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Investigation of a Methodology for the Quantitative Estimation of Nursing Tasks on the Basis of Time Study Data

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Additional information is available at the end of the chapter

1. Background and goals

Estimation of the quantity of nursing care required is regarded as a pressing need from the point of view of the investigation of both patient safety and care provision that meets patient for view of demand. Nursing is a very busy job, and up to now, much attention has been paid to problems arising from the physical and psychological effects of busyness on nurses, and to consequent problems relating to patient safety and quality of care. Because a large part of any estimates of whether a nurse is busy or not depends on subjective judgment, however, it is difficult both to define busyness and to formulate methods of measuring and assessing busyness. It is also true that merely demonstrating busyness will not have a significant effect in solving problems. Consequently, ways of estimating nursing care quantity itself have been sought. If it were possible to make quantitative estimates of necessary nursing care, we could expect to improve patient safety and achieve a better quality of patient care through such elements of nursing care management as appropriate allocation of nursing staff and effective distribution of tasks.

In studies of the measurement of work quantity for the purposes of nursing care management, a typical approach has been to conduct work quantity surveys based on time study (Meyers & Stewart, 2002). Various techniques for calculating work quantity have been used, some of which focus on patient condition (Fagerstom & Rainio, 1999) and others on patient outcomes (Hall et al., 2004), but methods based on time study have the particular advantage that they make it possible to obtain clear quantitative results in the form of work times. Time studies quantitatively examine how much time is spent on what sort of work activities, and

yield highly reliable results concerning the amounts of work time expended. They are therefore widely used not only in fields related to nursing but also in clinical locations where doctors and other co-medicals work (Vinson et al., 1996; Langlois et al., 1999; Magnusson et al., 1998). They are carried out in various forms (Thomas et al., 2000; Caughey & Chang, 1998) and in the course of this study also we have used time study to elucidate the actual state of ward nursing care from a variety of perspectives.

In most such studies, however, the analyses of the time study data do not go beyond factual descriptions of the actual state of affairs. So far, almost no methodology has been established for the purpose of linking the data to the calculation of quantities of nursing care required or to nursing care management. The following points may be cited as contributing factors:

1. It is difficult to carry out long-term time studies

2. It is difficult to obtain an overall picture of tasks in hospital wards

3. There is no place for trial and error in the actual execution of the plan devised.

With regard to point 1)→1, for example, researcher-administered time studies (see 2.2.1.1. below) produce what are regarded as the most reliable data, but the outlay in terms of staffing and financial costs, from the pre-survey preparation stage to the results analysis, as well as the high burden on the clinical location concerned, make it difficult to carry out such studies with any great frequency, and the survey periods must also be kept short.

With regard to point 2)→2, where nursing care management matters such as appropriate staff allocation are concerned, inconsistencies in shift conditions will arise (there will be days when shifts have crowded schedules and days when they do not), so it will be necessary to obtain an over-all picture of tasks on the ward based on the evidence of frequent or long-term surveys. For the reason given above, however, time studies are restricted, in almost all cases, to short survey periods. The results obtained therefore provide an interpretation only of the period when the survey was conducted and are confined to the realm of factual description.

With regard to point 3)→3, having obtained an over-all picture of the tasks on the ward, the next step in nursing care management is to formulate a concrete plan that takes into consideration changes in working hours when there is a shortage of nursing staff or when there is an increase in the number of patients admitted. In practice, however, it is difficult to carry out the formulated plan in the actual ward environment because such plans are accompanied by risks and involve many ethical problems. This means that an investigation of a new method of work management is in fact impossible. This has been a major barrier.

Considering the above adverse factors, it would be effective, for the purposes of time-study based management of ward tasks, to establish a methodology of the following kind:

• Estimates of ward task times based on time study data

• Creation of a computer-based virtual ward environment using the estimated values

• Test experiment on a plan for work management using the virtual ward environment

The goal of this study is therefore the formulation of a methodology, based on data from a short-term time study, for estimating ward task times and for creating a virtual ward environment relating to job times.

2. Method

The procedure followed was:

1. Framing a plan for the creation of a virtual environment

2. Computation of basic data required for a virtual environment based on short-term research and long-term cumulative information

3. Construction of a procedure for the creation of a virtual ward environment

4. Trial experiment using the virtual ward environment

2.1. Framing a plan for the creation of a virtual environment

First of all, in order to establish a way of thinking about how to simulate an actual ward environment, we drew up a diagram showing what kinds of factors would have a bearing on the time devoted to nursing tasks (Fig. 1).
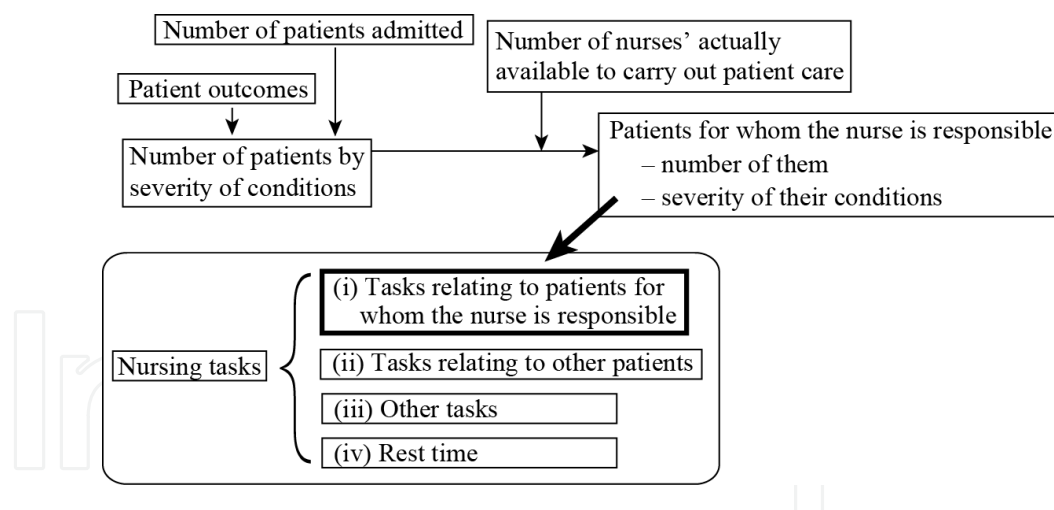
Figure 1. Constituent factors in nursing tasks.

We assumed that the tasks carried out by a given nurse during one shift would comprise (i) tasks relating to patients for whom the nurse is responsible, (ii) tasks relating to other patients, (iii) other tasks, such as those relating to the running of the ward, and (iv) rest time. Task times devoted to these four items would be interdependent and would vary, but we thought that 'task times devoted to patients for whom the nurse is responsible' would have particularly high priority, and would affect 'time devoted to other patients,' 'time devoted to other tasks' and 'rest time.' We also assumed, first, that the number of patients for whom a given nurse is

responsible, and the severity of their conditions, would affect 'task times devoted to patients for whom the nurse is responsible'; second, that 'number of patients' in the nurse's charge and 'severity of their conditions' would be affected by 'number of patients by severity of condition' who were on the ward at a given time and 'number of nurses' actually available to carry out patient care; and third, that 'number of patients by intensity of nursing care' would be affected by 'patient outcomes' and 'number of patients admitted.

2.2. Computation of basic data required for a virtual environment based on short-term research and long-term cumulative information

2.2.1. Short-term research

2.2.1.1. Time study

A continuous 24-hour researcher-administered time study was conducted over a total of fifteen days during 1999 and 2000 in a gastrointestinal surgical ward in a university hospital. Of the various forms of time study techniques we adopted the researcher-administered method for the present study because on the basis of the characteristics of the ward studied, we judged that there were limits to the extent to which nurses on duty would themselves be able to keep a record of the content of the tasks in the intervals between the tasks they performed. The survey was conducted in relation to all three work shifts: 'night shift,' 'day shift' and 'evening shift.' The total number of nurses observed was 69 (Table 1).

	Year 1999	Year 2000
Period	Jul. 5th ~ Jul. 14th	Aug 28th ~ Sep. 2nd
Number of days	10 days	5 days
Ward studied	Gastrointestinal surgical ward in a university hospital	
Number of nurses	13 (total 46)	6 (total 23)

Table 1. Time study period and subjects.

The ward studied was a fifty-bed ward with a staff of 23 nurses, including the head nurse. The average number of staff actually on duty on weekdays was 8.6. The ward's nursing system combined a three-module organization, under which ward nursing staff were divided into three groups, A, B and C, and a 'primary nursing' model, under which the same nurse was responsible for a given patient throughout, from admission to discharge (Fig. 2). When the primary nurse was not on duty, a nurse from the same group took responsibility for the patient. Information was gathered during the period of the survey on both the nurses being surveyed and the patients for whom they were responsible.

After completion of the time study, the task content recorded was coded in accordance with a specially created system of task classification and entered into a database. The nursing task classification was based on the Public Health Nurse, Midwife and Nurse Law [1948]. The four principal categories were 'clinical nursing,' 'consulting support nursing,' 'other nurs-

ing,' and 'non-nursing tasks.' At the most detailed level, there were 92 headings altogether. The overall number of individual task action-units recorded was 46,775.
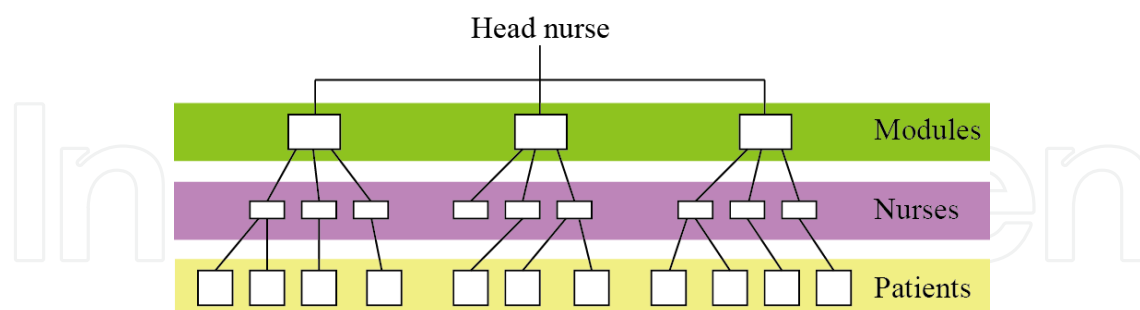
Figure 2. Module system and primary nursing model.

2.2.1.2. Patient condition information

Patient condition information for each patient on the ward was collected and recorded daily throughout the fifteen days of the time study period. 'Patient condition information' means information that indicates a hospital patient's condition, such as how many times in the course of the day vital signs are checked, whether an artificial respirator is in use, or whether there is any fever or bleeding. About 70 items are covered. Information collected during the day shift, at about 10 a.m., served as the base, and was incrementally updated for any patient who underwent an operation or other invasive procedure during the day shift and whose nursing intensity changed. The information recorded was entered into a database. Ultimately, the overall number of patient-shift units recorded was 2,015.

Nursing intensity, assessed daily by an experienced nurse, was included in patient condition information. Nursing intensity is a method of classifying patient severity from two points of view – 'level of observation' and 'freedom of life' – that was proposed in 1984 in a report by the Study Group on Nursing Systems set up by the Ministry of Health, Labor and Welfare (formerly the Ministry of Health and Welfare) (Table 2). In the process of the present study, it was suggested that patient severity observations collected on the ward being studied could be regarded as 'level of observation' for the purpose of assessing nursing intensity and these were used in carrying out our analysis.

By integrating the time study database and the patient condition information database on the basis of 'day of survey,' 'shift,' 'nurse ID' and 'patient ID,' we created a data set that made it possible to tell which nurse had spent how much time performing what tasks for patients in what condition. We assumed that among the task actions, subject patients would be available for nursing task classifications from 10101 to 301T1.

The names of nurses and patients included in the survey records, as well as any other items of information from which it would be possible to identify individuals, were all coded and only if this used for analysis after the information had been made secure.

Level of observation	A	Need continuous observation
	B	Need observation at regular (one to two hour) intervals
	C	Do not need regular observation
Freedom of life	I	Lie in bed at all times
	II	Be able to sit up in bed
	III	Be able to walk around the ward
	IV	No inconvenience in daily life

Table 2. Nursing intensity.

2.2.2. Long-term cumulative information

2.2.2.1. Information concerning patient outcomes

In order to understand over-all patterns of change in nursing intensity for the patients on the ward being studied, we obtained information from the HIS (Hospital Information System) under the headings 'date of admission,' 'date of discharge,' 'date of update of nursing intensity,' and 'nursing intensity' covering the period from January 1, 2000, to December 31, 2000. This information was obtained in addition to the patient condition information gathered during the time study period.

'Pattern of change in nursing intensity' shows the outcome for a given patient. We defined it in terms of the number of days for which the patient was hospitalized and any changes in nursing intensity during that period. Pattern of change in nursing intensity varies according to individual factors, such as the disease from which the patient is suffering, surgical procedures undergone, and medical treatment. For example, patient J is in hospital for 3 days. On the first day nursing intensity is B, on the second day C, and again on the third day C. The pattern of change in nursing intensity for this patient is 'BCC.' Patient S is in hospital for four days. On the first two days nursing intensity is A, and on the remaining two days B. The pattern of change of nursing intensity for this patient is 'AABB.' It is no exaggeration to say that, except in the cases of patients where there is no clinical pathway variance, each individual patient exhibits a unique pattern of change in nursing intensity during the period of hospitalization.

2.3. Basic data

Basic data required for the creation of a virtual environment was calculated from a short-term survey and a long-term cumulative information survey.

2.3.1. Ward environment

On the basis of time study data and patient condition information, we found recorded statistical values relating to the number of patients admitted to the ward studied. The re-

sults were as follows. Average daily number of patients on the ward was 44.2, and the standard deviation (SD) was 2.3. The greatest number of patients on the ward at one time was 49, the smallest 42. The average number of patients for whom one nurse was responsible was 4.9. The largest number was 7, the smallest 3. A total of 281 patterns of change in nursing intensity was abstracted from the HIS information in relation to admissions to the ward in question in the year 2000.

2.3.2. Task times by purpose

From the data set obtained by integrating time study data and patient condition information, we calculated, for individual nurses on the day shift, time spent on 'patients for whom the nurse is responsible,' time spent on 'other patients,' time spent on 'other duties' and 'rest time.' Results showed that the greatest amount of task time was spent on 'patients for whom the nurse is responsible.' Next came 'other patients' and 'other duties,' almost the same amount of time being spent on each. Average rest time was less than the 60-minute rest period stipulated by law (Table 3).

	Patients for whom the nurse is responsible	Other patients	Other tasks	Rest time
Average time (minute)	323.0	92.5	104.6	49.0
SD (minute)	73.4	40.2	33.3	11.6
Max (minute)	440.8	162.6	197.2	64.2
Min (minute)	158.1	25.8	58.9	17.9

Table 3. Recorded statistical quantities for task times by purpose.
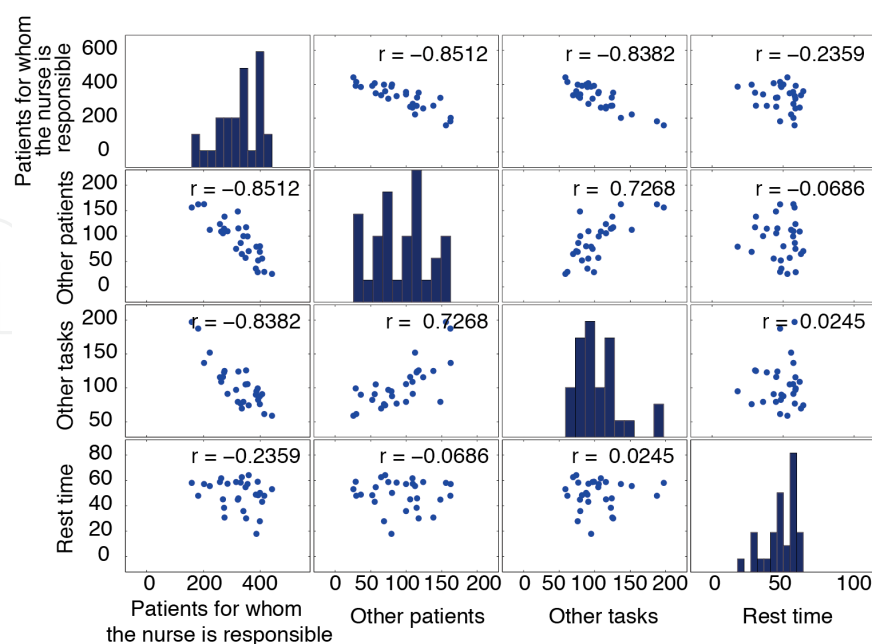
Figure 3. Correlations between task times by purpose.

Fig. 3 shows that there was a strong negative correlation between time spent on 'tasks relating to patients for whom the nurse is responsible' and time spent on 'tasks relating to other patients' and 'other tasks,' and that the correlation of 'rest time' with other task items was low. It appears at first glance that the correlation coefficient between 'tasks relating to other patients' and 'other tasks' is high at 0.727, but the partial correlation coefficient of the two is 0.019 and almost no direct correlation was observed. We were therefore able to judge that this was a spurious correlation influenced by 'tasks relating to patients for whom the nurse is responsible.' In other words, what this shows is that the relationship between the two is not such that when one increases the other decreases, but such that when time spent on 'patients for whom the nurse is responsible' increases, the two decrease together.

2.4. Construction of a virtual ward environment

In accordance with the plan formulated under 2.1, a virtual ward environment was created according to the following procedure:

1. Construction of a model for estimation of task time devoted to patients for whom the nurse is responsible.

   Construct a model to estimate the kinds of factors that influence care time devoted to a given patient.

2. Calculation of number of patients for whom one nurse is responsible and of care time

   Determine which patients a given nurse is responsible for and find the total task time spent by that nurse on patients for whom she is responsible.

3. Estimation of task time by purpose

   On the basis of the total task time devoted to 'patients for whom the nurse is responsible' calculated under 2., estimate time spent on 'patients for whom the nurse is not responsible,' 'other tasks,' and 'rest time,' all of which are correlated.

2.5. Test experiments in virtual ward environment

In the virtual environment we had created, we carried out the following test experiments and investigated the difference from actual data.

1. Estimation of number of patients on the ward by nursing intensity

2. Estimation of task times by purpose

3. Effect of increase or decrease in number of nurses on each task time

3. Results

3.1. Construction of a model for estimation of task time devoted to patients for whom nurse is responsible

Our 'model for estimation of task time devoted to patients for whom nurse is responsible' is a regression analysis model using 'care time devoted to a given patient for whom a given

nurse is responsible' as the dependent variable. When formulating a plan for the creation of a virtual environment, we entered the factor 'nursing intensity' as an independent variable on the assumption that task time devoted to patients for whom a nurse is responsible would be affected by patient severity. Bearing in mind that changes in shift time and in the number of nurses actually on duty on a shift would also have a great effect on care time devoted to patients, we included the factor 'shift' as well.

The subject of analysis consisted of records, extracted from the data set created by integrating time study data and patient condition information, which revealed responsibility relationships between nurses and patients. The data extracted related to a total of 425 patients (a total of 57 nurses on 57 shifts).

3.1.1. Multilevel analysis

A multiple regression analysis model is generally formulated as

$$y = \beta_0 + \beta_1 x_1 + \cdots + \beta_p x_p + \varepsilon \tag{1}$$

where y is a dependent variable, there are p independent variables $\{x_k\}$ that have fixed effects and ε is margin of error. As opposed to this, Multilevel Analysis (Jones, 1991; Goldstein, 2003) is a method of estimating parameters (coefficients) in which, by assuming random effects resulting from a given phenomenon j, it is possible to take into account internal correlations between data with the same value for j in relation to the correlation $\{\beta_k\}$ between an intercept β_0 in (1) and independent variables.

Because the time study survey periods were continuous, the same patients were included in different shifts in the data set relating to 425 patients subject to analysis. This means that there were elements that affected the care time, which is a variable dependent on patient identity (i.e., there were internal correlations in the data), although it was difficult to treat these elements as regular fixed effects, as in the case of the patient's bodily strength or personality.

In order to estimate parameters having variable effects that explained these internal correlations, we constructed, for the purposes of this study, a model for the estimation of task time devoted to patients for whom the nurse was responsible using Multilevel Analysis, introducing randomness for each 'patient' with respect to the intercept.

3.1.2. Optimal model

Rather than a model in which the actual care times are regressed in their original dimensions, we judged that the optimal model was one in which logistic conversion was performed with regard to the dependent variable.

Our reasons were as follows.

Because it is a mathematical model for explaining task times, when the estimated expected value y is negative, there is a marked lack of conformance of the times. For this reason, it is

necessary to perform logarithmic conversion such that the time value that is the dependent variable does not appear as a negative value.

In the later creation of the virtual ward environment, we used this model for estimation of task time devoted to 'patients for whom the nurse is responsible,' which used normal random numbers (see 3.2.4. below). Because the distribution of the raw data values (here, the distribution of the raw care times) was reproduced using normal random numbers, it was necessary at the point where random number values were generated to convert the raw data so that it showed a data distribution close to a normal distribution (see 3.3.1. for details) (Fig. 4).
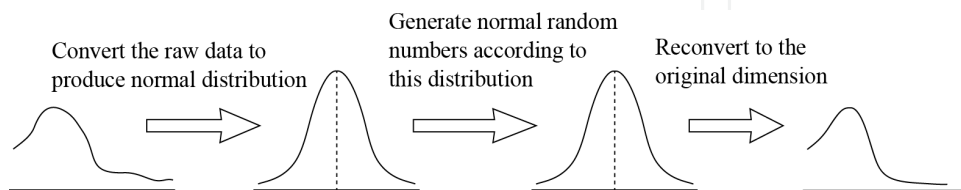
Figure 4. Conversions for the purpose of recreating actuality using normal random numbers.

We found parameters for a logistic conversion that would give real upper and lower limits by minimizing AIC (Akaike's Information Criterion) after performing logistic conversion. The data set used for this analysis included some extremely small time values, so we fixed the lower limit at zero. AIC for the case where the upper limit was a was calculated as follows:

$$\text{AIC} = n\log\hat{\sigma}^2 - 2n\log a + 2\sum_{i=1}^{n}\log\left\{y_i(a - y_i)\right\} + 2(p + 1) \tag{2}$$

Here, $\hat{\sigma}^2$ is a maximum likelihood estimator, y_i are individual time values, n is a sample number, and p is an estimated parameter number.

This means that the smaller the AIC value the closer to a normal distribution; we used MLwiN ver. 1.1 for model analysis.

The constant a that ultimately produced the smallest AIC was 300, and we used the conversion method

$$\log[y / (300 - y)] \tag{3}$$

The result was that a data conversion close to normal distribution became possible, as seen in Fig. 5.

$$\log[y_{ij} / (300 - y_{ij})] = \beta_{0ij} + \beta_{NA}N_{ij}^{A} + \beta_{NB}N_{ij}^{B} + \\ \beta_{NC}N_{ij}^{C} + \beta_{DA}D_{ij}^{A} + \beta_{DB}D_{ij}^{B} + \beta_{DC}D_{ij}^{C} + \beta_{EA}E_{ij}^{A} + \beta_{EB}E_{ij}^{B} \tag{4}$$

	β_0	β_{NA}	β_{NB}	β_{NC}	β_{DA}	β_{DB}	β_{DC}	β_{BA}	β_{BB}
coefficient	-3.834	1.653	0.704	-0.312	2.695	1.945	1.207	1.814	1.044
SE	0.245	0.296	0.260	0.256	0.289	0.253	0.245	0.301	0.266

$$u_j \sim N(0, 0.674) \qquad \beta_{0ij} = \beta_0 + u_j + e_{ij}$$

$$e_{ij} \sim N(0, 0.794)$$

With regard to the method of entering independent variables, we found as a result of repeated investigation that a model using 3x3 items in which 'shift' and 'nursing intensity' were confounded, as in 'night shift, nursing intensity A,' was optimal (equation 0.4→4). This numerical formula is a model for the estimation of nursing time devoted to one patient by the nurse responsible. Here, y_{ij} are i^{th} care times on nursing occasions for the jth patient, N, D, and E are respectively 'night shift,' 'day shift' and 'evening shift,' and superscript *A*, *B*, and *C* show nursing intensity. In this model, the value taken by a given independent variable is dichotomous, either (1) or (0), as, for example, in 'night shift nursing intensity is A (1)' or 'is not A (0),' so that when they are looked at as a whole, they form a categorical variable group in which if 'is (1)' appears with respect to an independent variable in a particular place, any other independent variables are necessarily 'is not (0).' For this reason, the independent variable 'evening shift, nursing intensity C' becomes the intercept itself, and in the case of 'day shift is nursing intensity A (1),' the parameter 'day shift, nursing intensity A' added to the intercept becomes the care time prescribed for 'day shift, nursing intensity A'. β_{0ij} is the intercept (evening shift, nursing intensity C), *u* is variability depending on the patient, and e_{ij} is margin of error (chance variability).
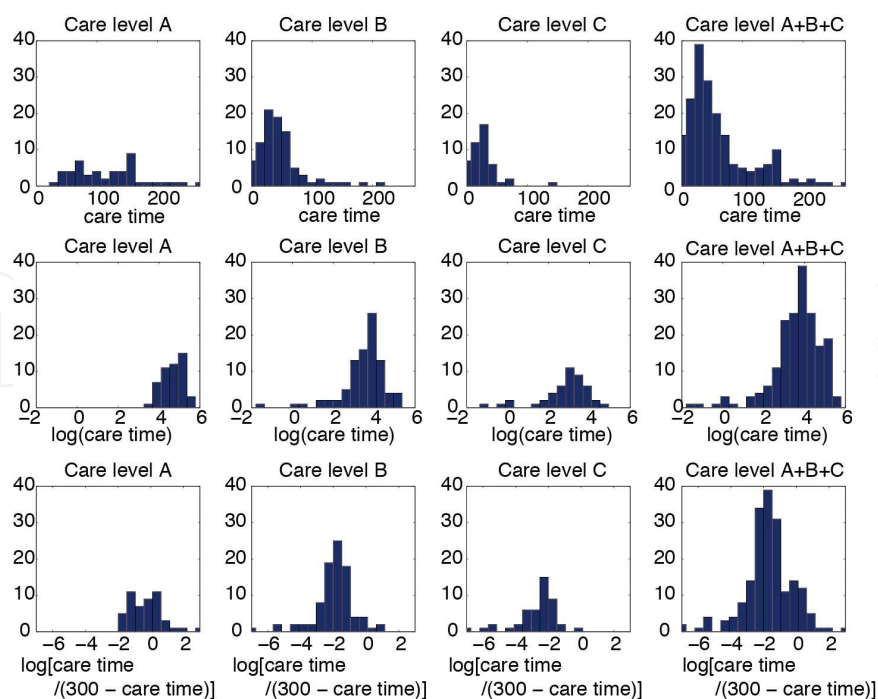
Figure 5. Data distributions after conversions.

According to the results of estimation using this model, given a patient with 'day shift, nursing intensity A,' adding the parameter value 2.695 of 'day shift, nursing intensity A' to the intercept -3.834, then adding variability due to the individual patient and margin of error, gives the care time for this patient. Returning to the time dimension by using the reverse logistic conversion shows it to be about 72.8 minutes. In the same way, in the case of 'day shift, nursing intensity B' the time is about 39.4 minutes, and in the case of 'day shift, nursing intensity C' about 20 minutes.

3.2. Estimation of number of patients for whom one nurse is responsible, and care times

Next, we determined the number of patients for whom one nurse was responsible and estimated the total time spent on those patients. At this point we embarked on the construction of an algorithm using a Monte Carlo Simulation.

A Monte Carlo Simulation is a method of obtaining approximate solutions to problems when simulating the processes of chance phenomena by carrying out numerical value calculations using random numbers. In this study, we used normal random numbers and created algorithms for them using MATLABR2012a. This simulation was conducted with respect to the day shift.

3.2.1. Bed matrix

We went through the process of recreating the actual bed occupancy status, which changes daily as a result of the admission and discharge of patients.

Since the ward studied was a 50-bed ward, we created a matrix for use in the simulation (hereafter 'bed matrix') consisting of vertical columns of 50 cells representing the beds, and on the horizontal time axis (representing days elapsed) we used rows containing enough cells to cover a long time period (for reasons explained later, we used rows of 1,000 cells in this study). Each cell in the bed matrix represents one bed-day.

3.2.2. Determination of number of patients on ward

By randomly determining the daily number of patients on the ward from the average number of patients on the ward already calculated and its standard deviation, we recreated the changes in the actual number of patients on the ward. In the case of Fig. 6, for example, the number of patients on the ward over a seven-day period is randomly divided up and shaded cells show patients on the ward.

3.2.3. Determination of patients on ward

Having determined the number of patients on the ward each day, we simulated the state of affairs relating to patients on the ward whose condition underwent change by inserting the patterns of change in nursing intensity by number of patients on the ward. For this purpose we apportioned patterns randomly chosen from among the total of 281 patterns of change in nursing intensity found under 2.3.1. At this time, the patients on the ward

were present for the number of days shown by the patterns of change. The patterns were inserted in column direction.
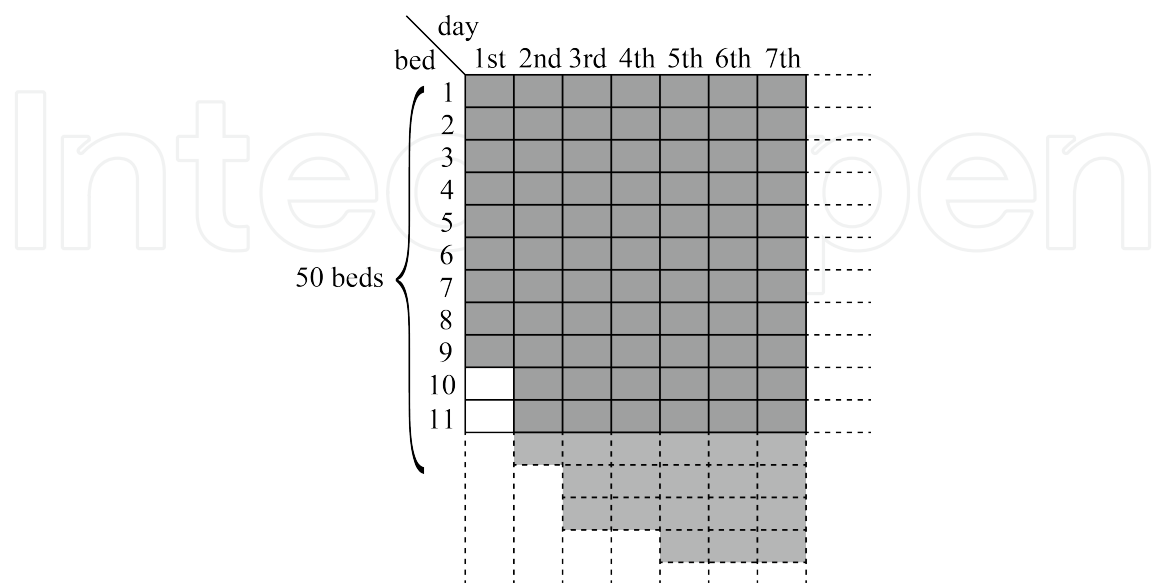

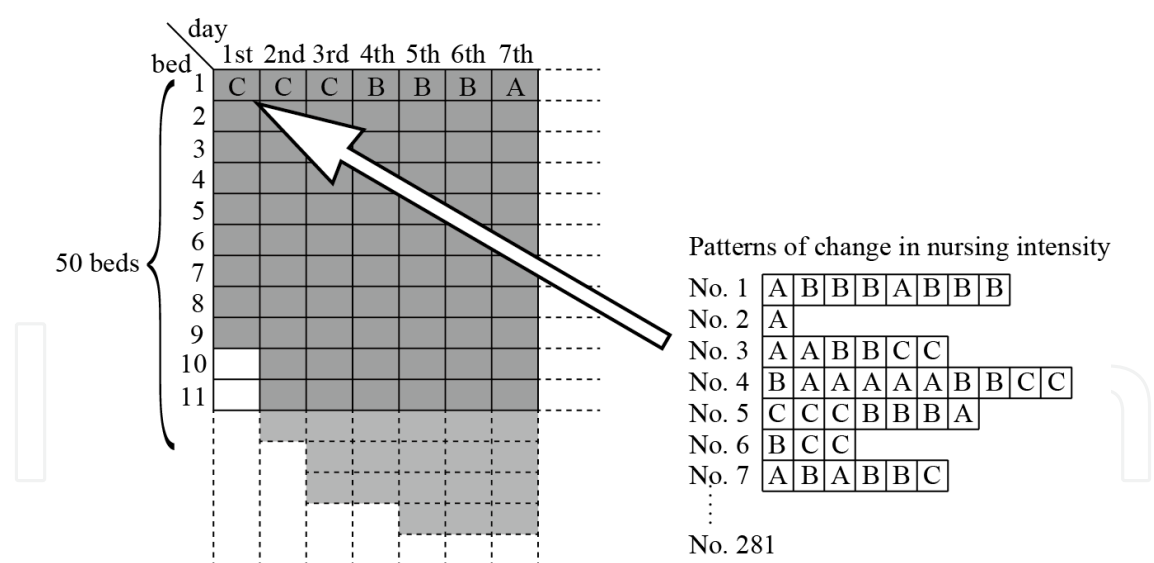**Figure 6.** Determination of number of patients on ward.

Figure 7. Layout of patterns of change in nursing intensity.

For example, in Fig. 7, pattern No. 5 was chosen and 'CCCBBBA' was inserted horizontally, one letter per cell, starting in bed number 1 on day number 1. At the beginning of the simulation there were no patients at all, and patterns of nursing intensity were allocated for the number of allocated patients on the ward. The pattern of nursing intensity differed depending on the number of days for which a patient was on the ward, so as days elapsed, patients

began to be discharged. In cases where the total number of patients given by change in patterns of nursing intensity for a given day fell below the specified minimum number of patients for the ward, we apportioned new patients randomly from the patterns of change in nursing intensity. At this point, we had reached the stage where the set number of days per patient and patients on the ward were shown by nursing intensity in the bed matrix.

3.2.4. Calculation of care time for each patient

On the basis of this nursing intensity, we calculated the care time believed necessary using the previously constructed model for estimating task time devoted to patients for whom the nurse is responsible. From equation (4) we saw that care time is not simply a function of nursing intensity but is the sum of (i) a quantity depending on nursing intensity, (ii) variability depending on the individual patient, and (iii) other chance variability. The average of each of the latter two items was 0, and they were the parts that varied according to a normal distribution with certain variances. For the calculation of care time, first we took as the basis an estimated value for care time corresponding to nursing intensity, then generated a normal random number with a certain estimated variance and an average of 0 as the common value for all the days the patient spent in hospital and added that number. We then added a normal random number with another estimated variance and an average of 0 as chance variability.

In Fig. 8, the right-hand side is an example of the bed matrix when there are patients on the ward. The figure shows the method of calculating care time for a given patient j, represented by the lightly shaded cells. This patient is on the ward for three days. On the first day, nursing intensity for this patient is B. On the second day it is C and on the third day also C, at which point the patient is discharged. Care time on the first day has the coefficient for day shift, nursing intensity B, of '−3.834+1.945.' Next, we take the value 0.21, randomly generated from the normal distribution average 0, variance 0.674, as the individual variability for patient j. The care necessary for this day has a total of −1.23, including the randomly generated value 0.45, generated from the normal distribution with average 0 and variance 0.794. We now perform reverse conversion of the logistic conversion previously performed and express the result in the time dimension: 68.1 minutes. Next, the care time for the second day has a total of −1.81, including the coefficient for day shift nursing intensity C, '−3.834+1.207,' the variable effect depending on patient j 0.21, and the randomly determined value 0.6. The care time ultimately obtained is calculated as 42.1 minutes. The variable effect depending on patient j has the same value from when patient j is admitted up to the time the patient is discharged. For another patient, k, a value for k is allotted which is also the same from admission to discharge. Further, the required care time on a given day changes at random daily with regard to every patient, and is allotted randomly each day. Consequently, on the third day, in spite of the fact that nursing intensity for the same patient j is the same, care time ultimately differs from that on the second day. By means of the above operations, a bed matrix of the kind shown in Fig. 9 is created, showing care time devoted to each patient for whom a given nurse is responsible.

3.2.5. Assignment of patients to nurses and total task times devoted by nurses to patients for whom they are responsible

On the basis of the statistical values already found for numbers of patients for whom nurses are responsible, we simulated the allocation of responsibility for these ward patients to individual nurses. The following two points suggested themselves as factors in determining the patients for whom nurses are responsible in the actual ward environment:

1.   Number of patients for whom the nurse is responsible
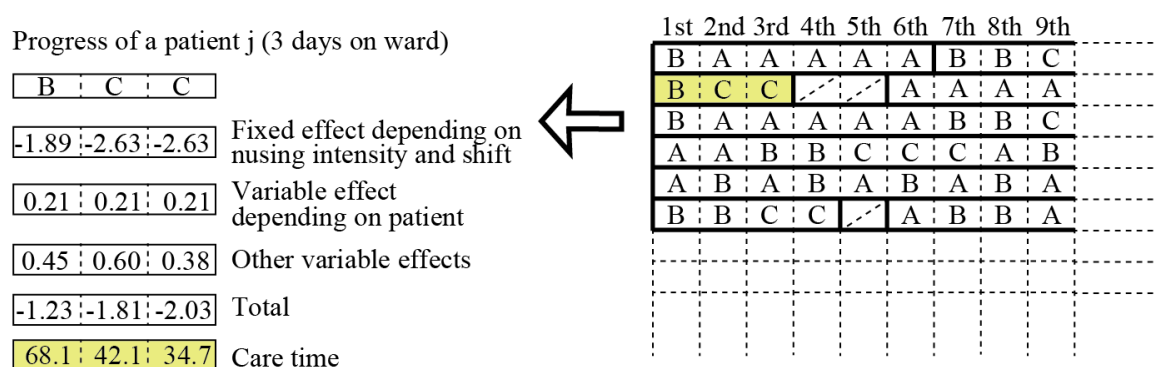
2.   Severity of the conditions of those patients

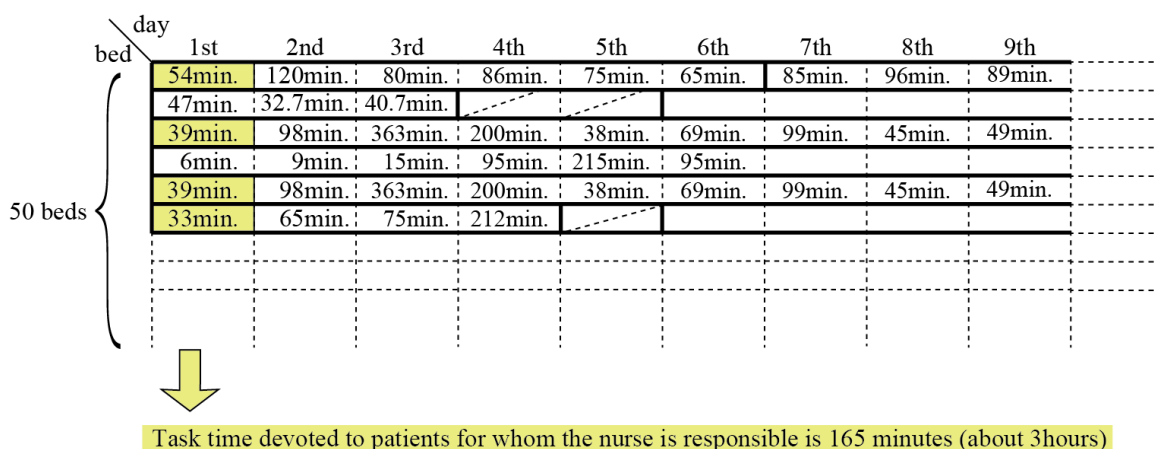**Figure 8.** Method of calculating care time for each patient.

Figure 9. Task times devoted to patients for whom nurse is responsible.

When the number of patients for whom a given nurse is responsible is large, or when they include patients whose condition is very severe, no further patients can be assigned to that nurse, and the quantity of tasks is distributed so that, for example, new patients are apportioned among other nurses with a relatively small number of patients in their charge or nurses whose patients have relatively mild conditions. Consequently, in the virtual environment, first, at the point where patients were randomly admitted to the ward, we totaled the

number of patients for whom each nurse was responsible and specified that if the number was 0, priority would be given to the assignment of patients to that nurse. We also controlled assignment of patients so that, as far as possible, each nurse was responsible for no fewer than 4 and no more than 7 patients. In addition, we carried out weighting such that extra patient responsibility was first given to nurses who were devoting a relatively small amount of task time to the patients for whom they had already been assigned responsibility.

In this way, we determined which patients a given nurse was responsible for. The shaded cells in the example shown in Fig. 9 show the task times devoted by one nurse to the patients in her charge. The total, 165 minutes, is the 'task time devoted to patients' by that nurse. At this stage, we have created a virtual simulation of the approximate amount of time a nurse devotes in reality to all the patients for whom she is responsible.

3.3. Estimation of task time by purpose

Next, on the basis of 'care time devoted to all patients for whom the nurse is responsible' by a single nurse found in 3.2.5, we randomly generated 'task time devoted to other patients,' 'time devoted to other tasks' and 'rest time' for the day shift and proceeded to simulate actual task times by purpose. As mentioned in 3.1.2, it is necessary to bear the following points in mind when carrying out these simulations.

1. It is a prerequisite that the random numbers generated should follow a normal distribution

In this study we have employed a Monte Carlo simulation using normal random numbers, and it is a prerequisite that the distribution for the generation of random numbers should be a normal distribution.

2. Negative values are to be avoided among randomly generated values

Since the units in the results obtained are times, task times that have negative values are not realistic and will prevent the simulation results from conforming to reality.

3. Covariance among the four task times by purpose is to be maintained

The generation of random values in which covariance among the variates is not taken into consideration makes it impossible to recreate the characteristic feature that they vary in relation to one another.

Bearing these points in mind, we carried out the following operations.

3.3.1. Logistic conversion

As Fig. 3 shows, a certain amount of skew with regard to all four of the items 'tasks performed for patients for whom the nurse is responsible,' 'tasks performed for other patients,' 'other tasks,' and 'rest time' and a degree of unevenness (probably attributable to sampling limitations) were observed. It is not possible to recreate the distribution exhibited by these original data even if one generates normal random numbers using only the average values

and variance of the original data. In order to recreate the distribution of the original data using normal random numbers, it is necessary to think of a conversion in which a distribution based on the conversion of the original is as close as possible to a normal distribution and, after having generated random numbers that have the post-conversion average and variance, it is then necessary to perform reverse conversion to obtain a value. At the same time, it is necessary to ensure that the randomly created values do not have a negative value. For these reasons, we decided in this study to perform the following logistic conversion with respect to task times by purpose y in order to solve problems 1), 2)→ 1 ,2 above.

$$\log[(y-b)/(a-y)] \tag{5}$$

We used AIC (Akaike's Information Criteria) to evaluate whether distribution of the post-conversion values was close to a normal distribution. We looked for an upper limit value a and a lower limit value b that would minimize AIC values. AIC were calculated by means of the following expression.

$$\text{AIC}=n\log\hat{\sigma}^2-2n\log(a-b)+2\sum_{i=1}^{n}\log\{(y_i-b)(a-y_i)\}+2(p+2) \tag{6}$$

As in formula (2), $\hat{\sigma}^2$ is a maximum likelihood estimator, y_i are individual time values, n is a sample number and p is an estimated parameter number.
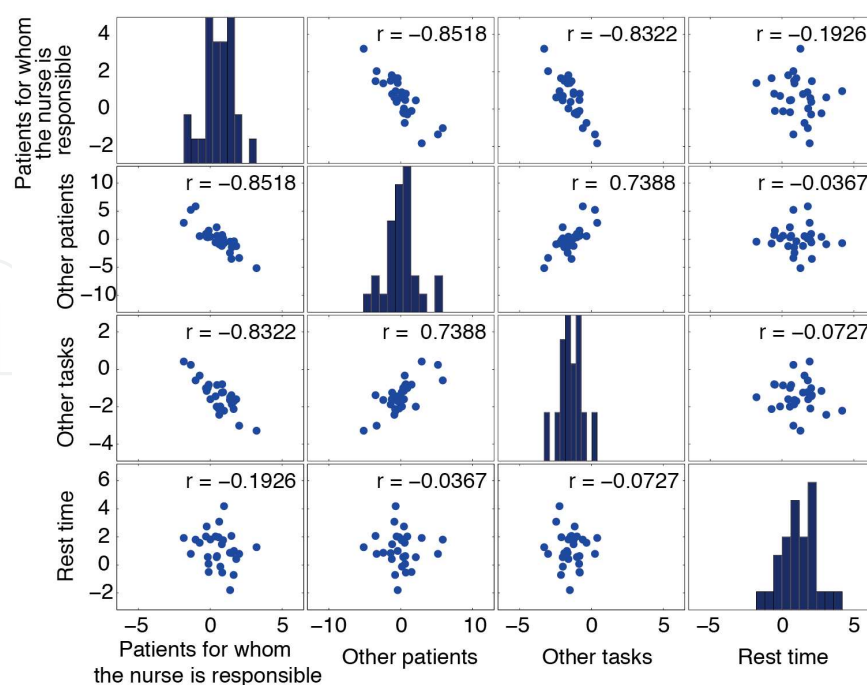
Figure 10. Conversion data plots.

The upper limit a and lower limit b for each task time by purpose that minimized AIC are as shown in Table 4.

It will be seen from scrutiny of the post-conversion data plots (Fig. 10) that in each of the variables, data distribution is closer to a normal distribution than before conversion (Fig. 3).

	a	b
Tasks relating to patients for whom the nurse is responsible	454	111
Tasks relating to other patients	163	25
Other tasks	295	50
Rest time	65	10

Table 4. Upper and lower limits of conversion functions.

3.3.2. Simulation of task times by purpose using covariance

Using the above conversion data, we generated random numbers that maintained cova-riance among the 4 variables (the third point to be borne in mind). Here, X is 'tasks per-formed for patients for whom the nurse is responsible,' Y is 'tasks performed for other patients,' Z is 'other tasks,' and W is 'rest.' In this study, we constructed the simulation algo-rithms on the basis of the hypothesis that 'tasks performed for patients for whom the nurse is responsible' would exert an influence on the allocation of task times to other tasks, and therefore designed the model so that X would exert an influence on Y, Z, and W.

If the equation

$$
\begin{aligned}
Y &= \alpha + \beta X + \varepsilon \\
\varepsilon &\sim N(0, \sigma^2)
\end{aligned}
\tag{7}
$$

is used when generating Y with a given covariance, expected value E(Y), variance Var(Y) and covariance Cov(X, Y) become

$$
\begin{aligned}
\text{E}(Y) &= \alpha + \beta \text{E}(X) \\
\text{Var}(Y) &= \beta^2 \text{Var}(X) + \sigma^2 \\
\text{Cov}(X, Y) &= \beta \text{Var}(X)
\end{aligned}
\tag{8}
$$

and the unknown quantities α, β, σ^2 are found by means of

$$
\begin{aligned}
\beta &= \text{Cov}(X, Y)/\text{Var}(X) \\
\alpha &= \text{E}(Y) - \beta \text{E}(X) \\
\sigma^2 &= \text{Var}(Y) - \beta^2 \text{Var}(X)
\end{aligned}
\tag{9}
$$

If coefficient values with regard to X are calculated in the same way for Z and W, with a given covariance, the result is

$$Y = \alpha_1 + \beta_1 X + \varepsilon_1$$
$$Z = \alpha_2 + \beta_2 X + \varepsilon_2 \tag{10}$$
$$W = \alpha_3 + \beta_3 X + \varepsilon_3$$

In this way, it is possible to maintain covariance between (X, Y), (X, Z), and (X, W). That is to say, it is possible to recreate changes in Y, Z, and W that occur when X changes, but because $\varepsilon_1, \varepsilon_2, \varepsilon_3$ are independent normal random numbers, covariance between (X, Y), (X, Z), (X, W) is 0, and it is not possible to recreate changes based on the residual in 'other tasks' and 'rest' that occur when 'tasks performed for other patients' changes. So in order to maintain covariance between $\varepsilon_1, \varepsilon_2, \varepsilon_3$ we decided to find the covariance structure of $(\varepsilon_1, \varepsilon_2, \varepsilon_3)$ by means of the equations

$$\varepsilon_1 = Y - (\alpha_1 + \beta_1 X)$$
$$\varepsilon_2 = Z - (\alpha_2 + \beta_2 X) \tag{11}$$
$$\varepsilon_3 = W - (\alpha_3 + \beta_3 X)$$

and generate 3-dimensional normal random numbers with this covariance.

Substituting the various coefficients calculated as a result of the above into formula (10) gives the result

$$Y = 1.04 - 1.77 X + \varepsilon_1$$
$$Z = -1.04 - 0.64 X + \varepsilon_2 \tag{12}$$
$$W = 1.26 - 0.22 X + \varepsilon_3$$

Covariance structure of $(\varepsilon_1, \varepsilon_2, \varepsilon_3)$ is shown in Table 5.

	ε_1	ε_2	ε_3
ε_1	1.40	0.06	-0.56
ε_2	0.06	0.21	-0.24
ε_3	-0.56	-0.24	1.49

Table 5. Covariance structure of residuals.

Using residuals with these regression coefficients and covariances, we generated random numbers. Fig. 11 shows on the same plots the values obtained after logistic conversion of the

original data (red dots) and the random numbers generated (blue dots). It can be seen that they have almost identical distributions. This shows that it is possible to generate random numbers that maintain the correlation structure between the variates (covariance).
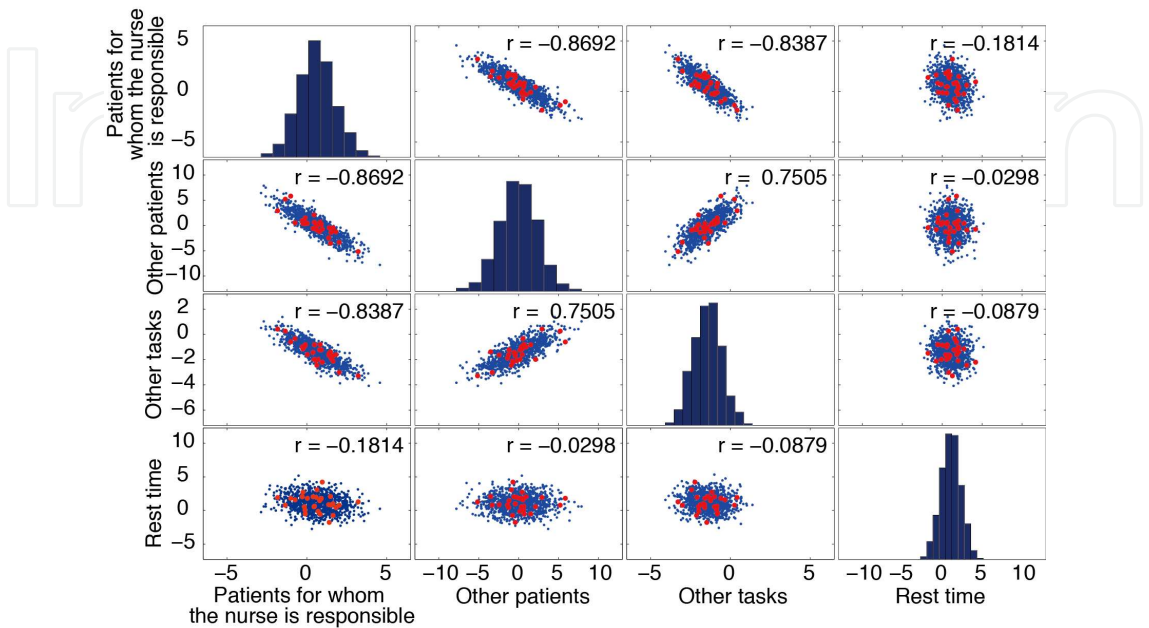

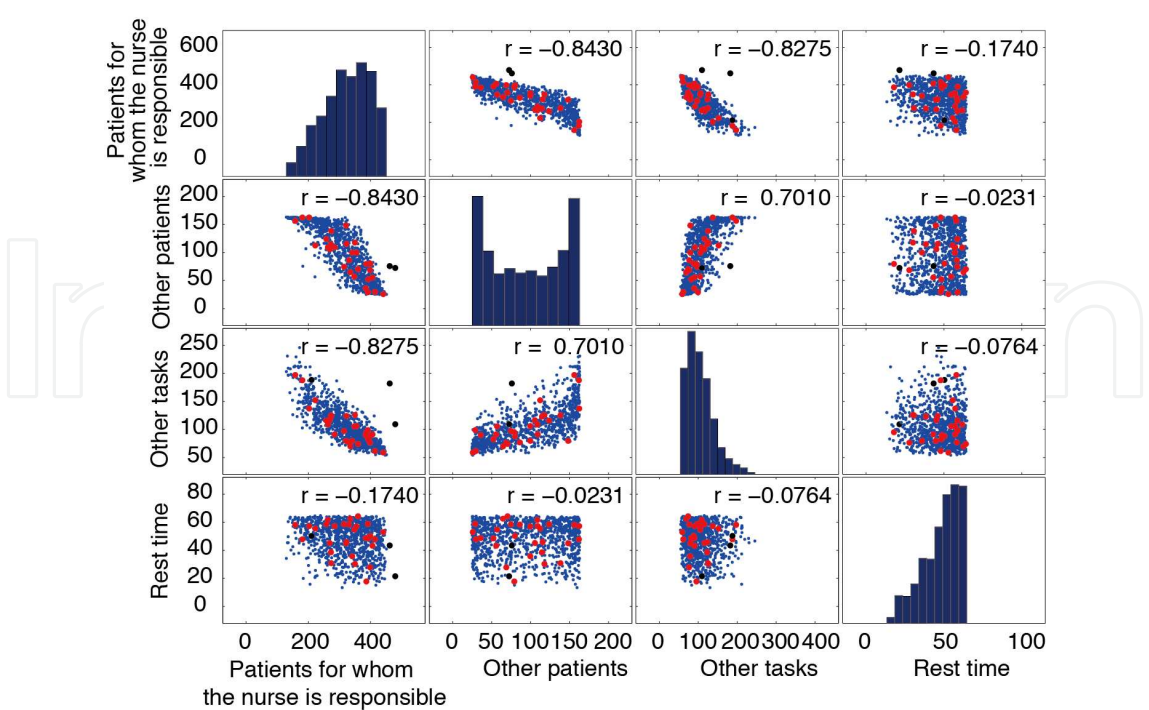**Figure 11.** Random number values and logistic conversion values.

Figure 12. Time dimensions and random number values.

Fig. 12 shows together the original data (red dots) and the values obtained after performing reverse conversion on the logistic conversions of the random numbers generated (blue dots). It can be seen that the distribution of the original data relating to time dimensions has been almost exactly recreated. The black dots represent what we judged to be anomalies in the original data. These data relate to anomalous tasks, such as receiving training or attending meetings, that were performed in the afternoons, with only the mornings being spent on ward duties. We therefore decided to exclude them from the analysis.

Following the above procedure, we randomly generated individual task times while maintaining associations between 'tasks performed for patients for whom the nurse is responsible,' 'tasks performed for other patients,' 'other tasks,' and 'rest.' At this point, we had completed construction of a virtual ward environment for the purpose of simulating actual 'time devoted to tasks performed for patients for whom the nurse is responsible,' 'time devoted to tasks performed for other patients,' 'time devoted to other tasks,' and 'rest time' for one nurse, and for conducting test experiments.

3.4. Test experiments in the virtual ward environment

Using the virtual ward environment we had constructed, we simulated long-term ward task times. On the first day of simulation the situation was that all patients were admitted to the ward at once, so none would be discharged for some time. As days passed in the simulation, gradually some patients began to be discharged. We disregarded simulation results obtained up to the point where it seemed that a stable situation had eventually been reached, with a balance between admissions and discharges. From that point, we specified 1,000 days of simulation. For the purposes of the simulation, we also specified that from the point of view of the work system, every day was a weekday.

3.4.1. Changes in patient numbers by nursing intensity

The result of the simulation was as follows: the total number of patients was 44,846; totals by nursing intensity were: A=11,193 (25.0%), B=26,469 (59.0%), and C=7,184 (16.0%). The largest cohort of patients comprised those subject to nursing intensity B, the next largest those subject to nursing intensity A, and the smallest those subject to nursing intensity C. Unsurprisingly, this trend reflected almost exactly the trend in the 281 nursing intensity patterns we had established, where the frequency of nursing intensity A was 3,287 (24.2%), that of B 8,010 (59.1%), and that of C 2,265 (16.7%).

Fig. 13 is a graph showing changes in number of patients by nursing intensity. The vertical axis shows number of patients and the horizontal axis days elapsed. The upper panel is a graph showing nursing intensity. The daily number of patients at nursing intensity C, the lowest level of severity, is smallest, and the number at B, the intermediate level, is highest. The lower panel shows cumulative totals by nursing intensity. It will be seen, first, that almost all patients on the ward are accounted for by nursing intensity A and B, and, second, that once the number of patients has risen, it remains for some time at the higher level.

3.4.2. Task times devoted to patients for whom the nurse is responsible from the point of view of nursing intensity

The quantity of care time per patient necessary when patients for whom the nurse was responsible were at nursing intensity A was on average 93.5 minutes. For patients on nursing intensity B the average time was 57.1 minutes, and for those on nursing intensity C the average time was 31.6 minutes.

3.4.3. Changes in task times by purpose for the whole ward

The upper panel in Fig. 14 shows changes in task times by purpose for the ward as a whole. The horizontal axis shows number of days elapsed and the vertical axis shows times. 'Task times devoted to patients for whom the nurse is responsible' show large fluctuations, while 'rest times' display nowhere near as large a range of variation. Further, it can be seen that when 'task times devoted to patients for whom the nurse is responsible' decrease, 'task times devoted to other patients' and 'times devoted to other tasks' increase; and when 'task times devoted to patients for whom the nurse is responsible' increase, 'task times devoted to
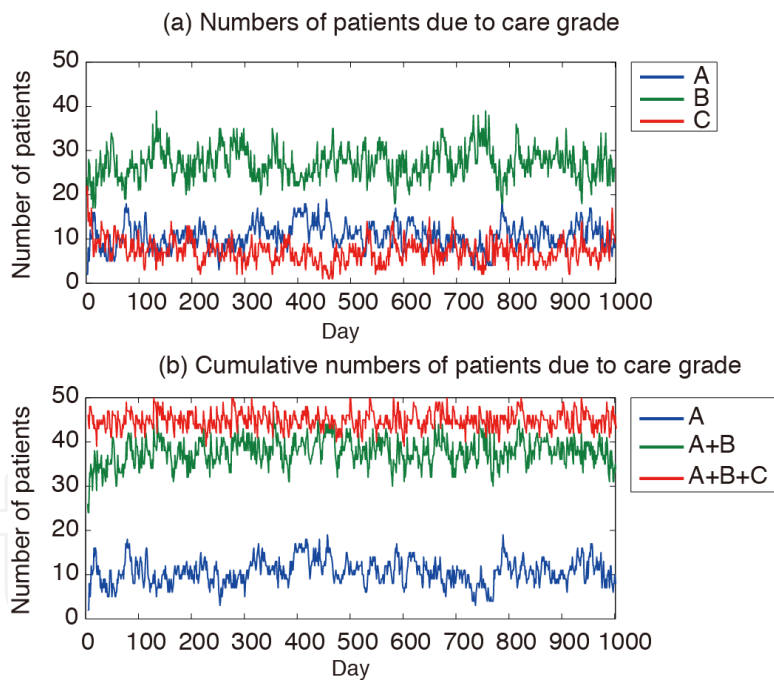
**Figure 13.** Changes in patient numbers by nursing intensity.

other patients' and 'times devoted to other tasks' decrease.

The lower panel in Fig. 14 shows cumulative totals of task times by purpose. In spite of the fact that 'task times devoted to patients for whom the nurse is responsible' and 'task times devoted to other patients' fluctuate widely, total task times as a whole are kept to an almost uniform level.

3.4.4. Changes in task times by purpose

We simulated changes in task times by purpose for an individual nurse when the number of nurses on a single day shift was increased gradually from 8 to 15. Assuming that the number of nurses actually on duty on a single day shift is 8, a 1,000 day simulation is equivalent to 8,000 nurse-shifts; assuming that the number is 9, a 1,000 day simulation is equivalent to 9,000 nurse-shifts, and so on. Figures 15-18 show the distribution of the number of patients for whom nurses are responsible when the total task times for the entire ward are shared by 8 to 15 nurses, and the frequency distribution of task times per nurse in each of those cases (Horizontal axis: minutes. Vertical axis: number of persons).

Let us look first at the situation where the number of nurses specified is lowest. Almost every nurse is responsible for between 5 and 7 patients. The largest number of nurses has overall task times of between 560 minutes (9.3 hours) and 570 minutes (9.5 hours). The average time for the whole group is 530 minutes. It can be seen that there are some nurses whose overall task time exceeds 10 hours (over 600 minutes). Next, with regard to 'patients
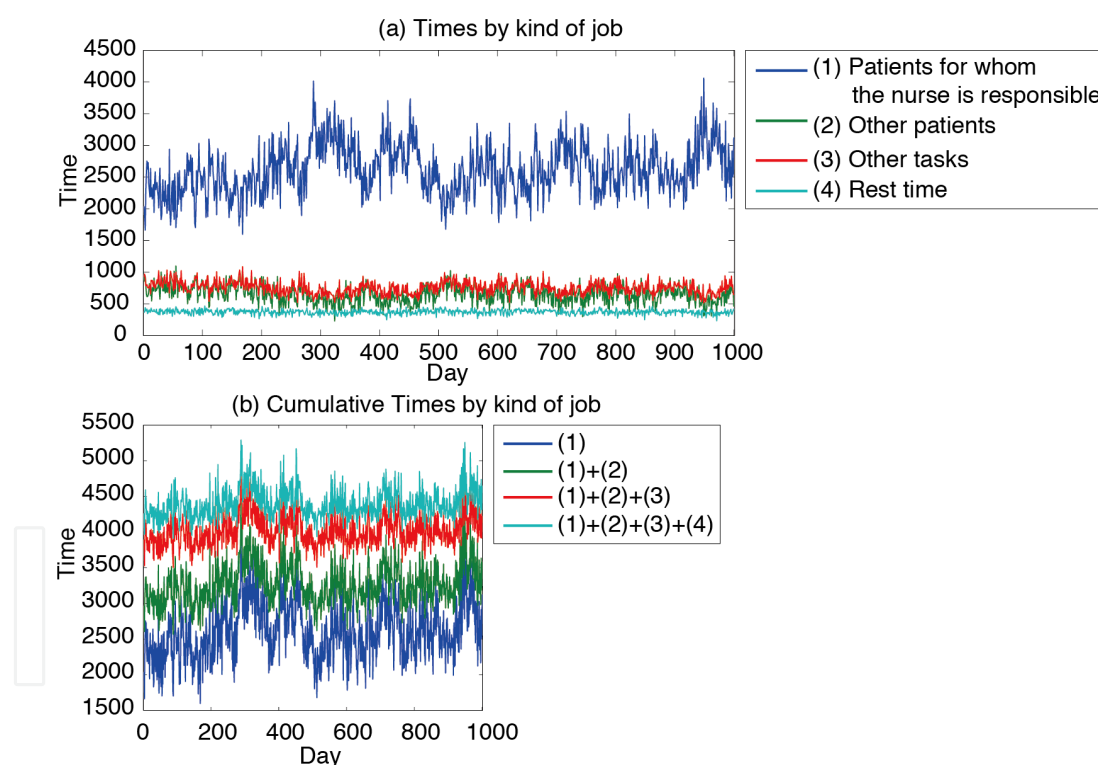

Figure 14. Changes in task times by purpose.

for whom the nurse is responsible,' the largest number of nurses have times corresponding to the median of 312 minutes, or about 5 hours. Time spent on 'tasks performed for other patients' is about 30 minutes, and the number of nurses who spend about 60 minutes on 'other tasks' stands out. With regard to 'rest time,' it will be seen that almost no nurses were able to take the 60 minutes of rest prescribed by law.

As the number of nurses on duty progressively increases, the number of patients for whom each nurse is responsible gradually decreases, until a situation is reached in which some nurses are responsible for 0 patients, and where the ward's nurse requirement can be said to be satisfied.
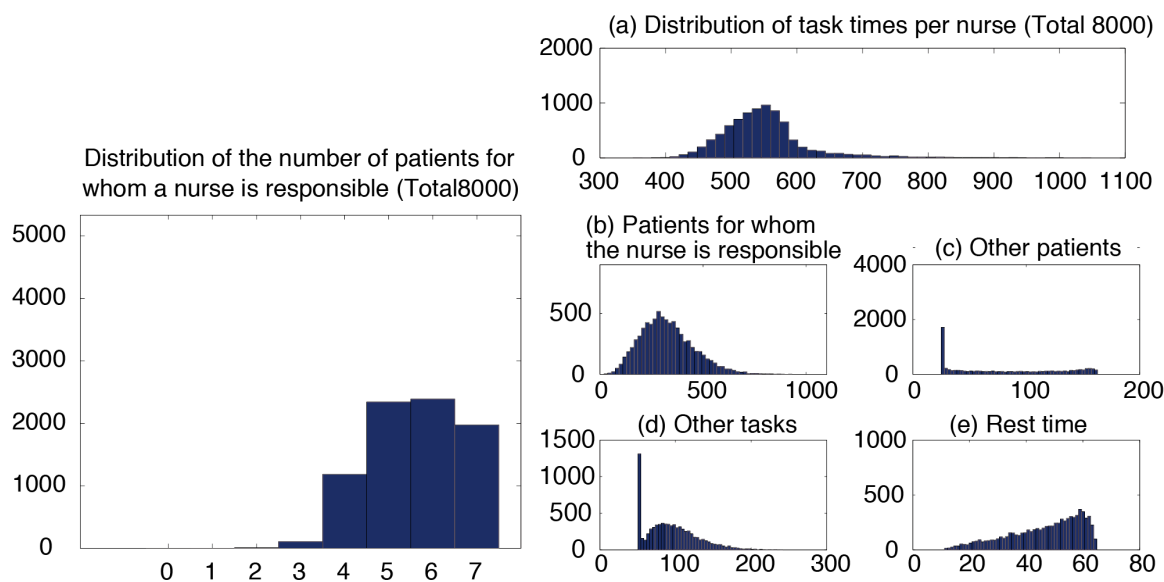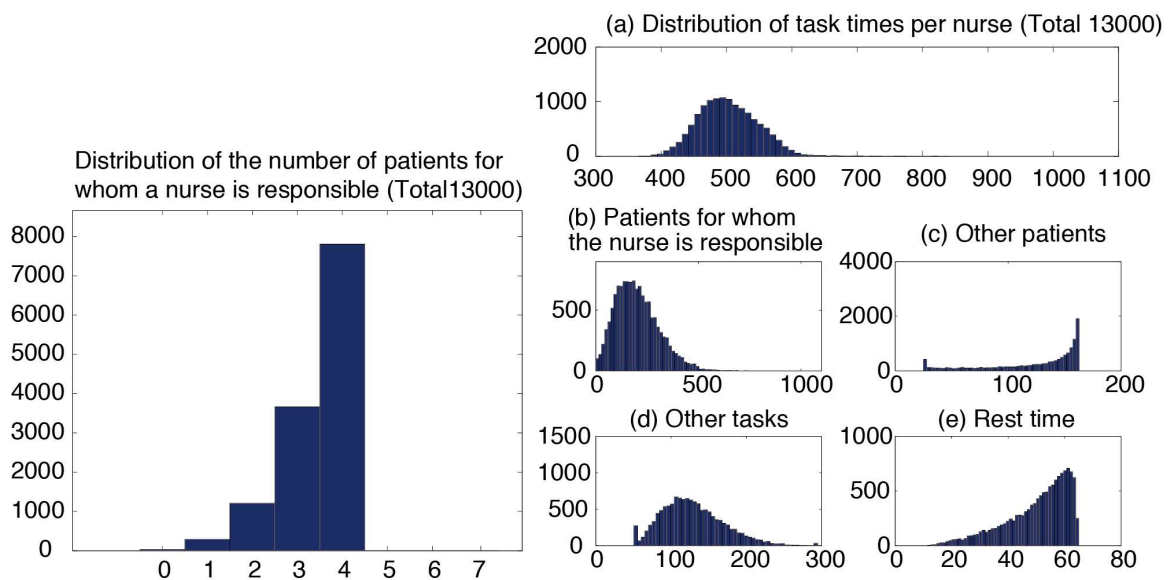

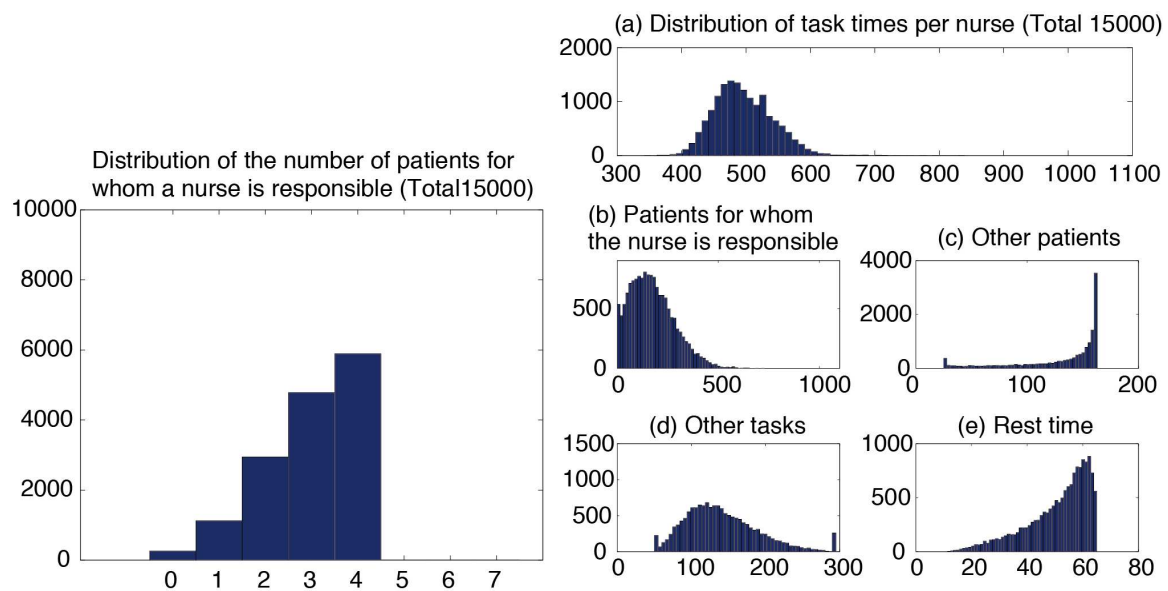**Figure 15.** Tasks times when number of nurses is 8.
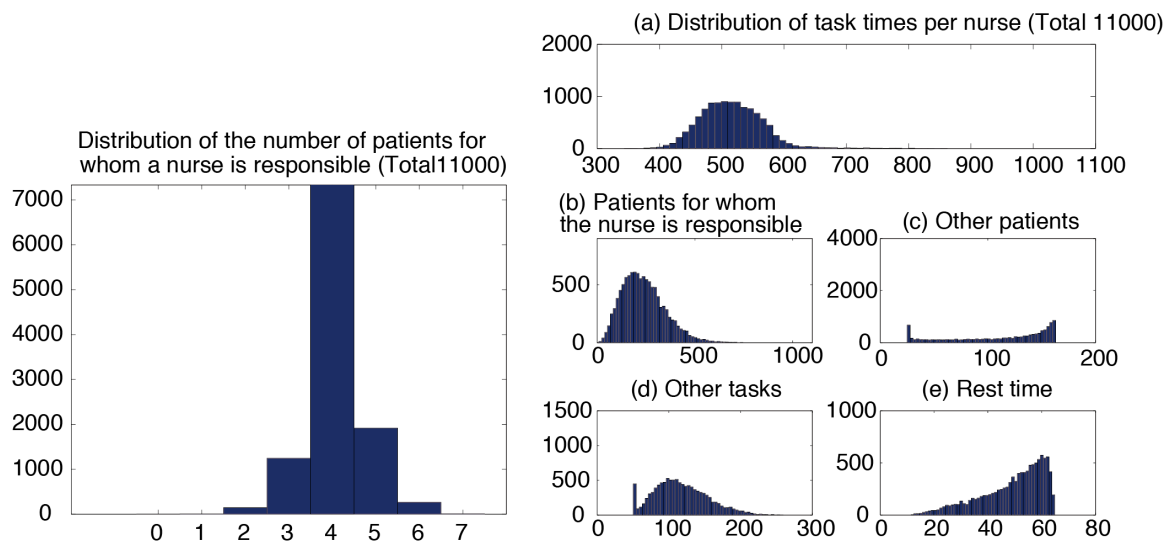
Figure 16. Tasks times when number of nurses is 11.

In addition, while time spent on 'tasks performed for patients for whom the nurse is responsible' decreases along with this variation in the number of patients for whom a nurse is responsible, more nurses are able to increase the time they spend on 'task times devoted to other patients' and 'time spent on other tasks,' while the number able to take a rest period approaching 60 minutes will be seen to have increased.

Figure 17. Tasks times when number of nurses is 13.

Figure 18. Tasks times when number of nurses is 15.

4. Observations

We carried out an evaluation of whether the simulation algorithms we constructed might be incompatible with reality.

4.1. Changes in numbers of patients by nursing intensity

We were able to judge whether the cohort of patients on the ward reflected the real-world situation, in which patients still requiring assistance are in a majority. The reasons are as follows.

The ward studied was a surgical ward, so for almost all patients the period immediately following surgery or related tests was when their condition was at its severest. After a few days they would emerge from the acute stage (when nursing intensity was A) and enter a period during which they received intravenous drugs or other active treatments as their wounds followed the healing process (the period of nursing intensity B). This follow-up period was the longest. As soon as the outlook was such that the patient could be sent home or return to work (the period of nursing intensity C), discharge followed within 1 to 2 days. In our simulation results also, almost all the patients on the ward were at nursing intensity A or B.

In addition, it seemed that not only nurses but also all medical professionals agreed that they had a sense that on occasion, after the number of patients in a severe condition increased, that state of affairs would continue for some time, and then the patients would all recover at once.

4.2. Task times devoted to patients for whom the nurse is responsible, by nursing intensity

It is, of course, entirely natural that care time required increases with severity of nursing intensity. The results we obtained conformed to this observation and thus seemed to reflect reality.

4.3. Changes in task time by purpose for the whole ward

There are some tasks that need to be performed when spare time becomes available, but, because there is a fixed limit on task time, tasks are in fact omitted. Our simulation appeared to reflect this reality. The reasons are as follows.

An increase in the amount of care time devoted to the patients for whom a nurse is responsible means that the quantity of care, in the form of treatment and observation of the patient, is greater. But on closer examination it appears that the number of drugs prescribed increases, many tests have to be carried out, extra treatments and prescriptions are added, tasks such as changing dressings increase in number, or the procedures involved become more complicated. This affects the usage quantities of documents, medicines, and other materials managed by the ward. The result is that management task time also expands. In theory, therefore, it seems that if 'task time devoted to patients for whom the nurse is responsible' increases, 'time devoted to other tasks' that have no direct connection with patients should also increase, and as a consequence overall task time (shift time) ought to increase. The results of our simulation show, however, that when 'task time devoted to patients for whom the nurse is responsible' increases 'task time devoted to other tasks' is reduced and overall task time does not increase very much. No extension of time devoted to 'other tasks' or of overall task time was observed.

4.4. Work time per nurse

The 9-hour work shift prescribed by law comprises 8 hours of working time and 1 hour of rest time. There was no marked deviation from this time in our simulation results.

4.5. Changes in task time by purpose

When task time available for completion of 'tasks performed for patients for whom the nurse is responsible' is insufficient, the nurse is unable to carry out 'tasks for other patients' and 'other tasks.' But when the number of nurses increases and adequate care time can be devoted to patients for whom a nurse is responsible, time can be found to spend on aspects of nursing care such as tasks performed for 'other patients' and 'other tasks' that have had to be neglected before the increase in nursing staff. Our simulation appeared to reflect this reality. This is also a reflection of the fact that, as noted under 4.3, there are tasks that are omitted because working time is limited. Specific examples are given below. There are occasions when a nurse is so busy providing care to patients for whom she is responsible that she is unable to respond to a call from another patient, even one she is responsible for. On occasion, under these conditions, if a nurse passing along a corridor discovers a patient whose intravenous drip is leaking, if that patient is not one for whom she is responsible the series of tasks involved in dealing with a leaking intravenous drip assume a low priority for her and she must call the nurse who is responsible for the patient in question. If the nurses continue to be fully occupied with patient care, they are unable to tidy up the ward or put things in order. As a result, the ward declines into a state where in an emergency staff must look for a wheelchair that is not in its proper place, or they trip over or bump into things that are in places that should be empty, or they find that when they need to fix a drip in place quickly the tape they need has run out, or that there are not enough specimen containers when specimens are needed for urgent tests, or when pressure of work slackens a little and they set out to update their records they find that the necessary forms have run out. However, when the patients on the ward are in a relatively settled state and care time requirements are met, if a nurse discovers a patient with a leaking intravenous drip in a corridor she will undertake the series of measures necessary to replace it, even if the patient is not one for whom she is responsible, and will fully carry out administrative and management tasks such as tidying the ward and putting things in order.

We observed in our simulation results also that when the number of nurses on a shift was increased, there was a decrease in the number of nurses who spent a very large amount of time on 'tasks performed for patients for whom the nurse is responsible' (unbalanced workloads were resolved) and at the same time there was an increase in the number of nurses who spent a large amount of time on 'tasks performed for other patients' and 'other tasks.'

We concluded from the above that the simulation algorithms constructed in this study conformed to reality.

5. Conclusions

We created a formula for the nursing times provided on the basis of time study data obtained through a short-term survey and patient condition information, and quantified factors governing tasks.

2) We constructed simulation algorithms combining the results under 1) with information accumulated over an extended period on the length of hospitalization and patient condition (nursing intensity).

6. Topics for further research

We believe that there is scope for further investigation of the points below to enable the algorithms constructed for this study to reflect reality more accurately.

6.1. On nursing intensity

Given that it is based on subjective observation, the concept of nursing intensity is lacking in objectivity. Evaluation of patient nursing intensity was carried out on the ward studied by highly experienced nurses. Fixed evaluation standards exist on certain wards and confidence is high with respect to the replicability of judgments on those wards, but it is clear that these standards differ from one ward to the next. In order to make clear what factors enter into evaluations relating to nursing intensity, it is necessary to secure methods of evaluation of patient condition that use phenomena observable by anyone, with objective indicators such as 'how many drains have been inserted.' We believe it is necessary to investigate objective indicators to replace nursing intensity, or to attempt to effectively quantify nursing intensity.

6.2. On the collection of patient condition information

Since there is a time-lag between actual patient condition and the collection of patient condition information, there may be some margin of error in estimated care times. The patient condition information used in this study was based on information gathered at about 10:00 a.m. during the day shift. Information on patients who underwent surgery or other invasive procedures during the day shift and whose nursing intensity changed was incrementally updated and adjusted appropriately. The reason for carrying out the evaluation at 10:00 a.m. was simply that this was a convenient time from the point of view of the running of the ward, and in spite of the fact that patients' conditions were actually changing hour by hour, care time was only estimated for one shift at a time. In the present study, we regarded this as a limitation about which nothing could be done, but we believe that it will be necessary to carry out further investigations in the future, as developments in IT systems within institutions make it possible to accumulate information concerning changes in patient condition in real time.

6.3. On the statistical values for numbers of patients on the ward

There is a need to calculate averages and variances for changes in number of patients on the ward over a relatively long period. For this study, averages and standard deviations for numbers of patients on the ward were calculated using data from a short-term time study

and cannot be used as population means with any confidence. But when long-term changes in numbers of patients on the ward are used, it has to be borne in mind that numbers of patients on the ward fluctuate markedly during holiday periods such as New Year and the summer O-bon Festival, on weekends, and at times when conferences attended by large numbers of doctors are held.

6.4. Handling skewed values

As mentioned in 3.3.2, data relating to anomalous tasks deviated from normal distribution and was therefore excluded from the present analysis. However, it is a fact that nurses may carry out duties on the ward in the morning and undertake anomalous tasks such as attending meetings in the afternoon. Such anomalous tasks occur in a certain proportion throughout the year and a special distribution, different from those of ordinary tasks, must be assumed for them. We believe that we need to improve the accuracy of our simulation by actively seeking to include data concerning unusual phenomena as variables.

6.5. Seasonality

In this study, as we explained under 'Method,' only simulations of day-shifts on weekdays were carried out and we were unable to accommodate the special systems in force on weekends and at the holiday times mentioned above. Under these special systems, the numbers of nurses on duty and of patients on the ward fluctuate considerably. Because this greatly affects task times, we believe that there is room here for future investigation.

6.6. On the roles and level of experience of nurses

We have not incorporated into our simulation the difference in function of nurses such as team leaders, who head and support a team rather than taking responsibility for patients, or nurses that have responsibility for a small number of patients and carry out management tasks alongside these duties, as is very often the case with ward supervisors. We assumed for the purpose of the present simulation that all nurses were nurses whose actual work involved being responsible for patients, but in fact there are nurses who perform their roles in different ways. In addition, each year there are new recruits who need constant guidance from experienced nurses. They may, after some months, be able to cope with basic tasks, but they still have limitations, such as not being able to take responsibility for patients whose condition is severe. Further investigation of a methodology that will reflect this state of affairs is needed.

6.7. Comparison with the real world

It is not possible at this stage, but an evaluation that compared simulation results with reality would be the most reliable form of evaluation. In recent years, computer systems such as ordering systems, distribution systems, and electronic patient charts have been actively adopted as hospital information systems, and even more widespread use of IT→it can be expected in the future. We believe that if it becomes possible to collect task time data without

committing large amounts of effort and funding, as required for time studies at present, this is an approach that must be investigated.

7. Outlook for the future

7.1. Standardization of methodology

We believe that it would be useful to standardize the methodology for carrying out the series of operations that was constructed for this study. Some reasons are suggested below.

Because each institution and each ward has different attitudes towards individual patient characteristics and tasks, and different methods of executing tasks, it is difficult to calculate universal quantities for essential nursing tasks that can be applied in any institution. In addition, there are cases in which it would be dangerous, or lead to the loss of desirable qualities, if a fixed value were applied to all institutions. It is desirable to go through the following series of operations. Having considered the task management appropriate to the ward, while preserving the ward's characteristics, a time study of the ward should first be carried out, then a virtual environment simulating the actual ward should be created, making use of existing cumulative information, and test experiments should be conducted using that virtual environment.

7.2. Combination with other information

7.2.1. Relationship to incidents and accidents

We believe that it is possible, on the basis of information derived from incident and accident reports, to explore the relationship between medical errors and task times from a number of viewpoints. As medical malpractice suits have increased in recent years, consciousness of medical errors by nurses has increased and the number of nursing departments that make it a requirement to write near-miss incident reports has grown. Protection of patient safety requires maintenance of minimum standards in all medical jobs, including nursing, and is of the utmost importance. Fujita et.al. have pointed out that there are errors that are related to busyness and errors that are not related to busyness. It is possible to extract from the analysis results the answers to such questions as: 'What kinds of incidents and accidents increase with an increase in task time?' 'What amount of task time elapses before the number of cases reported begins to increase?' and 'After how many hours of overtime work over how many days in a row does the number of cases reported begin to increase?' These analysis results will also provide important material for the investigation of task allocation and assignment of nursing staff with a view to minimizing medical errors.

7.2.2. Patient satisfaction

It is possible to explore the relationship between nurse's task time, particularly 'time devoted to patients for whom the nurse is responsible,' and patient satisfaction. We believe

that this has great significance for the improvement of nursing care. We are entering an era when patients are expected to draw sharp distinctions among hospitals. As a result, more and more hospitals are increasing the number of their private rooms, where patients can spend their hospital stay in privacy, and are giving thought to the appearance of the hospital's interior and the richness of its amenities. But we believe that what is more important to patients than the physical elements of the institution is that they should be able to receive care that they are satisfied with in an atmosphere based on a relationship of trust with the medical personnel. Sickness is a special condition, and patients need warm-hearted support at all times. The nurses, who spend more time in contact with the patient than any other medical personnel, have a particularly large role to play, and are at the forefront of ensuring customer satisfaction.

7.2.3. Level of fatigue

In the present study we analyzed only the day shift, but we believe that by constructing a virtual ward environment that takes other shifts into account and carrying out simulations, it would be possible to show the relationship between task time and nurses' fatigue. It has been pointed out that symptoms of fatigue among nurses are greatest after the evening shift and that where the night shift is concerned there is considerable fatigue before the shift begins. There is concern that the physical and mental fatigue of nurses on the night shift has a negative effect on their work. Attempts have long been made to reduce the burden on nurses and to establish an efficient nursing system. One notable example was the introduction of the two-shift system, but no reference has been made to investigation of specific aspects of this working system, such as how its merits and demerits are related to the characteristics of the ward. It is important to re-investigate nurses' work systems, including conditions such as these.

7.2.4. Link between patterns of change in nursing intensity and clinical path

In this study we chose pattern of nursing intensity as the clinical path and, having fixed patient severity as a definite condition, it was possible to make a preliminary calculation of actual nursing task times. In recent years, much has been made of efficiency of treatment, and an increasing number of institutions have introduced the clinical path as a specific methodology. Among city hospitals and privately run general hospitals, there are institutions and wards that have almost completely adopted clinical paths, and that have been successful in the management of planned admission with almost no variance. We believe that in hospital institutions like this, it will be possible to effectively apply patterns of change in nursing intensity to items such as preliminary calculations of nursing personnel costs, which have a great influence on hospital management.

We feel that a combination of the experimental results derived from virtual environments as described in this study and other information will be helpful in the management of nursing tasks suited to various goals.

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References

[1] Burke, T. A., Mc Kee, J. R., Wilson, H. C., et al. (2000). A Comparison of Time-and-Motion and Self-Reporting Methods of Work Measurement. JONA, , 30(3), 118-125.

[2] Caughey, M. R., & Chang, B. L. (1998). Computer Use and Nursing Research Computerized Data Collection:Example of a Time-Motion Study. *Western Journal of Nursing Research*, 20(2), 251-256.

[3] Fagerstom, L., Rainio, A., & , K. (1999). Professional Assessment of Optimal Nursing Care Intensity Level: A New Method of Assessing Personnel Resources for Nursing Care. *Journal of Clinical Nursing*, 8, 369-379.

[4] Goldstein, H. (2003). *Multilevel Statistical Models* (Third Edition), Oxford University Press Inc., New York.

[5] Hall, L. M., Doran, D., Pink, G. H., et al. (2004). Nurse Staffing Models, Nursing Hours, and Patient Safety Outcomes. *JONA*, 34(1), 41-45.

[6] Jones, K. (1991). Specifying and Estimating Multi-Level Models for Geographical Research. *Trans. Inst. Br Geogr. N. S.*, 16, 148-160.

[7] Langlois, S. L., Vytialingam, R. C., & Aziz, N. A. (1999). A Time-Motion Study of Digital Radiography at Implementation,. *Australasian Radiology*, 43, 201-205.

[8] Magnusson, A. R., Hedges, J. R., Ashley, P., et al. *Resident Educational Time Study: A Tale of Three Specialties*, *Academic Emergency Medicine*, 5(7), 718-725.

[9] Meyers, F. E., & Stewart, J. R. (2002). *Motion and Time Study for Lean Manufacturing* (3rd ed.), New Jersey, Prentice Hall.

[10] Vinson, D. C., Paden, C., & Amelia-Sales, Devera. (1996). Impact of Medical Student Teaching on Family Physicians' Use of Time. *The Journal of Family practice*, 42(3), 243-249.