Quality in fives

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CHAPTER 3

METHODOLOGICAL FOUNDATION OF THE RESEARCH APPROACH

The last chapter discussed a comparison of approaches to supporting nurse scheduling. This comparison revealed that none of the approaches discussed scores positively on all comparison criteria. Therefore, a new approach was suggested which would provide the required positive scores. This chapter discusses the methodological foundation of this approach.

The first section reformulates the assumptions on which this approach is based, as discussed in the previous chapter, into testable hypotheses. This section also describes the research questions that specify the testing of these hypotheses.

This chapter ends with discussing the research method designed to answer the research questions. This research method consists of five phases. In the second section, the methodological foundation of this research approach will be described for each research phase.

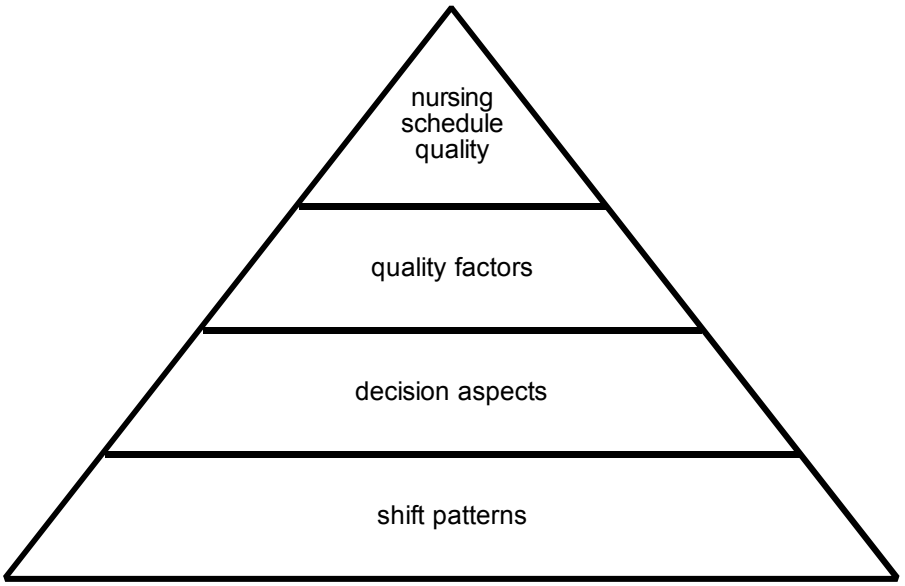
3.1 RESEARCH QUESTIONS AND HYPOTHESES

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 to attain this objective is based on the assumption that a formal representation of this concept of nursing schedule quality is essential for an effective support of this task. The nature of this approach is empirical; it rests on the belief that direct observation and experience provide the only firm basis for this understanding. Therefore, as the next section will describe, this study's research design is based on the empirical cycle of scientific research (De Groot, 1969). This empirical cycle consists of five phases: observation (i.e. collection of empirical data), induction (i.e. formulation of hypotheses), deduction (of testable predictions), testing (of the predictions on the basis of new empirical data) and

evaluation (of the results of the testing). This study, therefore, is affiliated to methodological pleas for a shift in research in the field of management and organization, including the domain of planning and scheduling, towards an empirical approach (see Jansen, 1994).

This study aims to represent nursing schedule quality as a model consisting of hierarchical layers. The top layer contains the concept of nurse schedule quality itself. The assumption of formalization, as described in the previous chapter, states that this concept of nursing schedule quality will consist of a number of independent quality factors. The second layer of the hierarchical model of nurse schedule quality contains these quality factors. The contents of the third and fourth layers stress the empirical nature of this study's research approach. This approach assumes that each quality factor can be divided into a number of decision aspects. The third layer contains these decision aspects. Finally, the fourth and 'bottom' layer of the hierarchical model of nurse schedule quality contains 'shift patterns' (i.e. a shift pattern is a specific pattern (horizontal, vertical or diagonal) of several shifts). This approach assumes that for each decision aspect the value for each specific pattern of shifts can be determined. Figure 3.1 shows these hierarchical layers of nursing schedule quality.

Figure 3.1 FOUR HIERARCHICAL LAYERS OF NURSING SCHEDULE QUALITY



As described below, three hypotheses can be formulated to specify the role of this

hierarchical model for the analysis, operationalization and application of nursing schedule quality. These hypotheses are testable reformulations of the assumptions described in the previous chapter. This testability refers to the analysis of empirical data. Below, the next subsections discuss these three hypotheses in more detail.

3.1.1 Hypothesis of formalization

The hypothesis of formalization states that the concept of nursing schedule quality can be modelled as a concept consisting of quality factors. To be more precise, this hypothesis states that the second layer of the hierarchical model shown above consists of a number of independent factors of nursing schedule quality. The hypothesis of formalization claims that nurse schedulers will have the same notion of each of these independent factors of nursing schedule quality. This notion concerns the values of specific shift patterns for each decision aspect per quality aspect (i.e. the corresponding contents of the third and fourth layer). This means that, for a nursing schedule, the value for each quality factor can be determined independently of nurse schedulers' views on nursing schedule quality.

Summarizing, the hypothesis of formalization states that all layers of the hierarchical model of nursing schedule quality can be fully specified. This means that the concept of nursing schedule quality can be unravelled as number of independent quality factors, that each quality factor consists of a number of decision aspects, and that for each decision aspect the value of each relevant shift pattern can be determined. This unravelling facilitates a measurement of nursing schedule quality, which is a prerequisite for effective quality management (Besterfield, 1990, p. 408).

3.1.2 Hypothesis of robustness

The hypothesis of robustness asserts that the quality of a particular nursing schedule will not be assessed in the same way by all nurse schedulers. To be more precise, this hypothesis states that the total quality value given to a nursing schedule by a nurse scheduler equals a weighted sum of the factor values. In other words, this hypothesis states that a nurse scheduler weighs each quality factor according to an individual summation weight in order to determine the total quality

value.

Formula 3.1 expresses the hypotheses of robustness. In words, this formula states that the total quality value ($Q_{s,i}$) of a particular nursing schedule s, according to the view of a nurse scheduler i, equals a weighted sum of several (the total number is expressed by N) independent quality factors ($F_{s,j}$). The summation weights ($\omega_{i,j}$) vary per quality factor j and nurse scheduler i.

$$Q_{s,i} = \sum_{j=1}^{N} \omega_{i,j} \times F_{s,j}$$

Formula 3.1: Specification of the hypothesis of robustness

In this formula, the factor values are generic (i.e. equal for all nurse schedulers), while the summation weights are specific.

3.1.3 Hypothesis of effectiveness

The hypothesis of effectiveness asserts that informing nurse schedulers on the values of the quality factors will improve the quality of nursing schedules. This scheduling using information about the quality factors will be called 'quality indication scheduling'. The hypothesis of effectiveness will be tested by comparing the mean total quality value in a new situation (Q^n), in which quality indication scheduling is applied, with the mean total quality value in an old situation (Q^o), in which quality indication scheduling is not applied. The null hypothesis states that this difference will be zero, while the alternative hypothesis states that this difference will be larger than zero:

$$H_0 : Q^n - Q^o = 0$$
$$H_1 : Q^n - Q^o > 0$$

In short, the hypothesis of effectiveness predicts that the null hypothesis will be rejected and that the alternative hypothesis will be accepted.

3.1.4 Research questions

In the first chapter, three preliminary research questions were formulated. On the basis of the three hypotheses discussed above, these preliminary questions can be refined into four final research questions:

1. What are the independent factors of nursing schedule quality?

2. How can one operationalize each of these quality factors?

3. Can the total nursing schedule quality be explained on the basis of a weighted sum of factor values?

4. Does quality indication scheduling improve the quality of nursing schedules?

The first two research question are related to the hypothesis of formalization. The last two questions concern the correctness of the hypothesis of robustness and the hypothesis of effectiveness, respectively.

3.2 RESEARCH DESIGN

This section describes the research method designed to answer the research questions discussed above. This research method can be identified as a mixture of techniques, originating from 'qualitative research[1]' (see Glaser & Strauss, 1967; Strauss & Corbin, 1990; Patton, 1990), 'quantitative analysis' (see Lawson & Hanson, 1974; Neale & Liebert, 1986), and 'knowledge engineering' (see Burton & Shadbolt, 1987; Boose & Gaines, 1988; Parsaye & Chignell, 1988). The designed research method consists of four phases: a questionnaire, a ranking experiment, an auditing experiment and a scheduling experiment. Each of these four research phases answers one of the final research questions stated above. The following four subsections discuss these research phases.

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[1] Qualitative research is defined as research that produces findings not arrived at by means of statistical procedures or other means of quantification (Strauss & Corbin, 1990, p. 17).

3.2.1 Questionnaire

The objective of the first research phase is to answer the first research question (i.e. "What are the independent factors of nursing schedule quality?"). This phase is called the questionnaire and it consists of four research steps. The first two steps are designed to find the independent factors of nursing schedule quality, while the last two research steps are designed to validate the factors found.

In the first research step of the questionnaire, all possible candidates for the required quality factors described in literature on nurse scheduling will be summarized. This results in a set of candidate quality factors.

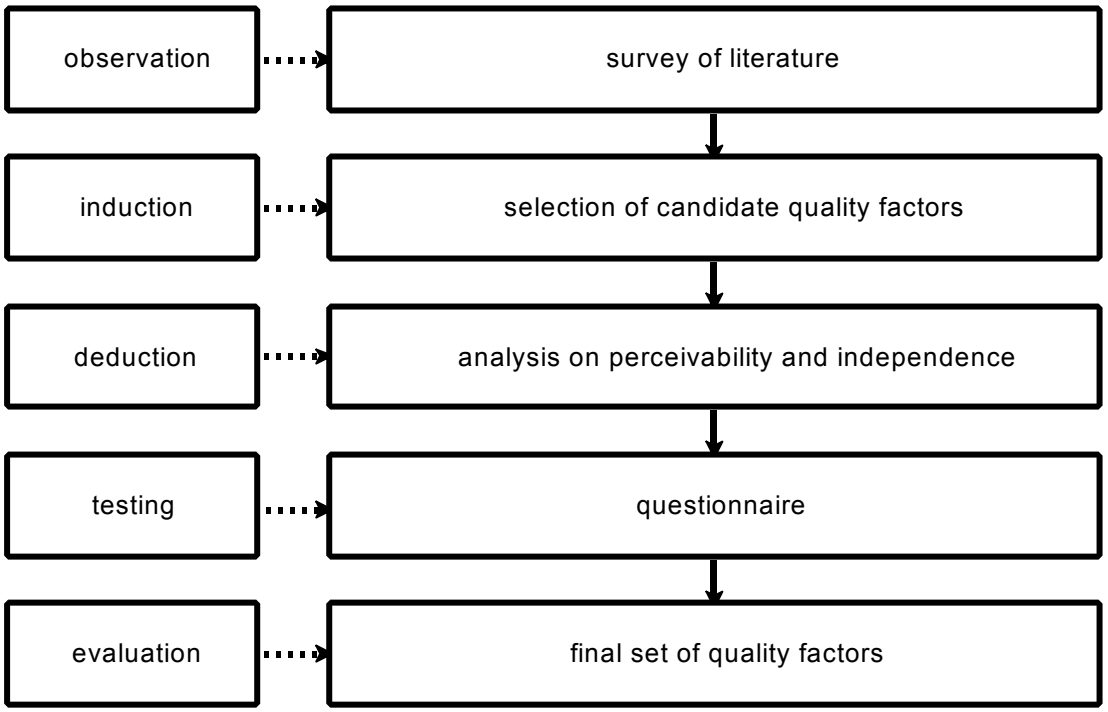
Secondly, each candidate quality factor will be qualitatively analyzed on both independence and perceivability. The independence analysis focuses on the decision aspects underlying each candidate quality factor. Whenever two of these candidates include a similar decision aspect, then these candidates will be identified as dependent. The perceivability analysis investigates the shift patterns related to the decision aspects underlying each candidate quality factor. Whenever the determination of the value of a candidate quality factor requires information other than perceivable shift patterns, then this candidate will be identified as imperceivable. This second step will result in a working set of quality factors. This working set contains only perceivable and independent factors of nursing schedule quality.

In the third research step, a questionnaire will be designed and sent to several nurse schedulers. This questionnaire will ask about a number of characteristics of the nurse scheduling task and for a definition of nursing schedule quality. The focus in this second phase is on these definitions of nursing schedule quality. The resulting characteristics will be used in the following research phases, described below.

In the fourth step of the questionnaire, the given definitions will be qualitatively analyzed. This analysis will try to relate the definitions to the perceivable and independent quality factors of nursing schedules found in the first phase. This step will be called the 'qualitative factor analysis'. The result of this qualitative factor analysis will be a final set of quality factors. This final set contains only validated (perceivable and independent) factors of nursing schedule quality. The results of this and the previous research steps of the first phase are the subject of the fourth chapter.

The steps of this first research phase complete one empirical cycle. Figure 3.2 shows the relation of the research steps described above to the five phases of the empirical cycle.

Figure 3.2 THE FIRST EMPIRICAL CYCLE OF THE RESEARCH DESIGN



3.2.2 Ranking experiment

In the second research phase, a ranking experiment will take place. The objective of this experiment is to operationalize each factor of the final set of quality factors. These operationalizations require the specification of each quality factor into a number of decision aspects and the determination of the values of all relevant shift patterns per decision aspect. Five research steps are designed to attain these operationalizations.

Firstly, each (final) quality factor of nursing schedules will be further specified into a number of possible decision aspects. These specifications will concern a fictitious nursing unit, which will be designed on the basis of 'average' nursing unit characteristics resulting from the questionnaire applied in the previous phase. This fictitious nursing unit will be called 'East-5'.

Secondly, each of these possible decision aspects will be further specified into a number of possible shift patterns. These shift patterns will also based on the characteristics of the fictitious nursing unit of East-5.

Then, in the third research step, a number of nurse schedulers will be asked

to rank the shift patterns per decision aspect. The nurse schedulers will be instructed to rank according to each shift pattern's value for the relevant quality factor. This third step is based on a knowledge acquisition technique known as 'cart sort' (see Burton & Shadbolt, 1987). The objective of both the ranking task and the cart sort task is to reveal a 'hidden' dimension. In the case of the ranking of shift patterns, this dimension is the corresponding quality factor.

In the fourth step, the given rankings will be analyzed on the basis of the communality in these rankings. A statistical measure to determine the amount of communality is the coefficient of concordance (Kendall, 1975, pp. 94-106). This measure is based on the variance in the rank per object. Formula 3.2 shows the computation of this coefficient of concordance, represented as W.

$$W = \frac{\sum_{i=1}^{N} (\overline{s}_i - \overline{\overline{s}})^2}{N (N^2 - 1) / 12}$$

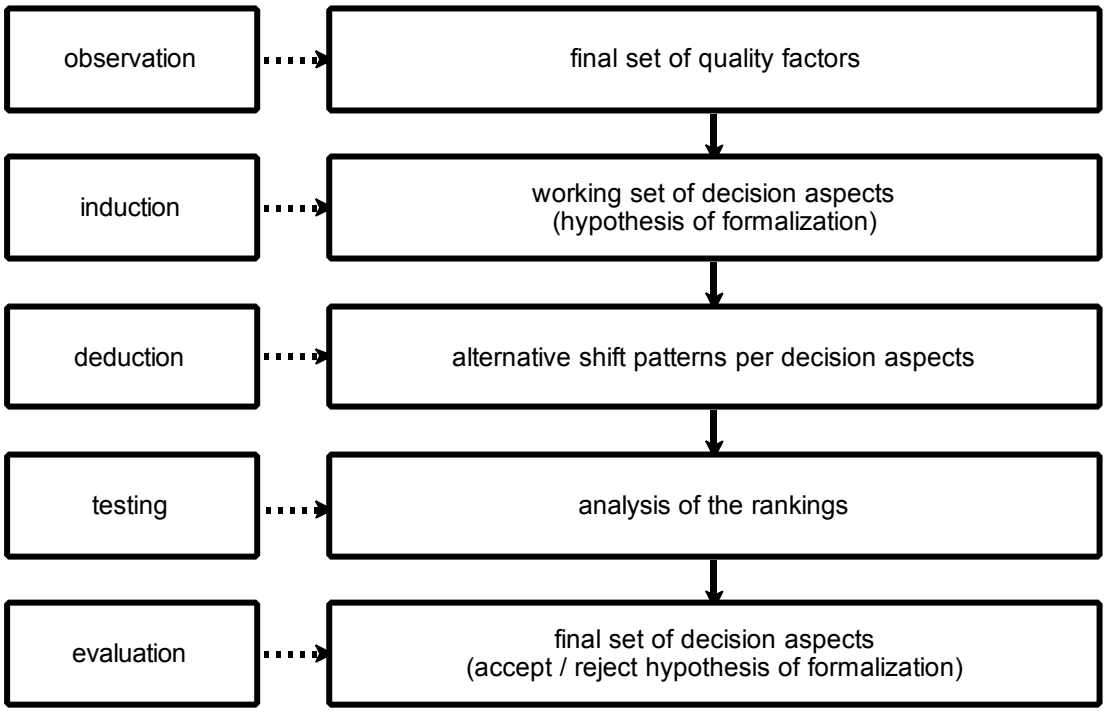
Formula 3.2: Kendall's coefficient of concordance

This formula computes the coefficient of concordance per k rankings of N objects. Applying this formula to the ranking experiment, the variable of N represents the number of alternative shift patterns per decision aspect and $\bar{p}_i$ stands for the mean ranking of shift pattern i (i.e. the mean of all s_i per shift pattern). The position of a shift pattern in a ranking is represented as s_i. In the case of tied ranks, these s_i have the value of the average of the positions these shift patterns would have had if they had been distinguishable (see also Kendall, 1975, p. 34). Furthermore, $\bar{p}$ represents the mean of all shift pattern rankings per decision aspect.

In the fifth and final step of the ranking experiment, a number of conclusions will follow from the rankings per decision aspect with a significant coefficient of concordance. These conclusions provide the basis for the operationalizations of each factor of the final set of quality factors. These conclusions provide an answer to the second research question (i.e. "How can one operationalize each of these quality factors?"). This last step of the ranking experiment draws a conclusion about the (in)correctness of the hypothesis of formalization. The results of this and the previous research steps of the second phase are the subject of the fifth chapter.

The steps of this second research phase also complete one empirical cycle. Figure 3.3 shows the relation of the research steps described above to the five phases of the empirical cycle.

Figure 3.3 THE SECOND EMPIRICAL CYCLE OF THE RESEARCH DESIGN



3.2.3 Auditing experiment

In the third research phase, an auditing experiment will be conducted. The objective of this experiment is to test the hypothesis of robustness. To perform this test, the auditing experiment consists of five research steps.

Firstly, the quality factors will be operationalized on the basis of the rankings per significant decision aspect. This significance refers to the each decision aspect's coefficient of concordance, which will result from the ranking experiment conducted in the previous phase. This step will result in so-called nursing schedule quality metrics.

In the second step, a number of nursing schedules for the 'average' nursing unit of East-5 will be arranged. These fictitious nursing schedules will strongly differ in the values of each quality factor.

Next, in the third step, a number of schedulers will be asked to audit these fictitious nursing schedules. The nurse schedulers will be instructed to give each nursing schedule a quality mark on a scale from one to ten.

In the fourth step, these audits will be analyzed by applying a least-squares

algorithm (Lawson & Hanson, 1974). The objective of this analysis is to determine each scheduler's individual weights per quality factor. In order to apply a least-squares algorithm, the results of the auditing experiment will be reformulated as an overdetermined set of linear equations in the form of $Ax \approx b$, where A represents the $m \times n$ matrix ($m \geq n$) of factor values and b represents the quality marks given to a nursing schedules by a nurse scheduler. The values per nurse scheduler of the column x, which minimizes the Euclidean norm of the residual vector $r=b-Ax$, will be determined by using a standard algorithm for finding the minimal solution to the overdetermined linear least-squares problem $Ax \approx b$ (Lawson & Hanson, 1974, pp. 180-198). The resulting least-squares solutions (i.e. the column x) will show the best estimations of the individual summation weights of the nurse schedulers.

Finally, the fifth step of the auditing experiment draws a conclusion about the correctness of the hypothesis of robustness. This correctness concerns the validity of the assumed weighted sum of quality factors. The required conclusion will be based on the results of the analysis conducted in the previous step. This will answer the third research question: “Can the total nursing schedule quality be explained on the basis of a weighted sum of factor values?”. The results of this and the previous research steps of the third research phase are the subject of the sixth chapter.

Again, the steps of this third research phase complete one empirical cycle. Figure 3.4 shows the relation of the research steps described above to the five phases of the empirical cycle.

3.2.4 Scheduling experiment

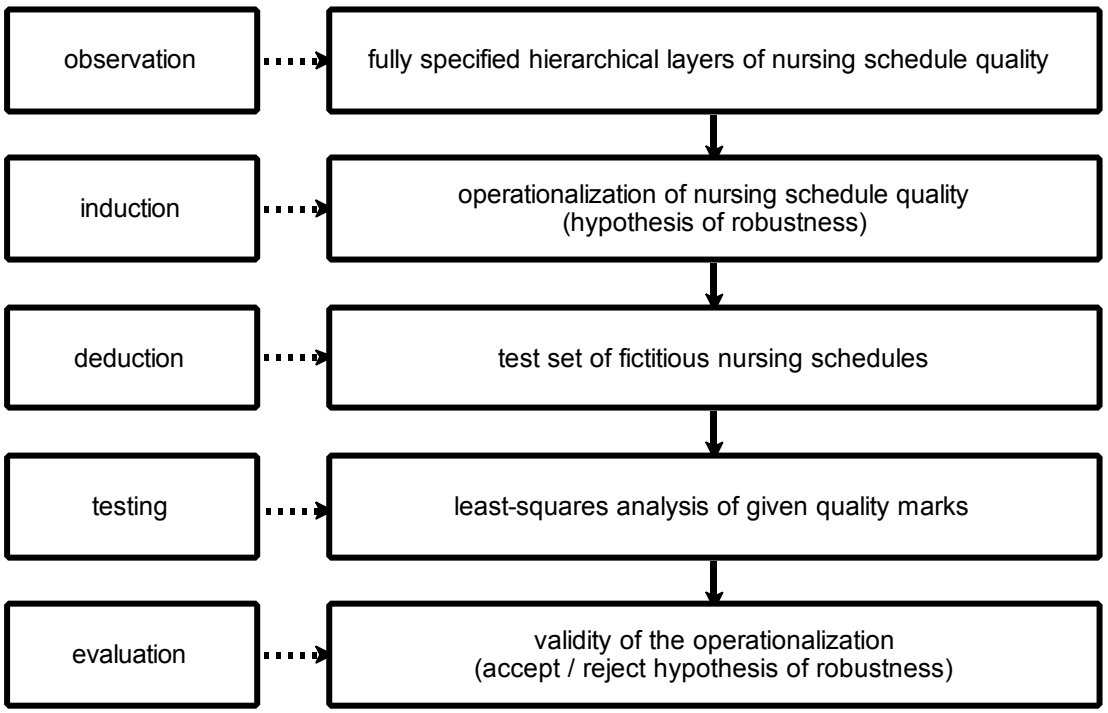
In the fourth and final research phase, a scheduling experiment will take place. The objective of this experiment is to test the hypothesis of effectiveness. Four steps are designed to perform this test.

Firstly, a software module will be developed, which can measure the values of each quality factor on the basis of the operationalization used in the auditing experiment.

Subsequently, in the second step, two groups of nurse schedulers will be asked to arrange a nursing schedule for the fictitious East-5 nursing unit used in both previous experiments. After arranging this nursing schedule, one group of nurse schedulers — the experimental group — will receive additional information (i.e. quality indication) from the developed software module, while the other group

of nurse schedulers — the control group — will not receive this quality indication.

Figure 3.4 THE THIRD EMPIRICAL CYCLE OF THE RESEARCH DESIGN



The third step will focus on the resulting nursing schedules. The factor values of each arranged nursing schedule will be used to compute the estimated total quality values. For practical reasons, these estimations will be based on average summation weights. Then, the difference in mean estimated total nursing schedule quality between the informed (Q^n) and the non-informed group (Q^o) of nurse schedulers will be analyzed. This difference will determine whether the null hypothesis (H_0 : $Q^n - Q^o = 0$) or the alternative hypothesis (H_1 : $Q^n - Q^o > 0$) is correct.

And in the fourth and final step of this scheduling experiment, the conclusion concerning the effectiveness of the approach of quality indication scheduling will follow from the results of the comparison of the estimated total quality values between the control group and the experimental group. This step will draw a conclusion about the (in)correctness of the hypothesis of effectiveness. This will answer the fourth and final research question: “Does quality indication scheduling improve the quality of nursing schedules?”. The results of this and the previous steps of the fourth research phase are the subject of the seventh chapter.

Also, the steps of this fourth and last research phase complete one empirical

cycle. Figure 3.5 shows the relation of the research steps described above to the five phases of the empirical cycle.

Figure 3.5 THE FOURTH EMPIRICAL CYCLE OF THE RESEARCH DESIGN