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### Quality in fives

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## CHAPTER 8

### ANALYSIS, OPERATIONALIZATION, AND APPLICATION OF NURSING SCHEDULE QUALITY

The research objective of this study is to analyze, operationalize, and apply the concept of nursing schedule quality in order to support the task of nurse scheduling. The approach followed to attain this objective was based on the assumption that an understanding of the concept of nursing schedule quality is essential for an effective support of this task. As described in the first chapter, this study started by investigating three preliminary research questions: “How can one analyze the concept of nursing schedule quality?”, “How can one operationalize the conceptual model of nursing schedule quality?” and “How can one apply the operationalized concept of nursing schedule quality in order to effectively support the task of nurse scheduling?”.

A survey of literature on supporting nurse scheduling, as described in the second chapter, showed that none of the discussed approaches to supporting nurse scheduling scored positively on all theoretical quality aspects. Therefore, a new approach was suggested which was based on three assumptions: the assumption of formalization, the assumption of robustness and the assumption of effectiveness.

In the third chapter, which dealt with this study's methodological foundation, these assumptions were reformulated as testable hypotheses: the hypotheses of formalization, robustness and effectiveness. To test these three hypotheses, the preliminary research questions were refined into four final research questions. These four final research questions are “What are the independent factors of nursing schedule quality?”, “How can one operationalize each of these quality factors?”, “Can the total nursing schedule quality be explained on the basis of a weighted sum of factor values?” and “Does quality indication scheduling improve the quality of nursing schedules?”.

The first four sections of this chapter summarize the answers obtained by this study to the research questions asked in the third chapter. The fifth section generalizes these answers towards staff scheduling in general. The sixth and last section describes indications for future research.

## 8.1 ANALYSIS OF NURSING SCHEDULE QUALITY

The analysis of the concept of nursing schedule quality was guided by the first research question. This question asked about the independent factors of nursing schedule quality. Three steps were taken to answer this question.

Firstly, a survey of literature was conducted in order to acquire candidates for these quality factors. This resulted in eight candidates (i.e. possible quality factors).

Subsequently, these candidates were analyzed on independence and perceivability. Three candidates did not survive this analysis. Therefore, this step resulted in a working set of five independent and perceivable quality factors of nursing schedules.

The third step involved a questionnaire. The answers given by eighteen nurse schedulers to the question “How would you define nursing schedule quality?” were then qualitatively analyzed (by means of a so-called ‘qualitative factor analysis’) in order to validate the working set of five quality factors. The results of this analysis supported each of the five quality factors of this working set.

The results of the analysis of the concept of nursing schedule quality show that this concept consists of five independent quality factors (i.e. ‘Quality in Fives’). These factors were identified as completeness, optimality, proportionality, healthiness and continuity. The completeness factor represents the degree to which the quantitative demands for occupation per shift are met. The optimality factor represents the degree to which nursing expertise is distributed over the different shifts. The proportionality factor represents the degree to which each nurse has been given about the same number of night shifts, evening shifts and weekends off. The healthiness factor represents the degree to which care has been taken of the welfare and health of the nursing staff. And finally, the continuity factor represents the degree to which there is continuity in the nursing staff during the different shifts.

## 8.2 OPERATIONALIZATION OF NURSING SCHEDULE QUALITY

The operationalization of the concept of nursing schedule quality was guided by the second and third research question. The second research question asked how to operationalize each of the five quality factors, while the third research question asked if the total nursing schedule quality can be explained on the basis of a weighted sum of factor values. The ranking experiment and the auditing experiment

were designed to answer these two questions, respectively.

In the ranking experiment, ten nurse schedulers were asked to rank several alternative shift patterns according to the schedulers own view on nursing schedule quality. In total, each nurse scheduler was asked to make thirty rankings of a maximum of ten ranking objects (i.e. alternative shift patterns).

The results of the ranking experiments showed that nurse schedulers have the same notion about the values of (most) alternative shift patterns per corresponding quality factor. Those decision aspects, of which the rankings of alternative shift patterns showed a significant coefficient of concordance, were included in the specification of each of the five quality factors. On the basis of these specifications, each quality factor was operationalized into a so-called ‘quality indicator’. These quality indicators measure the value of the corresponding quality factor on a scale from zero to one. These quality indicators provide an answer to the second research question. Therefore, the results of the ranking experiment support the hypothesis of formalization.

In the auditing experiment, nurse schedulers were asked to audit several nursing schedules by giving each nursing schedule a quality mark on a scale from one to ten. The results of this auditing experiment showed that the total quality values of nursing schedules (i.e. the given quality marks) can be explained on the basis of a weighted sum of factor values. In this explanation, the factor values are generic (i.e. vary per nursing schedule), while the summation weights are specific (i.e. vary per nurse scheduler).

The results of the auditing experiment can be summarized by a formula:

$$Q_{s,i} = \omega_i^c \times C_s + \omega_i^o \times O_s + \omega_i^p \times P_s + \omega_i^h \times H_s + \omega_i^t \times T_s$$

Formula 8.1: The operationalization of nursing schedule quality

Formula 8.1 shows the total quality value ( $Q_{s,i}$ ) of a nursing schedule  $s$  according to nurse scheduler  $i$  as a weighted sum of the values of the quality factors. In this formula, the factors values are represented as  $C_s$ ,  $O_s$ ,  $P_s$ ,  $H_s$  and  $T_s$ , while the summation weights are represented as  $\omega_i^c$ ,  $\omega_i^o$ ,  $\omega_i^p$ ,  $\omega_i^h$  and  $\omega_i^t$ . The sixth chapter describes the formulas for the computation of the generic factor values, and also shows the determination of the individual summation weights.

The research results of the auditing experiment answer the third research question positively. Therefore, these results support the hypothesis of robustness.

### 8.3 APPLICATION OF NURSING SCHEDULE QUALITY

The application of the concept of nursing schedule quality in order to effectively support the task of nurse scheduling is guided by the fourth and last research question. This research question asked whether ‘quality indication scheduling’ improves the quality of nursing schedules. This quality indication scheduling informs nurse schedulers about the factor values of the arranged nursing schedule. This application of the operationalized concept of nursing schedule quality is based on the hypothesis that this information will enable the nurse scheduler to improve the nursing schedule's quality (i.e. the hypothesis of effectiveness). The scheduling experiment was designed to test this hypothesis and thus to answer the fourth and final research question.

The results of the scheduling experiment showed an improvement of thirty percent in nursing schedule quality caused by quality indication scheduling. This improvement consisted of a decrease in low-quality patterns by forty-five percent. This provides a positive answer to the fourth and final research question. Therefore, the results of the scheduling experiment support the hypothesis of effectiveness.

### 8.4 CONCLUSIONS

This study showed how to analyze, operationalize and apply of the concept of nursing schedule quality. The analysis was based on the search for independent factors. The operationalization used the communality among nurse schedulers about the interpretation of these factors. And finally, the application showed the effectiveness of informing nurse schedulers about the values of these factors. Therefore, this study showed that task of nurse scheduling can be effectively supported by means of quality indication scheduling. This approach supports the nurse scheduler by providing quality indicators that measure the schedule's value for each of the five quality factors.

The focus of this study was the nurse scheduling problem, which was defined as a tactical problem. However, the results of this study also have strategic and operational implications. For example, this study's research results give grounds for a conclusion about the healthiness of nursing schedules. The results of the scheduling experiment, as described in the seventh chapter, showed that all nurse schedulers arranged original final schedules that scored low on the healthiness

factor. This conclusion is consistent with the findings of other research on the healthiness of nursing schedules (see De Vries-Griever et al., 1994).

## 8.5 GENERALITY OF THE RESULTS

Our society is increasingly becoming a twenty-four-hour economy. Worldwide, the numbers of employees who have to work on special working days (i.e. weekends or holidays) or special working hours (i.e. in the evening or at night) increase annually. This study has focused on a small part within this group of employees, namely the nurses who work at continuously operational health care organizations.

The nurse scheduling problem is an instance of a more general type of problem, which can be identified as the 'general employee scheduling problem'. The generality of the five factors of schedule quality, found in the present study, can be hypothesized on the basis of a description of this general employee scheduling problem given by Glover and McMillan (1986). This generality is described below per quality factor.

The completeness factor is present in all cases of staff scheduling with minimum staffing requirements. This is the case in all staff scheduling problems. The optimality factor is present in all cases of staff scheduling with a non-homogeneous employee pool. This is true for most staff scheduling problems (Glover & McMillan, 1986, p. 565). The proportionality factor plays a role whenever the employees have to work during weekends. Most staff scheduling problems meet this requirement. The healthiness factor is an essential part of schedule quality whenever the employees have to work at both during the day and at night. Again, this is true for most organizations with staff schedules. Finally, the continuity factor is present whenever the employees provide services (i.e. work with clients). This is true for a large portion of organizations with staff schedules. Therefore, the five identified quality factors of nursing schedules are likely to be relevant to other types of staff schedules as well. This suggests the possibility of applying this study's research results to other staff scheduling domains.

Another way to hypothesize the generality of this study's research results involves the five conditions for effective control (De Leeuw, 1990, pp. 112-116). Effective control requires an objective, a model of the controlled system, information about the system's environment and state, a sufficient number of controlling measures and sufficient information-processing capacity. This study showed an increased effectiveness of nurse scheduling by choosing an operational approach

to modeling the controlled system. This not only resulted in more information about the system's state, it also increases the nurse scheduler's information-processing capacity. This type of operational approach therefore seems likely to be applicable to other (scheduling) situations as well.

## 8.6 FUTURE RESEARCH

This section describes several suggestions for further research. These suggestions concern the evaluation of nursing schedule in practice, run-time quality indication and flexible support of nurse scheduling. Each of these suggestions for further research is based on this study's operationalization of nursing schedule quality.

### 8.6.1 Nursing schedule quality in practice

The results of a follow-up research, which was based on the results of the ranking experiment, showed a low quality of nursing schedules in practice (Lettenga, 1995, p. 28; see also Oldenkamp, Lettenga & Simons, 1996). This follow-up research compared the theoretical rankings of shift patterns (i.e. the rankings given during the ranking experiment) with these rankings in practice (i.e. the rankings based on the number of occurrences per shift pattern in arranged nursing schedules). These comparisons were made per scheduler (Lettenga, 1995, pp. 9-14). In total, five schedulers participated in this follow-up research, called 'ranking evaluation'. As described in the fifth chapter, the ranking experiment showed the rankings of the shifts patterns in theory. In the ranking validation, twenty-three of these rankings were compared with rankings of the same shift patterns in practice. These rankings in practice are based on the occurrence of each shift pattern in a schedule arranged by one of five schedulers who also participated in the ranking experiment. Subsequently, both rankings were analyzed on similarity by computing the rank correlation of both rankings. In total, nine out of ninety-five rankings (i.e. nine percent) showed a significant rank correlation when an error tolerance of five percent is applied (Lettenga, 1995, pp. 15-20). This shows that the quality of the arranged nursing schedules in practice is not as high as it theoretically could have been. This finding also provides justification for this study's subject of research.

It would be interesting, in future research, to investigate to what extent the

quality of nursing schedules in practice can be improved by applying quality indication scheduling. This can be investigated by using the research design described in the seventh chapter. Furthermore, this type of study can also include measurements based on nursing schedules after the schedule period has been completed. These measurements could include variables such as illness rates and numbers of shifts changed after the final schedule was completed.

### 8.6.2 Run-time quality indication

It would also be interesting, in future research, to investigate the effectiveness of run-time information about the values of the quality indicators. This run-time quality indication scheduling can be compared with an instrument landing system (Kendal, 1993). These instrument landing systems highly improve the quality of aircraft landing under bad weather conditions. The basic principle is that the pilot sees the aircraft as a point in a two-dimensional coordination system. This is an enormous decrease in information, compared with conventional instruments. The pilot's job is to keep the point inside a safe box, indicating the area of quality (i.e. high safety).

The nurse scheduler arranging a nursing schedule can be compared with a pilot flying an airplane. By means of run-time quality indication scheduling, the nurse scheduler can monitor the quality indicator(s). This monitoring might enable the nurse scheduler to arrange nursing schedules with quality values that are even higher than the ones described in the seventh chapter. This expectation is supported by the findings described in the third appendix (C). These findings are based on an additional case study. The nurse scheduler who participated in this case study was constantly aware of the low-quality patterns that were measured by the quality indicators (i.e. this nurse scheduler received virtual run-time quality indication). This enabled this nurse scheduler to arrange an original final nursing schedule with just six low-quality patterns. And after receiving quality indication, the nurse scheduler was even able to rearrange this schedule in such a way that no low-quality shift pattern occurred in the new final schedule. The findings of this case study suggests that run-time quality indication will be very effective.



### 8.6.3 Flexible support of nurse scheduling

Many researchers stress the importance of flexibility in the case of nurse scheduling (see Rosenbloom & Goertzen, 1987, p. 23; Ozkarahan & Bailey, 1988, p. 315). It would be interesting to combine the approach of quality indication scheduling with flexible scheduling algorithms. Rosenbloom and Goertzen (1987) conclude that such flexible scheduling algorithms allow both the hospital administration and the nurses to consider the effect of various labor constraints on the quality of the schedules (p. 23). By means of quality indication scheduling, these effects of scheduling regulations can be measured quantitatively.

A combination of a flexible 'scheduling engine' and quality indicators also allows nurse schedulers to gain more insight into the nurse scheduling problem (i.e. increase scheduling skill). This provides nurse schedulers, and also the hospital administration, with a tool for knowledge management (see Simons & Spijkervet, 1994, p. 14).

Finally, a number of studies have argued that 'requests scheduling' (i.e. scheduling based on special requests) causes working schedules with low healthiness (see Bisseling, 1993; De Vries-Griever et al., 1994). Quality indication scheduling can also be used to demonstrate these disadvantages of requests scheduling.