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Capacity Planning in Hospital Nursing: A Model for Minimum Staff Calculation

Executive Summary

- An aging population, emerging technology, heightening patient expectations, rising health care costs, shorter patient stays, and growing pressure to improve quality have made the management of nursing resources even more critical today.
- While approaching a model for staffing levels, the authors considered factors such as patient acuity, work redesign, and minimum quality standards.
- The methodology for analysis included estimating the time needed to complete nursing tasks and calculating the average number of tasks per patient.
- With respect to nursing quality measures, the study examined the adequacy of nursing documentation including admission history, assessments, nursing procedures, and discharge report as well as nursing-driven outcomes such as fall and phlebitis rates.
- Lastly, the authors determined the theoretical number of staff needed to provide nursing care according to quality standards.

TODAY, THE APPRECIATION of the important work of nurses in the sound running of hospital institutions, and in any health organization, is growing (Silva & Aderhodlt, 1989). At the same time, within the public budget devoted to health, the cost of staff is also a main concern. The successive cutbacks in staffing result in an increase in staff workload, especially in nursing services, where quality issues are also an important concern. This can lead to increased dissatisfaction of staff and to a notable increase in the risk of professional errors (Hendrickson, Doddato, & Kovner, 1990).

To design a model that permits the determination of the number of nurses required to cover minimum levels of quality, it is necessary to define several prior steps including (a) patients must be classified (not all patients require the same nursing care), so as to subsequently identify the different tasks that nurses carry out in their work; (b) discover a way of determining the time taken to carry out each nursing task, (c) identify the desired levels of quality in the hospital, (d) establish the relationships between the theoretical staff and quality levels, and (e) establish the procedure for calculating staff.

The purpose of this article is to present an efficient methodology for capacity planning in the case of hospital nursing, the ultimate aim being to determine the minimum staff needed to carry out all the functions corresponding to a nursing unit, bearing in mind the quality of the service provided.

The Problem of Capacity in Nursing

Managing nursing staff in hospitals is a complex task, not only because of the characteristics *per se* of staff management in whatever activity in the service sector, but also due to the social and economic importance of the work that these professionals carry out (Shullanberger, 2000). An urgent need exists to match patient needs

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with the health resources available. In recent years, both medical and nursing staffs have grown notably without an excess of available resources (Visser, 1997). The present study focuses on nursing staff.

In the United States, the management of nursing has been considered worthy of extensive, in-depth analysis. For instance, a study conducted in a hospital with six different specialized units (Hendrickson et al., 1990) concludes that on average nurses only spend 31% of their working time directly with patients, devote 45% of their time to clinical, indirect care, and spend 10% of their shift on nonclinical activities. At the same time, nurses spend 10% of their working day directly preparing therapies and spend an additional amount of time (5% estimated) on indirect tasks (correcting mistakes, checkups, counts, verifications, etc.). The results also indicate an average of 1 nurse for every 4.8 patients on the day shift and 6.9 on the night shift.

In Europe, hospitals are faced with a considerable increase in demand for health care, high patient expectations to improve service and quality, and tighter and tighter budgets and greater restrictions on the availability of resources (Visser, 1997). This provokes imbalances between the service offered to patients and hospital management since their respective objective levels of use of hospital resources differ (among which we find nursing staff grouped with the number of beds and operating theaters available). This situation is even more adversely affected by the following current tendencies in these services (Visser, 1997; Vries, Bertrand, & Visser, 1999):

- The present demand for care is growing as a result of the changes in population structure (more elderly).
- Through research, new therapies and techniques are appearing. Some of these technologies replaced previous outdated technologies, but many are new systems to be included alongside already available therapies and treatments. That is to say, the introduction of a new technology will simply lead to a new demand and not to the substitution of an old technique to cover one and the same treatment.
- Normally, patients do not wish to wait more than 15 minutes for a specialized consultation or for a checkup. Neither are they willing to go to the hospital twice for the combination of a visit to a specialist and a checkup, if they can do both in 1 day. In the case of having to be admitted to hospital, a previous appointment is preferred for admission or at least 1 week's prior notice. This requires greater organizational effort and frequently the use of more resources.
- The costs of health care must be controlled at a national level to maintain a competitive position with respect to other countries. This means that hospitals face heavy reductions in their budgets.
- The stay of patients in hospitals is being shortened due to the greater turnover of treatments of hospitalized patients, and to treatments at health and day care centers, all of which require the use of new technologies and increased specialization within the health system.
- Moreover, pressure is also building to increase the quality of services, and to reduce waiting lists and times within the process.

Faced with this situation, the aim of every nursing administrator is to balance the needs of offering patient services and the capacity of available human and material resources. To do so, a method should be defined to measure the seriousness of the patient's condition on admission, on the basis of which nursing care needs are generated. Given the diverse combination of treatments that a patient may require, it is essential that the topic of patient classification be tackled so as to ascertain the specific needs of each of the possible types of existing patient and, thus, make the problem at hand manageable.

Classification of patients: A prerequisite. A number of systems have been proposed at an international level for classifying patients that, on the basis of the category to which patients have been assigned, permit the estimation of the care activities that they will require, and which may thus be provided to them during their stay (or at least while their state does not vary, leading to the subsequent change of class or category). A patient classification system consists, therefore, of a set of tools for grouping together patients in such a way that each group receives equal or similar care. This has been used to assign nursing staff to shifts, normally in line with budgeting considerations, so that the needs of each patient may be covered by the available staff (Poulson, 1987).

In the last 40 years, patient classification has taken on more relevant significance for nursing administrator. Patients are classified according to the evaluation of seriousness of their illness, the severity of the symptoms they present, and the dependence on the nurse and/or the interventions required on the part of nursing staff (Rosendall, 1983). Traditionally, these systems for classifying patients have been based on others already predefined for the medical field and thus had to be redesigned in accordance with the particular characteristics of nursing for their subsequent application in this field. Furthermore, these tools are also a basis for evaluating staff productivity.

At the same time, measuring workloads in nursing is not a simple task. The time needed to carry out certain care depends on several factors, such as the place where it is carried out, the actual patient who receives the care, and even the

Table 1.
Record for Calculating the Total Number of Daily Hours of Care Required

Type of Beneficiary	Number of Beneficiaries	Relative Load According to Types	Total Load According to Types	Desired Hours of Care	Required Hours of Care per Day
1	...	...	...	...	...
2	...	...	...	...	...
...	...	...	...	...	...
	(Total beneficiaries)		(Total load of care treatments)		(Total)

Source: O'Brien-Pallas, Leatt, Deber, and Till (1998).

person who carries out the practice. In general, it may be said that two strategies exist for measuring or evaluating the workload in nursing (Giovannetti, 1979):

1. One based on the estimation of the average time needed to carry out the care treatments for each patient category, which requires having previously decided on the patient classification system to be used.
2. Another based on the times of standard care treatments for specific nursing procedures.

Among the most commonly used systems for evaluating nursing workloads are GRASP, PRN, and Medicus. All of these systems have in common the measurement of care treatments individually required for each patient, and the load imposed on the nursing staff due to activities other than direct care (for example, the filling out of the patients' nursing records or other administrative tasks). Therefore, the measurement of the total care received by a specific patient is not easy to calculate, since many indirect activities are intermingled for different patients or are tasks pertaining to the management of the unit (Williams, 1977).

Of all of these, Medicus is the system finally employed in the capacity model proposed in this study, since Medicus is the one that best adapts to the characteristics of the hospital subject to this empirical study. The desired time of care treatments is revised annually and adjusted to needs. With this methodology, different types of levels of dependence are established according to the nursing care required, and the relative workload is estimated for each. Then, depending on the patient's dependence level, multiplying this value by its relative load provides the total load of each level of care. This value, multiplied by the desired amount, gives the hours of care required per day of each type. The total is reached by adding up the hours of each level of care (see Table 1).

The greater accuracy of this type of measurement allows an objective evaluation of the care to be given, which makes it possible to know the nursing resources needed quite precisely. This presents, among other advantages, the assignment of tasks to each professional without work overloads, which improves his/her job satisfaction, thus contributing to an improvement in both the working environment, and (even more relevant) the quality of service perceived by patients and their families.

Proposed Methodology of Analysis

The model proposed for determining the minimum capacity of hospital nursing services requires six successive steps (see Figure 1).

1. *Estimating the times needed to execute the different nursing tasks.* The starting point consists in ascertaining as exactly as possible the real times of execution, under normal conditions, of each of the different tasks that the nurses carry out in their day-to-day work in a specific unit. Among the possible alternatives for carrying out this phase are those of time study using a stopwatch, laboratory experiments, or the Delphi methodology.
2. *Calculating the average number of activities per patient.* To calculate the theoretical staff, once the execution times of each of the different nursing tasks are known, it is necessary to ascertain for each type of patient (dependence level) how many activities A_i of type I are carried out on average per shift (see Table 2).
3. *Calculating the theoretical staff based on historical data.* The theoretical staff is calculated for each of the months for which registers are held, using a system of workload evaluation (the hospital's own or an adapted one).
4. *Calculating the historical ratio.* Subsequently, a ratio is determined which represents the quotient between the real number of staff on the ward and the theoretical number calculated previously (see Table 3).
5. *Consolidating the quality re-*

Figure 1.
Schematic Representation of the Proposed Methodology

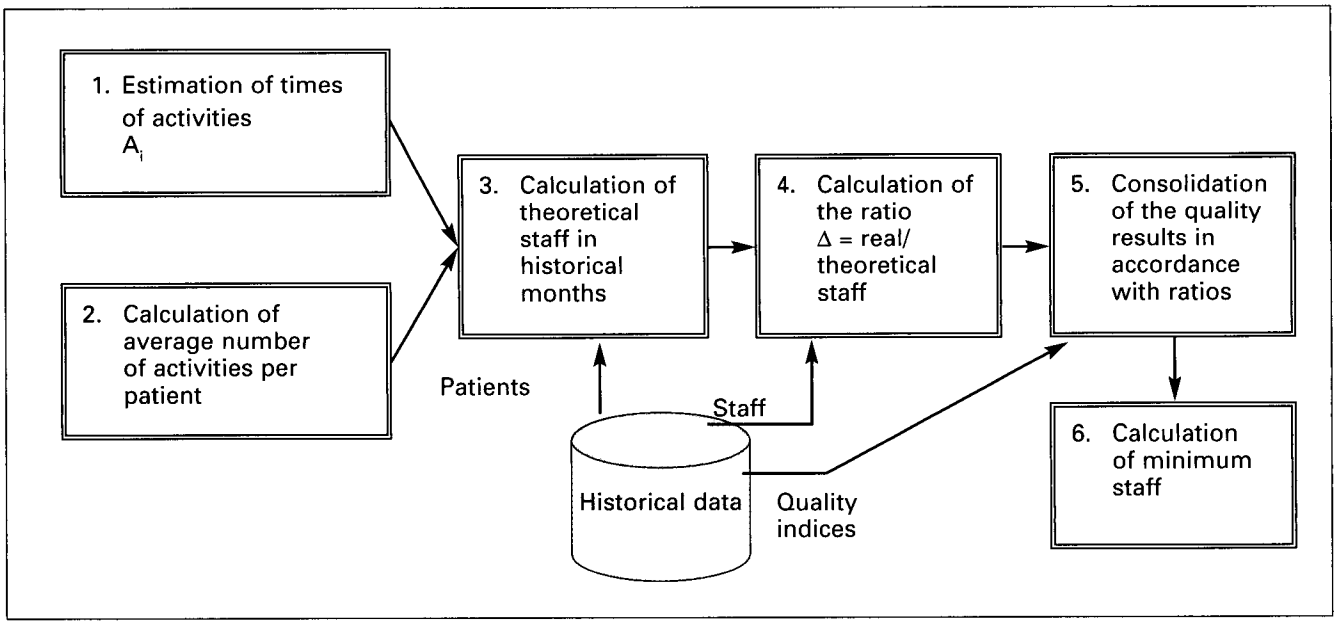


Table 2.
Average Number of Activities per Shift for Each Type of Patient (Assuming Three Levels of Dependence). This Information Is Obtained from the Sample of Patients.

Level of Dependence of the Patient		
1	**2**	**3**
Activity 1→2.0 times	Activity 2→4.0 times	Activity 1→1.0 time
Activity 2→0.5 times	Activity 5→0.5 times	Activity 3→1.0 time
...	...	...
Activity n→1.5 times	Activity n→1.0 time	Activity n→2.0 times

Table 3.
The Ratio Δ Between the Real Staff on the Ward and the Theoretical Staff Calculated by the Medicus System Using Historical Data

Month/Year	Theoretical Number of Nurses	Real Number of Nurses	Δ = Real/ Theoretical
October 1998	6	4	0.66
November 1998	7	7	1
December 1998	5	6	1.2
...	...	...	...

sults in accordance with the ratios. Next, the quality results I_i obtained in accordance with the historical data collected are analyzed (see Table 4). Subsequently, these data on quality are consolidated on the basis of the ratios.

6. *Calculating minimum staff.* The proposed model relates the available capacity to specific quality indexes, thus evaluating how the number of staff affects the quality of the services offered.

With the information obtained in the prior step, grouping together the quality indexes into a single one by means of a specific function, it is possible to estimate the expected quality on the basis of the values (and therefore on the basis of the theoretical staff).

Thus, given a specific ward on any day, on the basis of the type of patients that are received, it is possible to calculate the theoretical number of nurses on the ward (on the basis of standard times). By multiplying this staff by the specific factor determined according to the aforementioned analysis it is

possible to obtain the minimum admissible number of nurses on the ward, bearing in mind the desired levels of quality.

Applying the Model to a Real Environment

Description of the study. The methodology proposed in this study was applied to the Hospital Álvarez Buylla, belonging to the Spanish National Health System-Insalud, located in Mieres (Principality of Asturias, in the north of Spain). The hospital has 202 beds and offers services of hospitalized medical-surgical attention, outpatient consultations, and diagnostic support to the inhabitants of the area.

The hospital was built in 1954 though it has undergone modifications since then; its present structure dating from 1986. The Hospital Álvarez Buylla has a staff of 554 workers, of which 4 belong to the management staff, 101 are doctors, and 295 are nurses and nursing assistants. If the resources of this hospital are compared with the body of the Spanish National Health System, a level of staff slightly lower than the average is appreciated.

Of the different units in the hospital, the one chosen for this research study was internal medicine, since it was considered to be the most representative from the point of view of nursing tasks and, in the particular case of the hospital under study, has the youngest staff, and which is therefore more favorable with respect to obtaining a high level of participation in the study.

Empirical study. Due to the difficulties that the other alternatives presented in this study, it was decided to apply the Delphi methodology to determine the standard times. This type of methodology has already been applied on other occasions within the health field (for instance, Procter and Hunt [1994] presented an experience using this method, although their aim was to clearly define the professional concept of nursing and the tasks to be carried out on the basis of the patient's dependence level).

Table 4.
Quality Indices Registered for Each Month (And Therefore for a Specific Δ Ratio)

Δ	Month/Year	Registered Quality Indices			
		I_1	I_2	...	I_n
0.66	October 1998	0.8%	0.0	...	1.0%
1.00	November 1998	0.5%	0.0	...	0.0
1.20	December 1998	0.6%	0.1%	...	0.0
...		...	...	...	...

The questionnaire used in the first mailing was based on a listing of the different activities into which hospital nursing may be broken down, elaborated in the "Signo" project instigated by the Spanish National Health System (Insalud, 1996). This listing was corrected in accordance with the particular characteristics of the specific nursing unit under study (internal medicine), eliminating the tasks that do not belong to this nursing unit or that are normally carried out by nursing assistants. The panel of experts considered was formed by the nursing staff of the unit under study at the Hospital Álvarez Buylla in Mieres (14 nurses). The distribution of this initial questionnaire was carried out by mail to the homes of each professional on January 14, 2000 and replies were received until February 29, 2000.

Once the initial questionnaires were received, the pertinent statistical values (mean, standard deviation, and interquartilic interval) were calculated for each nursing activity under consideration. As consensus was not reached during the first Delphi round, a second mailing was elaborated only for those activities where a relevant degree of discrepancy had been demonstrated which needed to be justified. Eight of the activities included in the first questionnaire were eliminated from the second, as they were considered by a large number of the experts to belong to the tasks of nursing assistants and not to the nurse, who is the subject of study. The distribution of this second questionnaire was carried out in a similar way to the first; only soliciting the opinion or change in the original response of the expert in those cases where these fell outside the corresponding interquartilic interval. Finally, a number of definitive conclusions were extracted (see Table 5).

It is important to highlight the fact that on comparing the times obtained in this Delphi study with those already existing in the documentation of the "Signo" project (Insalud, 1996), with the aim of ascertaining whether or not some kind of relationship between both studies existed that would indicate the possibility of extrapolating these times to other potential hospital services, and on analyzing the existing correlation between both series, a Pearson correlation coefficient equal to 0.732 was obtained with a level of significance of 0.01. This sample estimator indicates the presence of a high, positive relationship between both. The corresponding simple linear regression analysis was then carried out to determine this relationship precisely. The results of this analysis

are given in Table 6.

Subsequently, taking a sample of the patients at the hospital in Mieres as the starting point, the number of activities of each type that are normally carried out were determined as a function of the dependence level of the patients. The system considers three dependence types:

- Type 1: Autonomous patient
- Type 2: Semi-dependent patient
- Type 3: Patient totally dependent on the nurse

Given the difficulty of managing the previous years' clinical records of the hospital's patients (still not completely automated) and the amount of episodes present in each of these, a random sample of 236 patients was used. Of these, 63.6% were men. Average patient age was 67 years. With regards to the dependence level of the patient, semi-dependent patients predominated (50%), followed by autonomous patients (43.2%). The sample serves as a reference base for ascertaining the number of times that each of the different nursing tasks are carried out each day for a standard patient of each level of dependence (see Table 7).

With respect to quality indexes, nine were handled in the hospital study:

1. *Graphs and therapy sheet.* This is the register of the daily activity for medical monitoring. Among the basic data are patients' pulse and temperature checks (at least twice daily) and daily data on urine, vomiting, and bowel movements.
2. *The nurse's notes sheet.* This includes information on the daily work carried out by the nurse with a particular patient, mainly indicating the time and quantity of treatments and doses received by the patient.
3. *Admission evaluation sheet.*

Table 5.
An Extract of the List of Estimated Times for Each of the Activities Employing the Delphi Methodology

Activity Code	Description	Estimated Time (Minutes)
R01	Administration of aerosols	6.67
R02	Administration of oxygen	3.00
R03	Aspiration of secretions	7.83
R06	Breathing exercises	12.00
...	...	...

Table 6.
A Summary of the Results of the Multiple Regression

- Dependent variable: Insalud (time determined by Insalud study)
- Independent variable: Delphi (time obtained in the Delphi study)
- Pearson's correlation coefficient: 0.732
- Regression line: Insalud = 0.737•DELPHI + 4.231
- Durbin-Watson value: 1.758

Table 7.
Register of the Frequencies of Execution of the Different Nursing Activities in Relation to the Type of Dependency of the Patient and Calculation of the Times Needed Considering the Number of Patients of Each Typology

Activity	Number of Times			Times		
	Degree of Dependence of the Patient			Degree of Dependence of the Patient		
	Type 1	Type 2	Type 3	Type 1	Type 2	Type 3
R 01	1.65	4.28	2.6	11.03	28.53	17.33
R 02	0.21	0.56	0.2	0.62	1.67	0.60
R 03	0.10	0.05	0.00	0.81	0.36	0.00
R 06	0.03	0.09	0.00	0.41	1.12	0.00
AH01	0.00	0.02	0.00	0.00	0.23	0.00
AH02	0.00	0.00	0.00	0.00	0.00	0.00
AH03	0.00	0.00	0.00	0.00	0.00	0.00
AH04	3.14	1.60	0.8	43.15	22.06	11.00
AH05	0.14	1.49	2.4	2.41	26.05	42.00
...	...	...	...	...	...	...

This includes the basic information needed for the sound health attention of patients, both their personal details (age, home address, family and labor status, etc.) as well as their medical characteristics (allergies, vital signs, previous operations or treatments, etc.). It is elaborated on the patient's admission to the hospital.

4. *Nursing discharge report.* This is a document that includes the care received by the patient during his or her stay in the hospital as well as the post-hospitalization care required.
5. *Phlebitis rate.* This indicates the problems of vein inflammation resulting from some of the practices or treatments received by the patient.
6. *Fall rate.* Some patients need more or less attention based on their condition, especially if they are prone to falls. These may include different types: falls from bed, falls when patients go to the bathroom, falls in the corridors when patients are accompanied by members of their family, etc. An attempt should be made at all times to avoid these types of situations, since they can give rise to the worsening of the general state of the patient.
7. *Scab rate.* This refers to scabs or similar manifestations produced in patients as a result of certain treatments. An attempt should be made to avoid them or at least to reduce them as much as possible.
8. *Care planning sheet.* This reflects the specific care plans that the patient must receive as prescribed by the physician.
9. *Urinary infection rate.* This problem presents primarily in patients with catheters.

The last two indices were not employed in the present study because insufficient data were collected (this is a recently introduced index in this hospital nursing service quality control) and no significant differences were found in these data, respectively.

Table 8.
Quality Function Designed for this Study

Overall quality function = $0.2 \cdot \sum_{i=1}^{3} T_i^{\Delta} + 0.1 \sum_{j=1}^{4} FH_j^{\Delta}$, where:

T_1^{Δ} : mean value of the phlebitis rate for the interval Δ

T_2^{Δ} : mean value of the fall rate for the interval Δ

T_3^{Δ} : mean value of the scab rate for the interval Δ

FH_1^{Δ}: mean value of errors in the graphs and therapy sheet for the interval Δ

FH_2^{Δ} : mean value of errors in the nurse's notes sheet for the interval Δ

FH_3^{Δ} : mean value of errors in the admission evaluation sheet for the interval Δ

FH_4^{Δ} : mean value of errors in the nursing discharge sheet for the interval Δ

The first four quality indices refer to the adequate completion of several documents that nurses manage in their work, evaluating their percentage of correction. To evaluate them, 6 monthly histories were randomly taken per unit and the completion of a series of parameters was observed. In contrast, the remaining three indices indicate the number of incidences of each event as a function of the total number of patients attended.

The first four indices were evaluated in percentages and the three others as a ratio. To standardize them, the indices were inverted to the correct completion of the documents managed by the nurse. The errors committed by the nurses were calculated in an effort to reduce them.

In evaluating the total quality of the care delivered by the nursing staff, not all the indices described above present the same relevance. Therefore, an overall quality function was constructed where these indices are weighted on the basis of their importance. The values corresponding to the rates of falls, phlebitis, and scabs are linked to the direct care of the patient, as a result of which they are accorded the greater weightings (20%). On the other hand, the remaining quality indices employed are related to the indirect tasks carried out by nurses, but which are also necessary for the adequate development of their work. The weightings accorded to these indices were 10% (see Table 8).

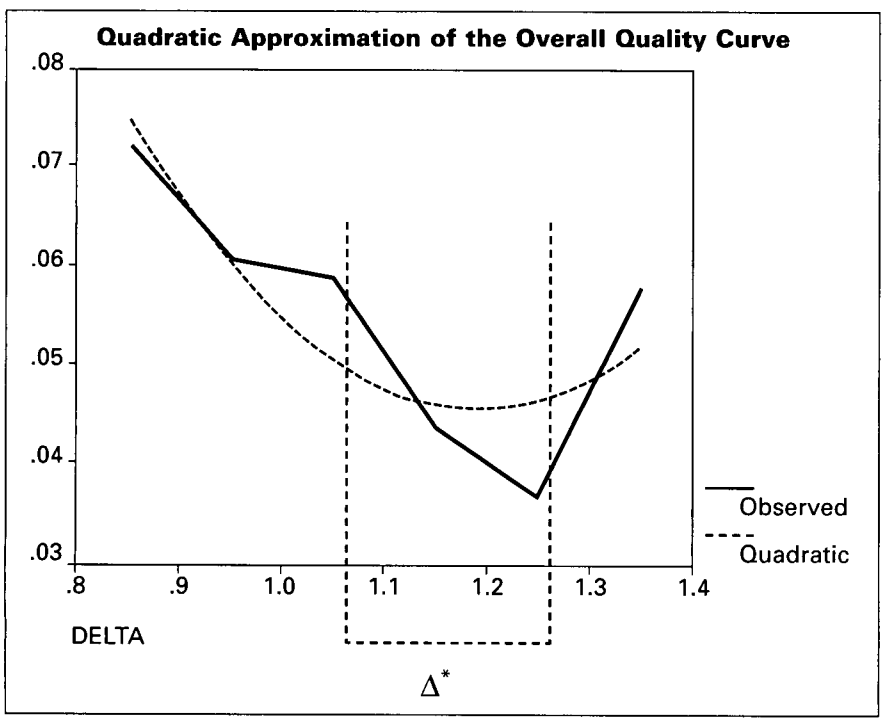
The overall quality function allows the determination of the staffing thresholds with which it is possible to offer the hospital nursing service while guaranteeing certain levels of quality. In this case, the quadratic function that approximates the relationship between the overall quality index and the delta ratio is shown in Figure 2. The values of Δ belonging to the interval [1.1; 1.3] appear to be acceptable for the service analyzed. Thus, the minimum staff is obtained on this ward by multiplying the theoretical staff obtained in each case by the inferior extreme of this interval, Δ^*_{min}=1.1.

One potential problem of data validation appears due to the fact that the majority of the temporary and stand-in contracts are made before vacations and rest periods of permanent staff in the holiday period (June, July, August, and December). There exists the possibility that the service offered to patients during these months is of an inferior quality, thus distorting the results. For this reason, the

Table 9.
Comparison of the Quality Index Means in Accordance with the Corresponding Time Period

	Holiday and/or Stand-In Periods	Mean	Levene's Test $H_o: \sigma_1^2 = \sigma_2^2$	Student t-Test $H_o: \mu_1 = \mu_2$
Δ	NO YES	1.0292 1.0486	Accept	Accept
FH_1	NO YES	0.1115 0.1008	Accept	Accept
FH_2	NO YES	0.0958 0.0836	Accept	Accept
FH_3	NO YES	0.0330 0.0526	Reject	Accept
FH_4	NO YES	0.0667 0.0991	Accept	Accept
T_1	NO YES	0.0046 0.0035	Accept	Accept
T_2	NO YES	0.0266 0.0330	Accept	Accept
T_3	NO YES	0.0965 0.0993	Accept	Accept

Figure 2.
Determination of the Ratio Δ^* min



Overall quality index = 0.3997-0.5949•Δ+0.2500•Δ² (significance level of 0.135)

$\Delta^* = [1.11; 1.20] \rightarrow \Delta^*_{min} = 1.11$

hypothesis of the equality of the means of the quality indices in the aforementioned periods and the remaining months of the year was tested. The results of this analysis are found in Table 9. No significant difference appears to be confirmed between the quality indices in periods with high levels of temporary hiring of staff with respect to the remaining months of the year.

Conclusions

The present study proposes a model for calculating the minimum staff in a nursing unit, guaranteeing a minimum level of quality care to patients during their stay in the hospital. It is worth highlighting, on the one hand, the social relevance of the sector under study, and on the other, the contribution of this model at a time in which the health sector is undergoing budget cutbacks worldwide, especially in the area of human resources.

The proposed model was studied in a real environment, the Hospital Álvarez Buylla in Mieres (Spain), using a Delphi study to estimate the duration of the tasks (obtaining activity times strongly correlated with other prior contributions carried out by the Spanish National Health System), the study of real staff, the hospital's quality indices, and the register of patients.

The aim of the study was not limited to calculating theoretical staff, but also to determine the minimum levels of quality in the care offered with which the tasks of hospital nursing should be developed. To do so, as well as the theoretical staff determined previously, historical data were collected of the quality indices managed by the Hospital Álvarez Buylla which was the test subject of this method. This permitted the determination of the minimum staff needed to be offered by the nursing service while complying with the minimum levels of desired quality.

Subsequent studies might focus on the computerization of this process of calculation so as to facilitate its implantation in a general

nursing unit. Moreover, the results obtained might be extrapolated for implementing the system in other nursing units other than internal medicine. Likewise, a subsequent step to this study should consider a nonhomogeneous distribution of the activities among the different work shifts.$

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At the very least, case management is an extremely valuable service in the present managed health care environment, and may in fact be indispensable.$

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