2
5	2	1	3
6	2	1	3
7	2	1	3
8	2	1	3
9	2	1	3
10	3	1	2
$\bar{S}_i$	2.0	1.1	2.9

W = 0.86*

Table B.7 COMBINATION DECISION ABOUT OPTIMALITY ON NORMAL WORKING DAYS PER TYPE OF SHIFT (O-4)

O-4a	optimality during day shifts on normal working days
O-4b	optimality during evening shifts on normal working days
O-4c	optimality during night shifts on normal working days

O-4	a	b	c
1	3	2	1
2	3	2	1
3	1	2	3
4	3	2	1
5	2	1	3
6	3	2	1
7	1	2	3
8	1	2	3
9	3	1.5	1.5
10	2	1	3
$\bar{S}_i$	2.2	1.75	2.05

W = 0.05

Table B.8 DECISION ASPECT OF DAY SHIFT OPTIMALITY ON SPECIAL WORKING DAYS (O-5)

O-5	registered nurses	nursing assistants
O-5a	3	1
O-5b	2	2
O-5c	1	3

O-5	a	b	c
1	3	1	2
2	1	2	3
3	2	1	3
4	3	1	2
5	2	1	3
6	1	2	3
7	2	1	3
8	1	2	3
9	2	1	3
10	3	2	1
$\bar{S}_i$	2.0	1.4	2.6

W = 0.48*

Table B.9 DECISION ASPECT OF EVENING SHIFT OPTIMALITY ON SPECIAL WORKING DAYS (O-6)

O-6	registered nurses	nursing assistants
O-6a	2	1
O-6b	1	2
O-6c	0	3

O-6	a	b	c
1	2	1	3
2	1	2	3
3	2	1	3
4	3	1	2
5	2	1	3
6	2	1	3
7	2	1	3
8	1	2	3
9	1.5	1.5	3
10	2	1	3
$\bar{S}_i$	1.85	1.25	2.9

W = 0.70*

Table B.10 DECISION ASPECT OF NIGHT SHIFT OPTIMALITY ON SPECIAL WORKING DAYS (O-7)

O-7	registered nurses	nursing assistants
O-7a	2	0
O-7b	1	1
O-7c	0	2

O-7	a	b	c
1	2	1	3
2	1	2	3
3	2	1	3
4	3	1	2
5	2	1	3
6	2	1	3
7	2	1	3
8	2	1	3
9	2	1	3
10	3	1	2
$\bar{S}_i$	2.1	1.1	2.8

W = 0.73*

Table B.11 COMBINATION DECISION ABOUT OPTIMALITY ON SPECIAL WORKING DAYS PER TYPE OF SHIFT (O-8)

O-8a	optimality during day shifts on special working days
O-8b	optimality during evening shifts on special working days
O-8c	optimality during night shifts on special working days

O-8	a	b	c
1	3	2	1
2	3	2	1
3	1	2	3
4	3	2	1
5	2	1	3
6	3	2	1
7	1	2	3
8	1	2	3
9	3	1.5	1.5
10	2	1	3
$\bar{S}_i$	2.2	1.75	2.05

W = 0.05

Table B.12 COMBINATION DECISION ABOUT OPTIMALITY PER TYPE OF WORKING DAY

(O-9)

O-9a = optimality on normal working days

O-9b = optimality on special working days

O-9	a	b
1	1	2
2	2	1
3	1	2
4	1.5	1.5
5	2	1
6	2	1
7	1	2
8	1	2
9	1	2
10	1	2
$\bar{S}_i$	1.35	1.65

W = 0.35

re-interpretation of given rankings by introducing a third virtual item (b ? b and c)

O-9	a	b	c
1	1	2.5	2.5
2	3	1.5	1.5
3	1	2.5	2.5
4	2	2	2
5	3	1.5	1.5
6	3	1.5	1.5
7	1	2.5	2.5
8	1	2.5	2.5
9	1	2.5	2.5
10	1	2.5	2.5
$\bar{S}_i$	1.7	2.15	2.15

W = 0.07

Table B.13 DECISION ASPECT OF PROPORTIONALITY CONCERNING

THE NUMBERS PER TYPE OF SHIFT (P-1)

P-1	D	E	N
P-1a	14	6	4
P-1b	13	7	4
P-1c	13	6	5
P-1d	12	7	5
P-1e	11	8	5
P-1f	11	7	6
P-1g	10	8	6

P-1	a	b	c	d	e	f	g
1	1	2	3	4	5	6	7
2	3	1	2	6	5	4	7
3	5	4	7	2	1	6	3
4	4	4	4	4	4	4	4
5	2	1	5	6	7	3	4
6	6	3	2	1	4	5	7
7	1	2	3.5	3.5	6	7	5
8	7	5	6	3	4	2	1
9	4	5	2	1	3	6	7
10	1	2	3	4	5	6	7
$\bar{S}_i$	3.4	2.9	3.75	3.45	4.4	4.9	5.2

W = 0.16

Table B.14 DECISION ASPECT OF PROPORTIONALITY CONCERNING THE DISTRIBUTION OF DAYS OFF (P-2)

P-2	1	2	3	4	5	6
P-2a	2	3	2	3	1	-
P-2b	4	1	2	1	3	-
P-2c	2	2	3	2	2	-
P-2d	4	2	2	3	-	-
P-2e	2	1	4	2	2	-
P-2f	1	2	2	2	2	2
P-2g	4	2	2	2	1	-

P-2	a	b	c	d	e	f	g
1	4	6	3	7	5	1	2
2	5	6.5	1	2	6.5	3	4
3	6	3	5	1	4	7	2
4	4	4	4	4	4	4	4
5	5	7	1	2	5	3	4
6	4	7	3	1	3	6	5
7	4	7	1	2	5	6	3
8	5	7	2	1	4	6	3
9	4	7	1	2	6	3	5
10	3	7	1	6	4	2	5
$\bar{S}_i$	4.4	6.15	2.2	2.8	4.65	4.1	3.7

W = 0.36*

Table B.15 DECISION ASPECT OF PROPORTIONALITY CONCERNING

THE DISTRIBUTION OF WEEKENDS OFF (P-3)

P-3	1	2	3	4	5
P-3a	1	0	1	0	1
P-3b	1	1	0	0	1
P-3c	1	1	1	0	0
P-3d	1	1	1	1	0

P-3	a	b	c	d
1	1	2	3	4
2	1	2	3	4
3	1	2	3	4
4	1	2	3	4
5	1	2	3	4
6	1	2	3	4
7	1	2	3	4
8	1	2	3	4
9	1	2	3	4
10	1	2	3	4
$\bar{S}_i$	1	2	3	4

W = 1.00*

Table B.16 **COMBINATION DECISION ABOUT THE IMPORTANCE PER DECISION ASPECT CONCERNING PROPORTIONALITY (P-4)**

P-4a	proportionality concerning the numbers per type of shift
P-4b	proportionality concerning the distribution of days off
P-4c	proportionality concerning the distrubution of weekend off

P-4	a	b	c
1	2	1	3
2	1	2	3
3	1	3	2
4	2.5	2.5	1
5	3	2	1
6	2	1	3
7	2	1	3
8	2	1	3
9	3	2	1
10	1	2	3
$\bar{S}_i$	1.95	1.75	2.3

W = 0.08

Table B.17 on p. 186

table B.18a

table B.18b

table B.19a

table B.19b

Table B.17 DECISION ASPECT OF HEALTHINESS CONCERNING THE NUMBER OF CONSECUTIVE NIGHT SHIFTS (H-1)

H-1	shift pattern
H-1a	1
H-1b	2
H-1c	3
H-1d	4
H-1e	5
H-1f	6
H-1g	7

H-1	a	b	c	d	e	f	g
1	7	6	2	1	4	5	3
2	6.5	4.5	1.5	1.5	4.5	6.5	3
3	7	4	2	1	3	6	5
4	7	3.5	3.5	3.5	3.5	3.5	3.5
5	6	3	1	2	4	5	7
6	7	4	1	2	3	5	6
7	7	6	4	2	1	3	5
8	4	3	2	1	5	6	7
9	7	6	2	1	4	5	3
10	7	6	2	1	3	4	5
$\bar{S}_i$	6.55	4.6	2.1	1.6	3.5	4.9	4.75

W = 0.64*

Table B.20 DECISION ASPECT OF HEALTHINESS CONCERNING THE NUMBER OF CONSECUTIVE WORKING DAYS (H-4)

H-4	S
H-4a	? 4
H-4b	? 5
H-4c	? 6
H-4d	? 7
H-4e	? 8
H-4f	? 9
H-4g	? 10

S = number of consecutive days on

H-4	a	b	c	d	e	f	g
1	7	6	5	4	2	3	1
2	6	4	3	1	2	5	7
3	5	4	2	1	3	6	7
4	3.5	3.5	3.5	3.5	3.5	3.5	7
5	4	3	2	1	5	6	7
6	4	1	2	3	5	6	7
7	4	1	2	3	5	6	7
8	2	1	3	4	5	6	7
9	2	1	3	4	5	6	7
10	4	3	2	1	5	6	7
$\bar{S}_i$	4.15	2.75	2.75	2.55	4.05	5.35	6.4

W = 0.46*

Table B.21 COMBINATION DECISION ABOUT THE IMPORTANCE PER DECISION ASPECT CONCERNING HEALTHINESS OF CONSECUTIVE SHIFTS (H-5)

P-3a	not too many consecutive night shifts
P-3b	not too many consecutive evening shifts
P-3c	not too many consecutive day shifts
P-3d	not too many consecutive days on

H-5	a	b	c	d
1	2	3	4	1
2	1	4	3	2
3	4	3	2	1
4	3	3	3	1
5	2	4	3	1
6	4	3	2	1
7	4	2	3	1
8	2	3	4	1
9	1	3	4	2
10	3	2	4	1
$\bar{S}_i$	2.6	3.0	3.2	1.2

W = 0.49*

Table B.22 DECISION ASPECT OF HEALTHINESS CONCERNING THE AMOUNT OF REST AFTER A PERIOD OF NIGHT SHIFTS (H-6)

H-6	shift patterns	hours of rest
H-6a	NNNOOD	47.5
H-6b	NNNOOE	55.5
H-6c	NNNOOOD	71.5
H-6d	NNNOOOE	79.5
H-6e	NNNOOOOD	95.5
H-6f	NNNOOOOE	103.5

H-6	a	b	c	d	e	f
1	6	1	5	2	4	3
2	2	1	5	3	6	4
3	6	5	3	2	4	1
4	5.5	5.5	1.5	1.5	3.5	3.5
5	6	5	2	3	1	4
6	6	5	2	4	1	3
7	6	5	4	3	2	1
8	3	6	2	5	1	4
9	6	2	5	1	4	3
10	6	5	4	1	2	3
$\bar{S}_i$	5.25	4.05	3.35	2.55	2.85	2.95

W = 0.29*

Table B.23 DECISION ASPECT OF HEALTHINESS CONCERNING THE AMOUNT OF REST BETWEEN A CHANGE OF SHIFT WITHOUT DAYS OFF (H-7)

H-7	shift patterns	hours of rest
H-7a	DE	24
H-7b	DN	32
H-7c	ED	8
H-7d	EN	24

H-7	a	b	c	d
1	1	3	4	2
2	1	4	2	3
3	1	2	3	4
4	1	2	4	3
5	2	3	4	1
6	1	3	4	2
7	1	3	2	4
8	1	3	4	2
9	1	3	2	4
10	1	3	3	4
$\bar{S}_i$	1.1	2.8	3.2	2.9

W = 0.54*

Table B.24 DECISION ASPECT OF HEALTHINESS CONCERNING THE AMOUNT OF REST BETWEEN A CHANGE OF SHIFT WITH DAYS OFF (H-8)

H-8	shift patterns	hours of rest
H-8a	DOD	40
H-8b	DOE	48
H-8c	DON	56
H-8d	EOD	32
H-8e	EOE	40
H-8f	EON	48

H-8	a	b	c	d	e	f
1	1	5	6	4	3	2
2	3	1	2	6	4	5
3	3	1	2	5	4	6
4	3.5	3.5	3.5	3.5	3.5	3.5
5	4	3	2	1	6	5
6	3	4	5	1	6	2
7	2	1	4	5	3	6
8	1	2	6	4	5	3
9	2	2	2	5	5	5
10	1	2	3	5	4	6
$\bar{S}_i$	2.35	2.45	3.55	3.95	4.35	4.35

W = 0.23*

Table B.25 COMBINATION DECISION ABOUT THE IMPORTANCE PER DECISION ASPECT CONCERNING HEALTHINESS OF SCHEDULED REST (H-9)

H-9a	amount of rest after a period of night work
H-9b	amount of daily rest
H-9c	amount of weekly rest

H-9	a	b	c
1	1	2	3
2	2	1	3
3	2	1	3
4	1	2	3
5	1	2	3
6	1	2	3
7	1	3	2
8	2	3	1
9	1	3	2
10	2	1	3
$\bar{S}_i$	1.4	2.0	2.6

W = 0.36*

Table B.26 COMBINATION DECISION ABOUT THE IMPORTANCE OF HEALTHINESS OF CONSECUTIVE SHIFTS VERSUS HEALTHINESSS SCHEDULED REST (H-10)

H-10a	consecutive shifts
H-10b	rest

H-10	a	b
1	1	2
2	2	1
3	1	2
4	1	2
5	1	2
6	1	2
7	2	1
8	2	1
9	1	2
10	2	1
$\bar{S}_i$	1.4	1.6

W = 0.04

Table B.27 DECISION ASPECT OF CONTINUITY DURING NIGHT SHIFTS

(T-1)

T-1	(4,3)	(5,2)	(3,3)	(7)	continuity	
T-1a	2	0	0	0	2, 2, 2, 0, 2, 2, 0	(10 / 7)
T-1b	0	2	0	0	2, 2, 2, 2, 0, 2, 0	(10 / 7)
T-1c	0	0	2	0	2, 2, 0, 2, 2, 0	(8 / 6)
T-1d	0	0	0	2	2, 2, 2, 2, 2, 2, 0	(12 / 7)
T-1e	1	1	0	0	2, 2, 2, 1, 1, 2, 0	(10 / 7)

T-1	a	b	c	d	e
1	1	4	2	5	3
2	1	5	3	2	4
3	1	4	5	2	3
4	3	5	4	1	2
5	1	5	3	4	2
6	1	4	5	2	3
7	1	5	3	4	2
8	1	3	2	5	4
9	1	5	3	2	4
10	1	5	4	2	3
$\bar{S}_i$	1.2	4.5	3.4	2.9	3.0

W = 0.57*

Table B.28 DECISION ASPECT OF CONTINUITY DURING EVENING SHIFTS

(T-2)

T-2	(4,3)	(3,4)	(3,2,2)	(2,3,2)	(2,2,3)	continuity	
T-2a	0	0	2	0	1	2, 1, 2, 1	(6 / 4)
T-2b	0	0	1	0	2	1, 2, 1, 2	(6 / 4)
T-2c	0	1	1	0	1	2, 1, 2, 2	(7 / 4)
T-2d	1	1	0	1	0	2, 2, 2, 2	(8 /4)
T-2e	1	0	1	1	1	1, 1, 1, 1	(4 / 4)

T-2	a	b	c	d	e
1	1	2	4	5	3
2	3	3	3	3	3
3	1	2	4	3	5
4	3	5	2	1	4
5	4.5	4.5	2	1	3
6	5	4	2	1	3
7	3.5	3.5	3.5	1	3.5
8	5	4	1	3	2
9	2.5	2.5	4	5	1
10	1	2	4	5	3
$\bar{S}_i$	2.95	3.25	2.95	2.8	3.05

W = 0.01

table B.29

Table B.30 COMBINATION DECISION ABOUT THE IMPORTANCE OF CONTINUITY PER TYPE OF SHIFT (T-4)

T-4a	continuity during night shifts
T-4b	continuity during evening shifts
T-4c	continuity during day shifts

T-4	a	b	c
1	2	3	1
2	1	3	2
3	3	2	1
4	2	2	2
5	2	3	1
6	3	2	1
7	3	2	1
8	3	2	1
9	3	2	1
10	3	2	1
$\bar{S}_i$	2.5	2.3	1.2

W = 0.49*

APPENDIX C

THE ZKR SCHEDULING SUPPORT SYSTEM

This appendix gives additional information about the ZKR scheduling support system (ZKR is an acronym of a description of the program in Dutch). Figure C.1 shows a representation of a nursing schedule in the this program.

The members of the nursing staff are represented vertically. The nurses with the codes ‘vk-01’ up to ‘vk-09’ are registered nurses, while the nurses with the codes ‘vm-10’ up to ‘vm-23’ are nursing assistants. From top to bottom, the shifts represented in this nursing schedule are night shift, evening shift, day shift (these three in the second week), holiday, day off and ‘not available’ (these three in the third week).

The current ZKR system (version 2.0) was developed by a Dutch firm called IKS-Produkten b.v. (IKS stands for Institute for Knowledge (-Based) Systems). This system supports all the administrative tasks involved in scheduling, and is also able implement to all sorts of computations. Furthermore, this system can generate alternative shift patterns. For more information about this system, contact:

IKS-Produkten b.v.
P.O. Box 253
9700 AG Groningen
The Netherlands
? +31 50 5270 929

APPENDIX D

REFERENCE CASE STUDY

On the basis of the results of the scheduling experiment, an additional case study was conducted. The objective of this case study was to determine if quality indication scheduling also improves nursing schedule quality when the initial schedule is less flexible. This case study used an initial schedule with twice as many fixed vacations as the one used in the scheduling experiment. Figure D.1 shows this initial schedule.

Table D.1 FACTOR VALUES OF THE ORIGINAL SCHEDULE

C	O	P	H	C	Q
1.00	0.48	0.62	1.00	0.59	7.4

In total, ten vacations, each consisting of five holidays, were already arranged in this initial schedule. Furthermore, on eight occasions, a nurse was not available for a day-, evening- or night shift.

One nurse scheduler was asked to arrange a final nursing schedule on the basis of this initial schedule. This nurse scheduler also participated in the scheduling experiment. Because this nurse scheduler was aware of all low-quality shift patterns penalized by the quality indicators, this nurse scheduler was able to arrange a high-quality nursing schedule. Table D.1 shows the resulting values of the quality factors.

Table D.2 shows the corresponding numbers of occurrences of low-quality patterns in this original final schedule.

It took this nurse scheduler 128 minutes to arrange this original final schedule. Figure D.2 shows this final schedule.

Subsequently, the information about the quality factors was presented to the nurse scheduler. On the basis of this information, the nurse scheduler rearranged

the original final schedule into a new final schedule. This rearranging took 18 minutes. In this rearranging, the nurse scheduler succeeded in eliminating all six occurrences of low-quality patterns in the original final schedule. Therefore, the values for all five quality factors for the rearranged new final schedule are 1.00, which results in an estimated total schedule quality of 10.0 (i.e. an improvement in total schedule quality of 35 percent). Figure D.3 shows this rearranged new final schedule.

Table D.2 NUMBERS OF OCCURRENCES OF LOW-QUALITY PATTERNS IN THE ORGINAL FINAL SCHEDULE

O1	O2	O5	P2	T1	total
1	1	1	1	2	6