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## NURSE STAFFING MANAGEMENT

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A great deal of attention has been given by operations researchers and industrial engineers during the past several decades to the nurse staffing problem – how to assign nursing staff to provide a desired level of patient care. This has been a natural area for research, because of the extent and high cost of nursing activities and the range of seemingly applicable operations research techniques available.

This area will become even more important in the future as hospital costs are subject to increasingly tighter public regulation. New reimbursement methods, which provide incentives to halt the escalation of costs, are being instituted. Output and process performance, rather than input resources, are increasingly being used as a basis for both reimbursement and inter-hospital comparison. Clearly, hospitals will continue to be under increasing pressure to bring about improved cost control. We believe that the development of innovative approaches to the organisation and management of nursing resources holds great promise for cost savings in the delivery of hospital services.

In this chapter we discuss quantitative procedures that have been developed to support nurse staffing activities. The strengths and deficiencies of these techniques are analysed, and extensions of certain techniques are suggested. A major difference between this review and those of Stimson and Stimson<sup>1</sup> and Aydelotte<sup>2</sup> is that the suggested procedures are viewed in the context of a conceptual framework of nurse staffing management. In addition, successfully applied procedures and methodologies are presented for those who wish to undertake further applications as well as those who wish to extend current knowledge.

The framework we propose includes five areas of management activity:

1. activity analysis and workload prediction;
2. tactical nurse staffing decisions – corrective allocations, shift scheduling and manpower planning;
3. performance monitoring;
4. strategic planning;
5. co-ordination with other hospital activities.

This framework provides a basis for pinpointing those activities and

aspects which have been largely overlooked by operations researchers and industrial engineers but which are potentially important for improving over-all nurse staff utilisation and performance.

After the framework is presented, we review studies which have analysed nursing activities and how the workload varies with the numbers and types of patients to be served. Methods developed to provide forecasts and demand and use rates are also discussed. The next section reviews quantitative procedures that have been developed to assist in making tactical nurse staffing decisions, and describes how these procedures can be integrated with performance monitoring, strategic planning and other hospital activities as well. The final section summarises our major conclusions and suggests areas where more research and development seem desirable.

We have found that the great bulk of nurse staffing research has concentrated on activity analysis and workload prediction, and on two of the three levels of tactical nurse staffing decisions – corrective allocations and shift scheduling. There has been little examination of potential improvements in the third tactical decision level – manpower planning – or of the interrelationships among the three levels. Finally, minimal attention has been given to improving performance monitoring, strategic planning, or co-ordination with other hospital activities such as admission and treatment scheduling.

It is our hope that this chapter will serve several purposes:

1. it should guide future nurse staffing research toward more comprehensive and fruitful problem-solving approaches;
2. it should give hospital systems analysts a good appreciation of the state-of-the-art and help them select procedures which might be applicable in their own setting;
3. it should help hospital administrators identify areas where, although no ready-made solutions are currently available, they might want to support specific studies in their own hospitals;
4. because it focuses on a major manpower administration aspect of health care, it should provide a basis for developing comprehensive plans for the care of patients and for determining the most effective facilities in which to provide patient care.

### **The Nurse Staffing Process**

The nurse staffing process can be conceptualised as a hierarchy of three

tactical decision levels which operate over different time horizons and with different precision. These three decision levels will be called corrective allocations, shift scheduling and manpower planning.

Within a shift, the staff capacities among units may be adjusted to unpredicted demand fluctuations and absenteeism by using float, part-time, relief, pulling, overtime and voluntary absenteeism. ('Float' refers to a pool of cross-trained nurses who are floated among units to smooth demand fluctuations; 'pulling' refers to the temporary reallocation of a nurse to a unit other than the one where she normally works.) These 'corrective allocations' should be based upon the individual's preferences and capabilities, and they are restricted by shift schedules and the employees' capabilities.

The second decision level is 'shift scheduling', i.e. uniform and smooth matching between expected workload and staff capacity among units on a week-to-week and day-to-day basis. For each employee days on and off, as well as shift rotation and time for classes, are determined. The individual's preferences should be considered to bring about high personnel satisfaction and one should ensure that personal capabilities are made use of in the best way.

These two 'scheduling' levels concern the utilisation of personnel already existing within the organisation; they have a known mix of specialisation and experience. However, the long-term balance of numbers and capability of nursing personnel among units is obtained by hiring, training, transferring between jobs and discharging. We call this decision level 'manpower planning'. Because of the time-lags involved, manpower-planning actions should be taken early to meet anticipated long-term fluctuations in demand and supply. As we shall see, very few studies have addressed this decision level.

The vital interdependence of the three levels must be recognised in order to bring about systematic nurse staffing improvements. Each level is constrained by available resources, by previous commitments made at higher levels and by the degree of flexibility for later correction at lower levels. Therefore, each decision level is strongly dependent on the other two; one level should not simply be considered in isolation.

In general, the later a decision is made the more reliable the available information is, but the alternatives that remain are fewer in number and generally more expensive. Hence, there is a trade-off between early and inexpensive actions based upon unreliable information (e.g. transferring) *v.* late and expensive corrections made when more reliable information is available (e.g. using overtime). This trade-off can be likened to the balance between fire prevention and fire-fighting capability.

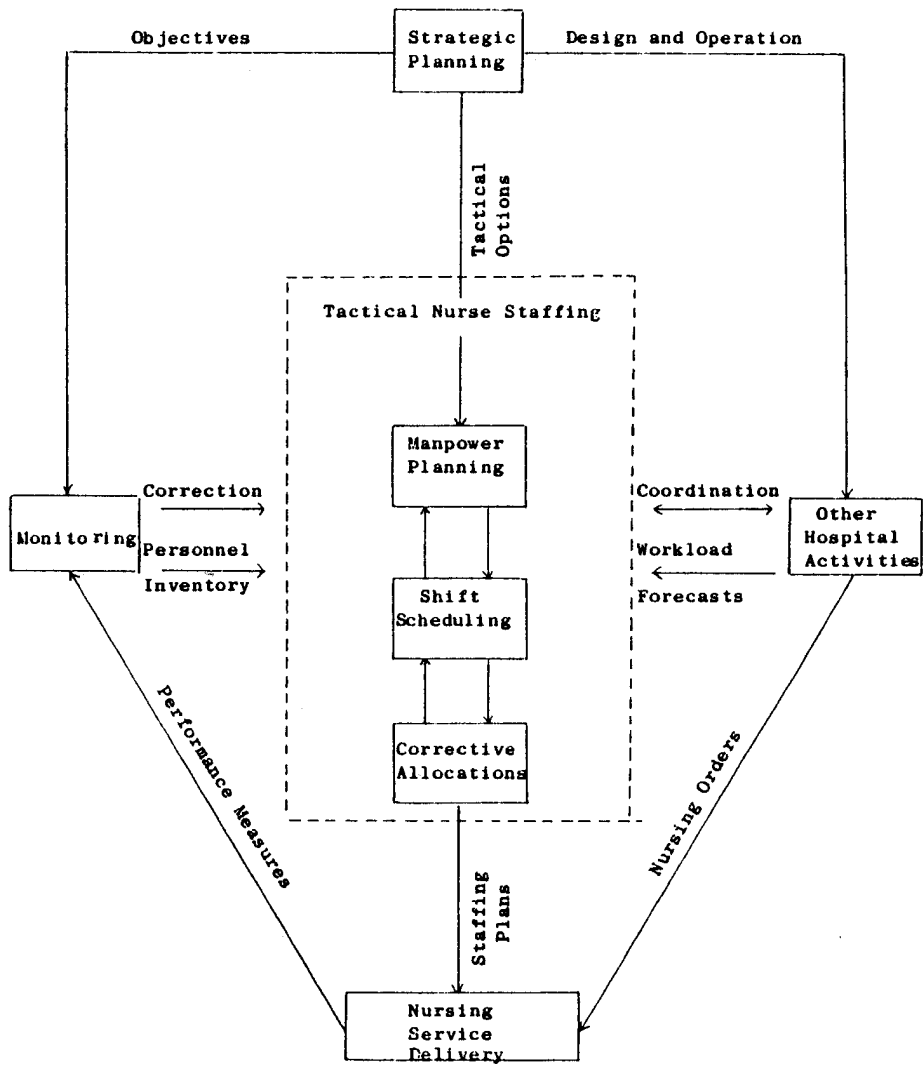
Furthermore, decisions at each level should be co-ordinated not only with decisions at the other two levels, but also with future and past events within the level itself. Co-ordination with the future should be accomplished through the planning stages: forecasting, tentative planning, action planning and execution. All of the uncontrollable or partially controllable variables that have a major influence on the staffing process have to be forecast. Examples of these variables are workloads for each skill category, hiring prospects, turnover and absenteeism. However, the planning process at each level should be dependent on the other two. The plans can be said to be 'gliding' or 'rolling'. That is, an action plan for one level should be the basis for a tentative plan for the level below, and they should be updated and made firmer as execution is approached and more information becomes available.

These three decision levels are depicted in Figure 8.1. It can be seen from this figure that there are important interactions between these tactical nurse staffing decision levels and other management activities. As shown in the box at the left of Figure 8.1, co-ordination with the past should be accomplished through a monitoring system, which should: (a) take an inventory – number and capabilities – of employed personnel; (b) measure, control, evaluate and correct staffing performance; and (c) gather statistics to be used as a basis for forecasting.

There are also important strategic policy and design decisions taken in a hospital that restrict the number of alternatives available at each of the three tactical decision levels. This aspect is depicted in the box at the top of Figure 8.1. Examples might include policies about the use of float personnel, the control of admissions, the skill mix of the nursing personnel, or the number of nurses in the training pool at any one point in time. These policies should be part of any investigation into new methods to improve productivity. The impact upon cost, quality and satisfaction of the policies in use should be recognised by the administrator; only then can the long-run value of maintaining them be intelligently assessed. Hence, the strategic planning level forms a decision level of its own which (a) dictates the range of options available in each of the three tactical decision levels, (b) sets the standards to be used for performance evaluation, and (c) makes policy and design decisions for all hospital functions.

We have stressed the importance of recognising the interdependence among the three tactical decision levels as well as among strategic, tactical, forecasting and monitoring activities. However, it is equally important to consider the interdependence between nurse staffing and the other hospital activities, shown at the right of Figure 8.1. Each

Figure 8.1: The Nurse Staffing System



nurse staffing level should co-operate with equivalent and related levels in the demand and facility control systems. That is, corrective allocation should be co-ordinated with task assignment; shift scheduling with the scheduling of admissions, operation rooms, treatment and supportive services; and manpower planning with budgeting, recruitment, training and facility planning. Gross imbalances among these activities are common, due to a lack of organisational and motivational incentives for co-ordination. This reflects ambiguous and sometimes conflicting objectives based on traditional and strong value systems. Unfortunately, most studies have omitted these crucial horizontal interdependencies.

In summary, the nurse staffing process can be conceptualised as a hierarchy of three highly interdependent tactical decision levels that are restricted by strategic decisions. Staffing decisions should be co-ordinated with other hospital activities and the performance of the staffing process should be measured and evaluated frequently in order to obtain over-all staffing effectiveness. (For greater elaboration of this framework, see Abernathy, Baloff and Hershey<sup>3</sup> and Wandel and Hershey.<sup>4</sup>)

### **Activity Analysis and Workload Prediction**

Before examining the quantitative procedures that have been proposed to assist nurse staffing, we will review studies which have analysed the activities nurses perform and how nursing load varies with the numbers and types of patients. In particular, we will review how these studies have been used to develop methods for workload prediction – a necessary input into any planning or scheduling procedure. (See Aydelotte for an extensive discussion of this literature.<sup>5</sup>)

For each tactical decision level – corrective allocation, shift scheduling and manpower planning – the activity analysis and workload prediction needs vary with respect to the amount of detail required and the corresponding accuracy of the workload measures given by skill level on each nursing unit. On a shift basis, the actual patient mix and illness severity along the many dimensions which affect staffing needs must be accurately predicted at the beginning of the shift in order to allocate available personnel appropriately. On a daily and weekly basis, the average workload and minimum staffing needs on each shift must be predicted with cyclic and/or seasonal patterns in order to build 2, 4, 6 or 8-week work schedules for the personnel on each unit. Finally, on a monthly, quarterly, semi-annual and annual basis, the average workload and minimum staff by skill levels must be predicted, based on trends,

seasonal patterns and other hospital activities, in order to follow appropriate hiring, training and staffing policies.

#### *Staffing Based upon Average Patient Requirements*

For many years, it was assumed that nursing units should make staffing decisions for each specialty unit (e.g. medicine, surgery and obstetrics) by multiplying the average number of nursing hours required per patient by the number of patients (see Stimson and Stimson<sup>6</sup>). As early as 1940, Pfefferkorn and Rovetta used this approach<sup>7</sup> and similar procedures were developed by the American Hospital Association<sup>8</sup> and George and Kuehn.<sup>9</sup>

In 1947, the National League of Nursing Education developed a patient classification scheme for the care of pediatric patients.<sup>10</sup> An attempt was made to relate the amount of nursing time required to this classification but the times were not sufficiently refined to provide a sensitive tool for staffing needs.

Bernstein *et al.*,<sup>11</sup> Binhammer *et al.*<sup>12</sup> and Claussen<sup>13</sup> assigned patients to categories according to their individual needs for direct nursing care, and the time requirements for direct nursing care per patient in each category were also established. Then the average mix of patients was determined for each unit and average staffing requirements were also calculated. These requirements were assumed to remain constant overtime when used as a basis for staffing.

In the 1950s, work sampling and time study were introduced to clarify the various functions that nurses of different categories perform and to determine the skill levels required to perform these tasks, and, for each personnel category, the proportion of time devoted to tasks above or below the category's skill level. If there were striking deviations from what was expected, changes could be made in the organisation and operation of the nursing units.<sup>14</sup>

#### *Activity Studies Based on Direct Care Indices*

In the late 1950s and early 1960s, a group at Johns Hopkins University revealed wide swings in demand for nursing care within each unit from day to day, even when the total number of patients remained the same, because of variations in the distribution of patients in various 'need' categories.<sup>15</sup> Three need categories – total care, partial care and self-care – were defined through checklists of observable patient characteristics. Work sampling studies were then used to determine the means and standard deviations of minutes per day spent on direct nursing care for patients in each category. It was also shown that the distribution

of direct care times could be approximated well with normal distributions (Connor<sup>16</sup>). By multiplying the number of patients in each care category by the average direct care times for that category, and then summing over all categories, a 'direct care index' was obtained. This index could be used to estimate the number of hours of direct nursing care required in each unit and each shift to meet existing standards of care for a given patient load.

Some of the advantages of this approach are its simplicity, objectivity and reliability. As to simplicity, it is easy to train personnel (such as a charge nurse) to fill out the data collection form quickly and consistently. On a thirty-bed unit it can be done in about five minutes. The approach is objective and reliable since it consists of evaluating the status of patients with regard to physical and hygienic needs so that evaluation bias is kept to a minimum.

However, a criticism of this approach is the strong emphasis on physical and hygienic needs and the exclusion of instructional, observational and emotional support needs of patients. For some patients the intensity of these latter needs correlate highly with physical and hygienic needs but for others they do not.

Based on the definitions developed at Johns Hopkins, the direct care load comprised only about 30 per cent of the total workload. Therefore, Connor made further work sampling studies to determine the relationships between the time nursing personnel spent in productive activities (direct patient care, indirect patient care, paper-work, communications, etc.) and the following three independent variables:

1. the amount of direct care to be given (direct care index);
2. the total number of patients (i.e. 'census');
3. personnel hours available.<sup>17</sup>

Using a step-wise linear regression analysis, he concluded that the time spent in productive activities varied significantly with both the index and the personnel hours available, but not with the census.

Connor also noticed that, when hours available increased beyond a level required to give adequate care, the extra time was not used for increasing the level of direct care administered. Instead, it became mainly idle time, with a small percentage for communication, paper-work and indirect care. One important implication is that, if labour-saving equipment is introduced, the number of nursing hours should be reduced simultaneously. Otherwise, the personnel time saved will not go into direct care but into increased idle time. Another finding



important to nurse staffing was that the workloads among the units were statistically independent and only some 20 per cent of the total staff needed to be 'floaters' in order to smooth the daily fluctuations.<sup>18</sup>

The average time requirements used for calculating the direct care index and the coefficients in the regression equations were based on historical care patterns, not patient needs. To improve the standard of care, the content of patient care should be examined to evaluate the levels of skill and times required before a direct care index and regression equations are used to predict workloads.

Connor's regression analyses were extended to several variables by Jelinek.<sup>19</sup> He included four categories of nursing personnel (professional nurses, practical nurses, nursing aides and student nurses), whereas Connor studied only professional nurses. He verified Connor's conclusions, as well as the following important hypotheses:

1. marginal productivity decreased as staff increased, for all personnel except nursing aides;
2. contributions to direct care made by increases in staff were greatest for nursing aides, followed by practical nurses, student nurses and professional nurses respectively;
3. staff shortages in a given category were at least partially corrected by substituting nurses from other categories.

The regression analysis approach used by Connor and Jelinek is an important tool, not only to increase the understanding of the existing nursing system, but also to establish ratios and standards for planning and control purposes, obtain models for workload predictions and forecast effects of changes in the organisation or operation of the nursing system.

#### *Workload Predictions Based Directly on Nursing Activities*

Besides the patient classification methods of estimating workloads, several methods have been developed that use nursing activities directly. The alleged advantage of this direct method is that the workload for each individual patient is estimated separately, instead of using average workload estimates for patient categories. The most complete method would be to use time standards for all tasks on each nursing order to predict direct care time for each patient. The same method could also be used to calculate time requirements for indirect care and non-patient-related activities. Through summation, a total care time could be predicted. The major shortcomings are that (a) nursing orders and care plans are

generally not accurate enough, (b) some tasks are mutually dependent, (c) time standards are difficult to estimate and, above all, (d) the method is very cumbersome.

In order to circumvent some of these problems, several methods have been developed that use samples of nursing activities instead of all activities. They use either the most frequent activities of a unit, the most time-consuming activities, the activities that require the least skill, the activities that require the most skill, or some combination of the above. A time standard is established for each activity and, by studying the frequency of occurrence for each activity, an index of workload is established for each unit.

One example is the study of White, Quade and White.<sup>20</sup> They used five activity areas – diet, vital signs, respiratory aids, suction and cleanliness – to make estimates of care needs. Clark and Diggs added toileting and turning and/or assisted activity to the list of activity areas and showed that the time required for these activities made up 76 per cent of the total direct care time.<sup>21</sup> The staff utilisation and control programme developed by CASH also uses direct activity analysis.<sup>22</sup> It gives normative data on how occupancy levels should be translated into number of personnel in each category for each of the three shifts of a unit's operation.

SPRI used step-wise regression analysis to determine the relationship between patient characteristics and patient-dependent workload for each personnel category.<sup>23</sup> Using from five to eight patient characteristics, each with its own scale for measurement, nearly 60 per cent of the total workload, both direct and indirect care, for individual patients could be explained.

### *Markovian Workload Predictors*

One major disadvantage with all the methods reviewed above is that they can be used to predict workloads only one or two shifts in advance, since the status and number of patients on each unit changes rapidly. Thomas tried to overcome this by using a Markov model that utilised four phases of patient recovery, each subdivided into three categories.<sup>24</sup> These twelve states, together with entry and exit states, are linked with a matrix of transition probabilities. But since different diagnoses have different length-of-stay distributions, a separate matrix has to be established for each possible diagnosis. This makes the method extremely cumbersome to apply. Balintfy,<sup>25</sup> Kolesar,<sup>26</sup> Meredith,<sup>27</sup> Singer,<sup>28</sup> Warner,<sup>29</sup> and Wendell and Wright<sup>30</sup> also used Markovian analysis.

Offensend<sup>31</sup> and Smallwood, Sondik and Offensend<sup>32</sup> developed a

semi-Markov model. This semi-Markov model was used to calculate the mean and variance of the amount of nursing time required during each hour of the day in each nursing unit for each category of nursing personnel. It should be noted that both the index and the direct methods could also be extended to predict variance in workload. This would be valuable for calculating the accuracy of workload predictions and as a basis for establishing desired reserve staff capacity.

#### *Forecasting Monthly Workloads*

Since the length of stay in short-term hospitals is normally much less than one month, the movements of patients inside the hospital need not be followed in order to forecast monthly workloads. Average requirements for nursing hours from each category of personnel in each unit per patient in each admission category during the total length of stay would be sufficient information to translate expected admissions to expected workloads. However, the expected variance of the workload during a month is much more difficult to predict.

Several methods for making forecasts of demand and use rates have been developed, but few methods for translating these forecasts into workloads have been reported.<sup>33</sup> Kaplan used historical monthly average data in a linear regression model to determine the relationship between the number of professional nursing hours and patient days for each individual unit.<sup>34</sup> This is an improvement over the commonly used statistic – average number of nursing hours per patient day – since a fixed component is added.

The regression model was tested over a seven-month period to translate patient days into nursing hours. Most of the variations could be explained by the model and larger deviations were due to inconsistent staffing or transient effects. This information, which represented an evaluation of the staffing process, was not fed back to the decision makers for correction and adaptation. Kaplan remarked that providing supervisors with such information might reduce the number of extreme deviations.

#### *Conclusions*

The purpose of having accurate workload predictions is to be certain that the best possible data are available as an input to allocating personnel efficiently and effectively to the appropriate nursing unit to provide a comprehensive plan of care for each patient. In most hospitals workload measurement utilises data gathered by the head nurse based on each patient's needs. The data are estimated either subjectively

through her knowledge of the patients or formally using direct and indirect care activities on patient classification forms. Markovian workload predictions are not widely used.

More and more hospitals are adopting formal patient classification systems. Based on the above studies and our own experience, we recommend the following practical methodology for the implementation of a patient classification and nurse workload measurement system:

1. Establish good quality control on the nursing units in order to measure the impact of any changes in staffing levels, reassignment, or modified organisational structures. This will establish a 'base-line' against which to measure any changes. Ideally, this quality of nursing care measure will involve outcome as well as process criteria.
2. Initiate Patient Classification System (PCS)
  - (a) Define *objective* categories which measure: (i) physical needs of patients, (ii) hygienic needs of patients, (iii) instructional needs of patients, (iv) observational needs of patients, (v) emotional support of patients, (vi) medications and treatments, and which classify patients by age, degree of self-help, and other items useful in assessing nursing needs. These categories will vary by medical services; however, some attempt to achieve parallel categories across such services is worth while in order to provide a consistent system for the hospital.
  - (b) It is desirable to keep the total number of categories to around 20-30 for most units. More categories yield greater accuracy, but result in more resistance from the persons completing the forms; hence a balance must be struck. On a 25-bed unit, the time required to complete the form for *all* patients should not exceed ten minutes by a person with experience in using the form.
3. Initiate nursing unit work factors study.
  - (a) Relate the direct patient care to the particular class of patient defined by the PCS. 'Direct patient care' is loosely defined as 'care provided at the patient's bedside in direct support of that patient'.
  - (b) 'Indirect or non-direct patient care' must also be measured. This workload is usually expressed as a constant amount of time which depends on the number of patients and not on the PCS.
  - (c) Before beginning the study the distinction between direct and indirect care must be made clear, otherwise much confusion will result.
  - (d) The data on direct and indirect care should be gathered (i) over

- a two- to three-week time period when the unit is at a reasonably stable capacity, (ii) by each shift, (iii) by PCS (for direct care), (iv) by skill level (RN, LPN, aide, other), and (v) by hour of day.
- (e) This data can be gathered by (i) self-recording time forms completed by each person, or (ii) work sampling by a disinterested third party.
  - (f) Data so collected must then be analysed. Times for each skill level to do the daily PCS tasks for each category of patient must be computed. Averages are needed and variances are useful.
4. After the workload factors are computed as in (3) above, they can then be incorporated into a computer programme.
  5. Generally, the PCS is undertaken on a unit prior to the day shift and nursing workload is computed for the next three shifts. Unusual PCS events, happening later in the day, are then allowed for as they occur.
  6. Allocations of personnel can be made based on the workloads computed in (5) above and the supply of available nurses. Methods for corrective allocations are described in the next section.

The above approach to workload measurement is useful for the daily allocation of available staff. For forecasting daily and weekly unit staffing needs in order to construct two, four, six or eight-week schedules, a practical methodology is to use time series or regression methods which utilise the daily workloads collected over the past three to twelve months.

### **Quantitative Procedures for Nurse Staffing**

This section reviews quantitative procedures that have been proposed to assist in the management of nurse staffing activities in each of the three tactical decision levels – corrective allocations, shift scheduling and manpower planning. In our framework of Figure 8.1, staffing activities include not only the planning and co-ordination of staffing actions but also the monitoring of outcomes and the analysis of alternative policies and designs. Throughout the discussion, we shall point out those elements and aspects within this framework which have been largely neglected, but which are nevertheless important for over-all system effectiveness.

#### *Corrective Allocations*

The main purpose of the corrective allocation system is to smooth the workload to staff ratios among the units by using float, pulling, part-

time, relief, overtime, voluntary absenteeism and patient reallocation.

Connor *et al.* reported the use of the direct care index as a basis for the assignment of overtime and float pool.<sup>35</sup> Temporary shifting of personnel among wards has long been a common practice, and many hospitals have implemented some procedure for predicting workloads — often merely based on a census — to bring about more systematic and equitable personnel allocations.

In order to make the allocations more specific and objective, though often less individualised and flexible, computers have been programmed with heuristic decision-making procedures that evaluate the available information and suggest personnel allocations. For example, Jelinek *et al.* have developed a 'Personnel Allocation and Scheduling Control System for Patient Care Services' that has the following three interrelated but separate computer-based functions: personnel scheduling, personnel allocation and management reporting.<sup>36</sup> The allocation function is a heuristic procedure based on pre-established priorities that balance the trade-off between employee dissatisfaction and the workload to staff balance. Another example is Medinet's time-sharing programme.<sup>37</sup>

Wolfe<sup>38</sup> and Wolfe and Young<sup>39</sup> used a linear programming model to assess existing nursing personnel of different categories to match given demands from nine groups of tasks. The objective function value for a task from group  $i$  assigned to personnel category  $j$  is  $x_{ij} w_j + v_{ij}$ , where  $x_{ij}$  is the number of minutes required,  $w_j$  the wage per minute, and  $v_{ij}$  the intangible costs of having category  $j$  perform a task in group  $i$ . These intangible costs were assigned by a panel of nurses. Since personnel were assigned only for a full eight-hour shift, integer solutions were required and undistributed idle time had to be evaluated. However, a non-integer solution procedure was used. The difficulties of obtaining input data and integer solutions, the fact that the model covers only a single period, and the neglect of preferences and capabilities of individual nurses, indicate that more development is needed before the model can be successfully applied.

Warner<sup>40</sup> and Warner and Prawda<sup>41</sup> formulated the allocation problem as a mixed integer quadratic programme. Demand is assumed to be known and the objective function value for personnel category  $n$  in ward  $i$  during shift  $t$  is the quadratic 'cost'

$$W_{int} (R_{int} - \sum_m Q_{imnt} U_{imnt})^2$$

where  $R_{int}$  is the demand,  $U_{imnt}$  the number of nurses of category  $m$

who are working in category  $n$ ,  $Q_{imnt}$  the associated substitution ratio, and  $W_{int}$  the relative seriousness of shortage. The problem was decomposed by a primal resource-directive approach into a multiple-choice programming master problem, with quadratic programming sub-problems. As with Wolfe's model, additional work is required, particularly in estimating the subjective parameters.

Another mathematical programming model has been formulated by Liebman.<sup>42</sup> She used a psychometric technique called the Q-sort to measure quantitatively the existing nursing concepts of effective utilisation of personnel in an extended care facility. This was the basis for the objective function of a model that generated personnel allocations, given a set of patient requirements and a nursing team configuration. Actual assignments and computer-generated assignments were compared, and the model was found to produce a good fit.

A stochastic allocation model was developed by Miller and Pierskalla.<sup>43</sup> The objective was to minimise the cost of allocating nurses among nursing classes and units subject to constraints on the demand for, and the supply of, nursing services. Because the number of nurses reporting for work in the various classes and units form a random vector, the allocation model used was a stochastic programme with recourse. It was then transformed into a deterministic equivalent and solved.

Finally, we wish to mention Freund and Staats who developed a technique for describing 'elements' reflecting care task groups and patient conditions, obtained difficulty values for each element, and developed a heuristic procedure for allocating elements to nurses with difficulty as a measure of assignment 'load'.<sup>44</sup>

Most of the workload prediction techniques and allocation procedures are not used to monitor and adapt the procedures themselves or to bring about improved long-range staff balance. Quantitative benefit-cost analysis of alternative procedures and policies is generally not considered. However, Offensend used his workload predictor in experiments with various policies for admission control and assignment of patients to nursing teams.<sup>45</sup> He calculated the value of obtaining better information before making decisions, and he performed sensitivity analyses on several parameters.

Tani developed a model of a staffing reserve-resource system that supplies float and relief staff and scheduled voluntary absences and extra shifts.<sup>46</sup> Historical distributions of reserve demand and availability of relief, extra shifts and voluntary absences were estimated. A cost function was established and various sizes of the float pool were tried in order to find an optimal float pool size. The study exemplifies an

approach to benefit-cost analysis that can be used to predict the effects of changes in the availability of various corrective allocation alternatives or changes in operating policies.

The simulation model developed by Hershey, Abernathy and Baloff focuses on:

1. the prediction of savings in manpower requirements of introducing a float pool under a variety of operating and policy parameters;
2. forecasting manpower requirements for a given allocation procedure and policy.<sup>47</sup>

Several criteria which an administrator might adopt for equating levels of patient care under alternative staffing schemes are suggested and studied. Although the examples indicate savings in manpower requirements of 9-12 per cent from introducing a float pool for the most realistic combinations of parameters, no general conclusions should be drawn because many costs and benefits were not included in the model and the data were hypothetical.

All of the allocation models discussed require large data bases for their operation. Furthermore, these data bases must be accurate for every shift when allocations are performed. To maintain such data bases in the absence of time sharing and/or distributed computer systems is virtually impossible. Consequently, none of these mathematical allocation models is operating at the present time. However, as more micro- and mini-computers are introduced into nursing administration departments, simple interactive allocation models will be used to aid corrective allocation decisions.

Some of this development is already under way. It involves the construction of individual nurse data bases which indicate their work schedules, their nursing specialty skills, their previous experience on different hospital units and their preferences for floating or pulling. In addition, data are needed on the manpower task substitutability and the trade-off of performance of a task by the different skill levels, since, for example, one practical nurse does not substitute for one registered nurse (although the reverse holds). As the shifts change, the nursing shortage or excess for each unit and skill level can be computed (based on previously entered patient classification workload calculations). By interactive heuristic allocation rules, nurses can be pulled or floated to appropriate units. Such data bases are under construction and others exist in partial form at a few leading medical centres, for example Fairview Hospital in Minneapolis, Rush Presbyterian St Luke in Chicago



and Stanford Hospital in Palo Alto.

Given these data bases, simple or complex allocation models may then be tried. More importantly, linkages to other information and decision systems can be introduced. For example, the allocation information system can link to the payroll system to record who worked what shift and unit, to the admissions scheduling system to indicate not only bed availability and patient transfer but personnel availability for under- or over-staffed units, and to patient billing systems as hospitals begin to allocate manpower as well as supply costs to particular patients.

### *Shift Scheduling*

The nurse scheduling process may be viewed as one of generating a configuration of nurse schedules that specify the number and identities of the nurses working each day of the scheduling period. By specifying nurse identities, a pattern of scheduled days off and on is created for individual nurses. These patterns, along with hospital staffing requirements, define the nurse scheduling problem: how to generate a configuration of nurse schedules that satisfy the hospital staffing requirements while simultaneously satisfying the individual nurse's preferences for various schedule pattern characteristics.

The most common formalised procedures for scheduling shifts on and shifts off for individual nurses are based on the development of a fixed schedule that repeats itself on a cyclic basis, normally every fourth week.<sup>48</sup> The major shortcomings of such 'cyclic schedules' are that they cannot normally take into account fluctuations in workloads and absences, except on a fixed weekday pattern, and they do not consider preferences or the capabilities of individual nurses. Such inflexible scheduling procedures require high flexibility within the corrective allocation and manpower planning system to avoid expensive overstaffing.

Two non-cyclical scheduling papers of note are those of Rothstein<sup>49</sup> and Warner.<sup>50</sup> Rothstein's application was to hospital housekeeping operations. He sought to maximise the number of day-off pairs (e.g. Monday-Tuesday) subject to constraints requiring two days off each week and integral assignments. Warner presented a two-phase algorithm to solve the nurse scheduling problem. Phase I is involved with finding a feasible solution to various staffing constraints, while Phase II seeks to improve the Phase I solution by maximising individual preferences for various schedule patterns while maintaining the Phase I solution.

Sanders let nurses distribute 1,000 disutility points among seven factors in their schedules, e.g. night duty and split weekend, to measure their attitudes concerning the relative unpleasantness of each factor.<sup>51</sup>

Substantial differences in attitudes from nurse to nurse and between wards were found. An evaluation of past schedules' disutility points for each individual showed great variances. He also found that nurses with relatively greater disutility points tended to be absent more often. The problem was then to find a scheduling procedure that minimises the sum of cumulative disutilities while considering all other constraints. He investigated alternative definitions of equitability, the existence of equitable solutions, the properties of some scheduling paradigms and the relationships between optimal and equitable solutions. A relatively equitable heuristic procedure seems to be to give the worst schedule to the nurse with the least accumulated disutility points and the best schedule to the one with the most, until all schedules have been distributed.

Despite the multitude of quantitative procedures that have been developed to assist in scheduling nursing staff, very few have been implemented and accepted; the vast majority of hospitals schedule nurses on an informal and subjective basis. One of the most successful implementations of quantitative nurse scheduling has been by Miller, Pierskalla and Rath,<sup>52</sup> Miller, Pierce and Pierskalla,<sup>53</sup> Miller, Pierce, Pierskalla and Rath<sup>54</sup> and Jelinek *et al.*<sup>55</sup> This computer-based nurse scheduling system has been successfully implemented in a number of hospitals in the United States and Canada. The theoretical basis is mathematical programming; the computer basis is the cyclic co-ordinate descent algorithm. This system is described in detail in a later case study section.

Although the above model has been implemented in several settings, it suffers from the extensive work needed to maintain a large data base, from the need for a large computer (although a mini would suffice) and from the lack of integration with other systems such as corrective allocations, payroll, admissions and other hospital activities. As with the corrective allocation level, little has been done continuously to evaluate and adapt scheduling systems themselves, and quantitative benefit-cost analysis of alternative design and operating procedures is even more exceptional.

#### *Manpower Planning and Performance Monitoring*

In contrast to the allocation and scheduling levels, for which many models and systems for decision support have been proposed and some adopted, few quantitative models have been developed to assist the planning of task substitution, hiring, training, transfer, discharge and other personnel allocation decisions. Instead, most studies concerned

with this level of nurse staffing have stressed the importance of variable budgeting – that is, procedures for the evaluation of outcomes that correct for variations in uncontrollable factors, such as workload, wages and procedural changes.

For example the purpose of Kaplan's study was to perform monthly evaluations of efficiency and scheduling by comparing the actual number of nursing hours with a variable standard expressed as a linear function of the actual number of patient days.<sup>56</sup> The coefficients in the linear function were estimated from historical data.

Olson describes an operating system for the bi-weekly monitoring of budget performance.<sup>57</sup> The number of hours worked in each department is compared with standard hours, calculated from a linear function with or without a fixed component. The coefficients are obtained from CASH standards or from historical data.<sup>58</sup> The ratio of hours worked to standard hours is plotted, together with the occupancy rate for each department, in order to estimate the flexibility in staffing performance and changes in personnel efficiency or utilisation.

Davis and Cowie stress the measurement and evaluation of both cost and quality by means of variable budgeting and effectiveness indices, but no specific technique is described.<sup>59</sup> Even traditional hospital budgeting and accounting handbooks discuss the trade-off between cost and quality and recommend flexible budgets for nursing services.<sup>60</sup>

The American Hospital Association has a central computer processing service called Hospital Administration Services (HAS). Direct expenses, certain resources measures such as man-hours, and some output measures such as patient days, meals and pounds of laundry are reported monthly to HAS by each participating hospital. In return, each hospital receives statistics comparing its current performance with its historic performance and with the distribution of performance of other hospitals of the same size, geographical location or function. High relative ranges in some performance indicators have been reported, probably due to great variations in both variable definitions and actual performance.<sup>61</sup> Furthermore, very little information to support nurse staffing can be found in the HAS reports and, when fed back to each hospital, the data are about five weeks old, thus making it too late to take useful corrective actions. Hospitals must therefore rely on their own information systems for staffing monitoring.

A promising approach to budgeting and control is the Hospital Management Monitoring System Project.<sup>62</sup> Costs, man-hours and output measures (patient days for nursing, number of examinations for laboratories, etc.) are accumulated for each responsibility centre, a first-

line supervisor post. The supervisors are then judged by their ability to meet man-hours to output standards that have been pre-established through negotiations between the administration and the supervisors. These standards, together with seasonally adjusted output volumes and expected wage rates, are also the basis for the annual budgeting of monthly expenditures. Furthermore, the volume forecast for each responsibility centre is updated monthly, using regression, indices and exponential smoothing. These forecasts, together with the man-hours to output standards, help the supervisors to foresee manpower requirements and then use part-time, overtime, transfer, vacation and attrition of personnel to adjust the workforce. Savings of \$150,000 per year have been reported due to the introduction of this variable budgeting and control procedure in the demonstration hospital.

The MEDICUS system (Jelinek *et al.*<sup>63</sup>) also contains a management reporting system. Three categories of data are reported:

1. nursing performance (cost, manpower and activity levels);
2. nursing personnel status (utilisation, overtime, turnover, absenteeism and personnel satisfaction);
3. quality level measurements (questions of measurable 'process' attributes are randomly selected from a large 'question master file' and used to generate questionnaires that are filled out and then used to calculate quality indices).

Abernathy, Baloff, Hershey and Wandel divided the staffing process into three decision levels:

1. policy decisions, including the operating procedures for nursing units and for the staffing process itself;
2. permanent staff allocation, including hiring, discharge, training and reallocation;
3. short-term scheduling and allocation of available staff within the constraints determined by the two previous levels.<sup>64</sup>

These three levels are used as decomposition stages in the development of a probabilistic programming model of the staffing process. Solution procedures are developed and demonstrated with a hypothetical example application. The example also illustrates the type of information that can be generated by the model and the utility of this information:

1. for policy evaluation and decision;

2. as an informational basis for actual staff planning and control;
3. for co-ordination of staff allocation with patient admission, treatment scheduling, vacation planning and load forecasting;
4. to suggest standards for budgeting purposes;
5. to monitor nursing performance and staffing effectiveness.

However, the adaptability and acceptability of the model has yet to be demonstrated.

### Shift Scheduling – A Case Study

This section discusses in detail a particular approach to quantitative nurse scheduling which has enjoyed some success.<sup>65</sup> The basis of the approach is a mathematical programming model which schedules days on and days off for all nurses on a given unit or ward for a given shift for a two, four, six or eight-week scheduling horizon, subject to certain hospital policy and employee constraints. Because of the large number of constraints, it is possible that no feasible solutions to the nurse scheduling problem would exist if all the constraints were binding. For this reason the constraints are divided into two classes: feasibility set constraints, which define the sets of feasible nurse schedules, and non-binding constraints, the violation of which incurs a penalty cost which appears in the objective function. Each hospital has the discretion to define which constraints go into each class.

#### *Constraints: the Feasibility Set*

Because of the possibility of special requests by nurses, no constraints are binding, in the sense that they hold under all circumstances except those constraints emanating from special requests. The model, however, distinguishes between constraints the hospital would like to hold in the absence of special requests and those which are allowed to be violated while incurring a penalty cost. These latter constraints (non-binding constraints) are discussed later.

The former constraints define the feasibility set  $\pi_i$ , i.e.  $\pi_i$  = the set of feasible schedule patterns for nurse  $i$ . In the absence of special requests, this set might include all schedules satisfying the following:

1. a nurse works ten days every pay period (i.e. 14-day scheduling period);
2. no work stretches (i.e. stretches of consecutive days on) are allowed in excess of  $\sigma$  days (e.g.  $\sigma = 7$ );

3. no work stretches for  $\tau$  or fewer days are allowed (e.g.  $\tau = 1$ ).

Hence one schedule in a  $\pi$  satisfying these values of  $\sigma$  and  $\tau$  might be 1 1 1 1 1 1 0 0 1 1 1 0 0.

Now suppose a nurse has a special request. For example, suppose the nurse requests the schedule 1 1 1 1 1 1 1 0 1 0 0 0 B, where B indicates a birthday. In this case all of the above constraints would be violated and  $\pi_i$  would consist of only the schedule just given. Thus, in the general case  $\pi_i$  is the set of schedules which (a) satisfies a nurse's special requests, and (b) satisfies as many of the constraints the hospital would like to see binding as possible, given the nurse's special request.

The constraints the hospital would like to hold are a function of the hospital in which the model is applied. Thus, for example, the model could easily specify five out of seven days instead of ten out of fourteen or specify additional constraints such as one weekend off each pay period.

#### *Constraints: Non-binding*

Each schedule pattern  $x^i \in \pi_i$  may violate a number of non-binding schedule pattern constraints while incurring a penalty cost. Define  $N_i =$  the index set of the non-binding schedule pattern constraints for nurse  $i$ . For example, if the hospital in which the model is being implemented deems them as non-binding, the following constraints might define  $N_i$ :

1. no work stretches longer than  $S_i$  days (where  $S_i \leq \sigma$ );
2. no work stretches shorter than  $T_i$  days (where  $T_i \geq \tau$ );
3. no day on, day off, day on patterns (1 0 1 pattern);
4. no more than  $\kappa$  consecutive 1 0 1 patterns;
5.  $Q_i$  weekends off every scheduling period (4 to 6 weeks);
6. no more than  $W_i$  consecutive weekends working each scheduling period;
7. no patterns containing four consecutive days off;
8. no patterns containing split weekends on (i.e. a Saturday on, Sunday off, pattern, or vice versa).

In addition to non-binding schedule pattern constraints, there are also non-binding staffing level constraints. Define  $d_k =$  the desired staffing level for day  $k$ ; and  $m_k =$  the minimum staffing level for day  $k$ . Then (a) the number of nurses scheduled to work on day  $k$  is greater than or equal to  $m_k$  and (b) the number of nurses to work on day  $k$  is equal to  $d_k$ .

*Objective Function*

The objective function is composed of the sum of two classes of penalty costs: penalty costs due to violation of non-binding staffing level constraints and penalty costs due to violation of non-binding schedule pattern constraints.

*Staffing Level Costs*

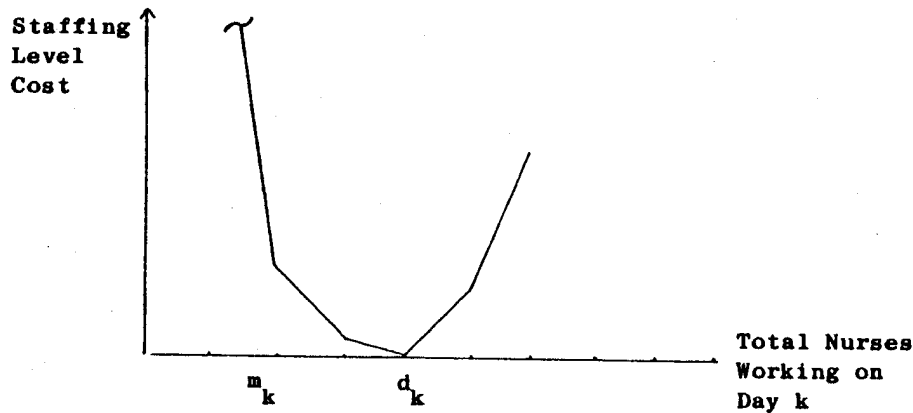
The group to be scheduled is defined as the set of all the nurses in the unit who are to be scheduled by one application of the solution algorithm. A sub-group is defined as a sub-set of the group specified by the hospital. For example, the group to be scheduled may be all those nurses assigned to a nursing unit and the sub-groups may be registered nurses (RNs), licensed practical nurses (LPNs) and nursing aides. Alternatively, the group may be defined as all RNs and a sub-group might be those capable of performing as head nurses.

Then, for each day  $k = 1, \dots, 14$  (where there are  $I$  nurses), the group staffing level costs are given by:

$$f_k \left( \begin{matrix} I & i \\ \Sigma & x_k \\ i=1 & \end{matrix} \right), \text{ where } x^i = (x_{14}^i, \dots, x_1^i).$$

For example, this function might appear as in Figure 8.2. Now let  $B_j =$  the index set of nursing sub-groups  $j$ , and  $J =$  the index set of all sub-groups.

Figure 8.2: An Example of a Daily Staffing Level Cost Function for a Nursing Group



If  $m_k^j$  and  $d_k^j$  are the minimum and desired number of nurses required on day  $k$  for sub-group  $j$ , respectively, the staffing cost for violating those constraints on day  $k$  for sub-group  $j$  is:

$$h_{jk} \left( \sum_{i \in B_j} x_k^i \right),$$

where  $h_{jk}(\cdot)$  is defined similarly to  $f_k(\cdot)$ .

Then, the total staffing level costs for all 14 days of the pay period are:

$$\sum_{k=1}^{14} f_k \left( \sum_{i=1}^I x_k^i \right) + \sum_{k=1}^{14} \sum_{j \in J} h_{jk} \left( \sum_{i \in B_j} x_k^i \right).$$

### Schedule Pattern Costs

For each nurse  $i = 1, \dots, I$ , the schedule pattern costs for a particular pattern  $x^i$  measure:

1. the costs inherent in that pattern, in relation to which constraints in  $N_i$  are violated;
2. how nurse  $i$  perceives these costs in the light of her schedule preferences;
3. how this cost is weighed in the light of nurse  $i$ 's schedule history.

For example, regarding (1), the pattern 1 1 1 1 1 0 0 1 1 1 0 0 1 1 may incur a cost for a nurse whose minimum desired work stretch is four days. This is a cost inherent in the pattern. Considering (2), we need to know how nurse  $i$  perceives violations of the minimum desired stretch constraint, i.e. how severely are violations of this non-binding constraint viewed *vis-à-vis* others in  $N_i$ . Finally (3) gives some indication of how to weight this revised schedule pattern cost on the light of the schedules nurse  $i$  has received in the past. Intuitively, if nurse  $i$  has been receiving pool schedules, the cost of a given schedule should be relatively higher than the costs for schedules of other nurses, in order to cause a good schedule to be accepted when the solution algorithm is applied and vice versa. Thus:

$g_{in}(x^i)$  = the cost of violating non-binding constraint  $n \in N_i$  of schedule  $x^i$ ;

$\alpha_{in}$  = the 'weight' nurse  $i$  gives a violation of non-binding constraint



$A_i$  = the aversion index of nurse  $i$ , i.e. a measure of how good or bad nurse  $i$ 's schedules have been historically *vis-à-vis* nurse  $i$ 's preferences.

Then the total schedule pattern cost to nurse  $i$  for a schedule pattern  $x^i$  is:

$$A_i \sum_{n \in N_i} \alpha_{in} g_{in}(x^i)$$

and the sum of these costs for all nurses  $i = 1, \dots, I$  is the total schedule pattern cost.

**Problem Formulation**

Let  $\lambda \in (0,1)$  be a parameter that weights staffing level and schedule pattern costs. It is chosen such that the weighted staffing and schedule pattern costs are of approximately equal magnitude. Experience has shown a trial-and-error procedure to be effective in arriving at satisfactory values of  $\lambda$ .

Given  $\lambda$ , the problem is to find  $x^1, x^2, \dots, x^I$  which minimise:

$$\lambda \left[ \sum_{k=1}^{14} f_k \left( \sum_{i=1}^I x_k^i \right) + \sum_{k=1}^{14} \sum_{j \in J} h_{jk} \left( \sum_{i \in B_j} x_k^i \right) \right] + (1-\lambda) \sum_{i=1}^I A_i \sum_{n \in N_i} \alpha_{in} g_{in}(x^i)$$

subject to  $x^i \in \pi_i, i = 1, \dots, I$ .

The solution procedure used is a near-optimal algorithm. It starts with an initial configuration of nurse schedules, one for each nurse. Fixing the schedules of all nurses but one, say nurse  $i$ , it searches  $\pi_i$ . The lowest present cost and best schedule configuration are updated if, when searching  $\pi_i$ , a schedule is found which results in a lower schedule configuration cost than the lowest cost to date. When all the schedules in  $\pi_i$  have been tested, either a lower cost configuration has been found, or no lower cost configuration has been found. The process cycles among the  $I$  nurses and terminates when no lower cost configuration has been found in  $I$  consecutive tests. For more detail on the solution procedures, see Miller, Pierskalla and Rath.<sup>66</sup>

The use of this algorithm has resulted in less variation between actual and desired staffing levels, more weekends off, fewer long stretches, more split days off, higher personnel satisfaction and lower costs than

the previous manual or semi-automated systems. However, the data needs are great and require accurate maintenance. Consequently, in order to implement such a sophisticated system, the hospital must have access to systems programmers and a comprehensive mini- or full-sized computer.

As in any implementation which involves the preferences of hundreds (possibly thousands) of individuals, it is important that they are integrated with the implementation process. Once a hospital's top administrators have decided to install the computerised algorithm, the implementation process begins. It proceeds through a series of steps over several months. The initial step is to meet with the Director of Nursing to explain the system and gather data on hospital scheduling policies, such as the number of weekends off, maximum and minimum stretches, the start day and length of pay periods, schedule horizon (usually four or six weeks), rotation, use of part-time and/or float personnel, etc.

Next comes a group meeting with the head nurses to explain the operation of the system, what it can and cannot do for them, the types of reports and schedules they will receive, the time savings to them, the problems which it eliminates for them (and those it does not), and the need for timely data on special request. Emphasis is placed on the importance of co-operation on both sides and it is stressed that the computerised schedules do not take away any of the authority of the head nurse in approving special requests or changing the schedules to meet unanticipated needs. The computerised algorithm is a tool which removes some onerous tasks so that head nurses may have more time for more important tasks related to health care delivery.

Following the group meeting, individual meetings are scheduled with each head nurse. The purpose of these individual meetings is to answer any system questions and, more importantly, to gather data needed by the algorithm. The data comprise such items as who are the charge nurses, what groups and sub-groups must be scheduled together, what are minimum and desired group and sub-group staffing levels, and what specific scheduling problems are on the unit, such as parallel people, part-time restrictions, rotation restrictions, fixed patterns, team v. primary care groups, etc. Another important purpose of this meeting is to explain the limitations of the scheduler. For example, any group on a unit may specify which two days, Friday-Saturday or Saturday-Sunday, constitute a weekend; however, all of the nurses in that group must use the same definition for their weekend.

The next step is an orientation meeting with groups of nurses on the

units. The main purpose here is to remove the fear of impersonalisation, to emphasise that the head nurse still controls the schedules and to point out that the computer gives nurses fairer and more individualised schedules that meet their particular requests and more nearly reflect their preferences.

After the general orientation meetings each individual is interviewed (including nurses' aides, orderlies and medical technicians) to obtain rankings of her (or his) preferences for weekends, stretches, split days off, etc. and to explain the way such preferences affect schedules. These individuals are also informed that all schedule changes or requests must be approved by the head nurse just as in the past.

Following each of the interviews, data are prepared and stored in the master file of the algorithm. After all the necessary data have been stored, trial schedules are run to adjust the various hospital and individual parameters. These trial schedules are reviewed by the respective head nurses in order to identify any items missed in prior interviews.

The nurse scheduling system is now in operating condition and periodic schedules are produced. Even in this production phase, however, the schedules are reviewed every time and adjustments are made for new hires, terminations, changes in workload requirements and/or nurse preferences, etc. On a continuing basis it usually requires the full-time involvement of one trained high school graduate, who works well with people and enjoys the challenge of producing the best schedule for each head nurse, to operate the algorithm for a 40-unit hospital with 900 full- and part-time nursing personnel. If the hospital is one-half this size, then only one-half the time is needed, since the effort in running and maintaining the algorithm is essentially linear with respect to the number of units and people being scheduled.

The savings in head nurse time alone constitute a minimum of one day per month per head nurse and more usually two to four days per month. Of course, head nurses' time is not the only advantage of the algorithm. Other advantages are fairer schedules which meet nurse preferences, the more even staffing of units and the capability for the nursing administration to examine the effects of changes in policies prior to their implementation.

Among the locations where the algorithm has been implemented are: Mount Zion Medical Center, San Francisco, California; Pacific Medical Center, San Francisco, California; Stanford University Medical Center, Stanford, California; Kingston General Hospital, Kingston, Ontario; and Rush Presbyterian St Luke Medical Center, Chicago, Illinois.

### **Recommendations and Conclusions**

In this chapter, we have conceptualised the nurse staffing process as a hierarchy of three tactical decision levels. The great bulk of research in nurse staffing has concentrated on the shift-scheduling and corrective allocation levels and on activity analysis and forecasting procedures to support staffing decisions. Exploration of the potential benefits of improved manpower-planning procedures has only begun. This is an important research area which we believe deserves greater attention in the future.

Another area which should be investigated further is the interdependence of the decision levels discussed in this chapter. Each decision level is constrained by the resources made available at higher levels and by the degree of flexibility for later correction at lower levels.

Consider the manpower-planning decision level. The week-to-week and day-to-day shift-scheduling decisions and shift-by-shift corrective allocations obviously depend upon the permanent staffing levels established through the manpower-planning process. On the other hand, the range and flexibility of shift-scheduling and corrective allocation options available to management should be known so that their performance can be anticipated and included in the staffing decisions made during the manpower-planning process. That is, the over-all staff requirements cannot be fully assessed until it has been decided how fluctuations in load are to be accommodated. If overtime, for example, provides the only flexibility in short-term scheduling, the full-time staff requirements might be substantially higher than if part-time help and a float pool were also available.

The interdependencies of the three levels should be recognised to bring about systematic nurse staffing improvements. One general conclusion from this review is that greater attention should be given to studying these interdependencies of the decision levels, rather than studying each level in isolation.

The need for co-ordination between nurse staffing and other hospital activities, such as task assignment, scheduling of admission and operating rooms, budgeting, payroll and facility planning, should also be stressed. Many studies have examined alternative approaches for balancing patient numbers and mix, allocating patients to nursing units and scheduling patient care activities, but the impact of these admission- and treatment-scheduling procedures upon nursing utilisation and upon the need for flexibility in staffing procedures has not yet been fully explored.

Very few studies have attempted to evaluate systematically alternative

designs and methods of implementing nurse staffing systems and operating policies. We think it is crucial that the impact upon cost, quality and satisfaction of these strategic decisions be carefully investigated. There are many conflicting objectives, legal constraints and professional value systems in hospitals that place little emphasis on efficiency. More research and demonstration projects have to be undertaken before the adaptability, acceptability and significance of most of the reviewed procedures can be fully understood.

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