Sys Rev Pharm 2020; 11(3): 163 – 165
A multifaceted review journal in the field of pharmacy
E-ISSN 0976-2779 P-ISSN 0975-8453

Capacity Optimization model for Hospital Management Problem under Uncertainty

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Article History: *Submitted: 25.10.2019* *Revised: 22.12.2019* *Accepted: 18.01.2020*

ABSTRACT
Capacity management planning involves predicting the quantity and particular attributes of resources required to deliver health care service for hospitals at specified levels of cost and quality. For inpatient hospital care, capacity management requires information on beds and nursing staff capacity. This paper presents a capacity optimization model that gives insight into required nursing staff capacity and opportunities to improve capacity utilization on a ward level with some uncertainty parameters. A capacity model is developed to calculate required nursing staff capacity. The uncertainty turns up on the availability schedule of staff and the number of patient.

Keywords: Healthcare deliveries, Nursing-Staff Management, Stochastic Modeling.
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DOI: 10.5530/srp.2020.3.18

INTRODUCTION

Healthcare deliveries planning is essential in order to achieve a balance between the quality of the health care offered and the price of the service provided. Such planning includes the measurement of the amount and specific characteristics of the funds needed to provide health care services at a defined price and quality. Overall, effective healthcare capacity planning must answer a number of issues, including the length of the planning horizon, the level of service conducted, the type of service given, the quantity, capacity, cost and resources available or required (i.e. doctors, nurses, technicians, medical and clinical support personnel, facilities including buildings, rooms, beds, storage areas, laboratory tests and monitoring equipment, or any other component that contributes to the provision of health care) as well as the customer service metrics or performance measures expected for the facilit. While capacity planning has confronted health decision-makers and scholars for decades [1],[2] and [3], this issue has been addressed with a renewed sense depends on urgency.

This requires information on bed capacity and the capacity of nursing staff for inpatient care facilities in the hospital on a daily and annual basis. Quantitative models may be used to identify capacity needs for various planning purposes and for short, medium and long term planning matters. Even though a number of valuable models are outlined in global literature [4], [5] and [6], some of them are complicated to implement in reality because they involve a lot of information and clerical work [1].

Models must perform various functions in order to be able to implement capacity management in reality: "annual staff scheduling," "roster scheduling support" and "regular allocation of nurses to wards" [7] and [8]. "Strategic decisions" is also often referred to as a separate stage of planning [6], [9] and [10]. Models that rely on operational research mathematical optimization methods usually focus on short-term planning [11] and [12]. For example, [9] and [12] define models that integrate various planning horizons (daily, periodic (1–2 months) and yearly). There are linked models for periodic employee planning and day-to-day monitoring in these models. In addition, there were no literary works models that included operational planning problems with tactical and strategic decisions or support for operational scheduling with annual employee planning.

Capacity models are generally designed to determine the number of nurses required, while capacity management models should also provide an effective understanding of the potential for improving capacity utilization.

In fact, the issue may vary in uncertainty, such as the staff availability schedule and the number of patients. This paper discusses capacity issues with uncertainty parameters. The proposed model allows explicit incorporation of uncertain parameters. Most references to optimization issues in the presence of uncertainty come under the stochastic programming heading. The use of stochastic two-stage programs characterizes a particularly important model class. In such models, the objective function usually correlates to minimizing the estimated costs or maximizing the expected benefits (linear or non-linear), while it may also refer to the expected value of the absolute or quadratic deviations of certain specific objectives or the second-stage recourse function variance.

STOCHASTIC PROGRAMS: GENERAL FORMULATION

We define the stochastic (linear) program as the following model

$$\left.\begin{aligned} &\min\ g_0(x,\tilde{\xi}) \\ &\text{s.t.}\ \ g_i(x,\tilde{\xi}) \le 0, i = 1,\ldots,m, \\ &\qquad x \in X \subset \mathbb{R}^n, \end{aligned}\right\} \tag{1}$$

where $\tilde{\xi}$ is a random vector varying over a set $\Xi \subset \mathbb{R}^k$. More precisely, we assume throughout that a family *F* of "events", i.e. subsets of Ξ, and the probability distribution *P* on *F* are given. Hence for every subset $A \subset \Xi$ that is an events, i.e. $A \in F$, the probability *P*(*A*) is known. Furthermore, we assume that the functions $g_i(x,\cdot):\Xi \to \square \ \ \forall x,i$ are random variables themselves and that the probability distribution *P* is independent of *x*.

However, problem (1) is not well define since the meanings of "min: as well as of the constraints are not cleat at all, if we think of taking a decision on x before knowing the realization of $\tilde{\xi}$. Therefore a revision of the modeling process is necessary, leading to so-called deterministic equivalents for (1), which can be introduced in various ways.

DETERMINISTIC MODEL

First we formulate a deterministic model for the hospital capacity management problem.

Notations to be used

DA_{ij} : Initial number of doctors with type j in department i

SA_{ij} : Initial number of nurses with type j in department i

SBA_{ij} : Initial number of nurse aids type j in depertment i

D_{ij} : Type j doctors added in department i

S_{ij} : Type j nurses added to department i

SB_{ij} : Type j nurse-aids added to department i

TPA_i : Initial number of private beds in department i

TUA_i : Initial number of common beds in department i

TP_i : Number of private beds added to department i

TU_i : Number of common beds added to department i

TBP_i : Number of private beds used as common beds in department i

bd_{ij} : The cost of *j* type doctors in department *i*

bs_{ij} : The cost of *j* type nurses in department *i*

bsa_{ij} : The cost of *j* type nurse - aids in department *i*

bt_i : The cost of operating private beds in department *i*

bo_i : The cost of operating common beds in department *i*

bw_i : Waiting cost for private beds in department *i*

bwu_i : Waiting cost for common beds in department *i*

α_{ij} : Percentage of type *j* doctors needed to department *i*

β_{ij} : Percentage of type *j* nurses needed to department *i*

γ_{ij} : Percentage of type *j* nurse-aids needed to department *i*

δ : Percentage of private beds used as common beds in department *i*

μ : Maximum beds can be added to department *i*

ρ_i : Maximum fund available for department i

Objective Function

The objective of this problem is to minimize total operating cost which can expressed as

$$\text{Minimize} \sum_{i=1}^{n}\sum_{j=1}^{m} bd_{ij}(DA_{ij}+D_{ij}) + \sum_{i=1}^{n}\sum_{j=1}^{m} bs_{ij}(SA_{ij}+S_{ij}) + \sum_{i=1}^{n}\sum_{j=1}^{m} bsa_{ij}(SBA_{ij}+SB_{ij}) + \sum_{i=1}^{n} bt_i(TPA_i+TP_i-TBP_i) + \sum_{i=1}^{n} bo_i(TUA_i+TU_i) + \sum_{i=1}^{n} bw_i(TPA_i+TP_i) + \sum_{i=1}^{n} bwu_i(TUA_i+TU_i) \quad (5)$$

Constraints:

$$\alpha_{ij}(TP_i+TU_i) \le P_{ij}; i=1,2,...,n; j=1,2,...m \quad (6)$$

$$\beta_{ij}(TP_i+TU_i) \le S_{ij}; i=1,2,...n; j=1,2,...,m \quad (7)$$

$$\gamma_{ij}(TP_i+TU_i) \le SB_{ij}; i=1,2,...n; j=1,2,...m \quad (8)$$

$$\delta_{ij}(TU_i+TUA_i) \le TBP_i; i=1,2,...,n; j=1,2,...,m \quad (9)$$

$$TP_i+TU_i \le \mu; i=1,2,...n \quad (10)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} bd_{ij}D_{ij} + \sum_{i=1}^{n}\sum_{j=1}^{m} bs_{ij}S_{ij} + \sum_{i=1}^{n}\sum_{j=1}^{m} bsa_{ij}SB_{ij} + \sum_{i=1}^{n} bt_i TP_i + \sum_{i=1}^{n} bo_i TU_i \le; i=1,2,...,n \quad (11)$$

$$DA_{ij}, S_{ij}, SB_{ij}, TBP_i, TP_i, TU_i \ge 0 \text{ and integer} \quad (12)$$

EQUIVALENT DETERMINISTIC MODEL

P_s : Probability that scenario s will $s \in S$ (set of scenario)

Minimize:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} bd_{ij}(DA_{ij}+D_{ij}) + \sum_{i=1}^{n}\sum_{j=1}^{m} bs_{ij}(SA_{ij}+S_{ij}) + \sum_{i=1}^{n}\sum_{j=1}^{m} bsa_{ij}(SBA_{ij}+SB_{ij}) + \sum_{i=1}^{n} bt_i(TPA_i+TP_i-TBP_i) \quad (13)$$

Constraints:

$$\alpha_{ij}(TP_i^s+TU_i) \le D_{ij}; i=1,...,n; j=1,...,m \quad (14)$$

$$\beta_{ij}(TP_i^s+TU_i) \le S_{ij}; i=1,...,n; j=1,...,m \quad (15)$$

$$\gamma_{ij}(TP_i^s + TU_i) \le SB_{ij}; i = 1,...,n; j = 1,...,m \quad (16)$$

$$\delta_{ij}(TU_i + TUA_i^s) \le TBP_{ij}; i = 1,...,n; j = 1,...,m \quad (17)$$

$$TP_i + TU_i \le \mu \quad (18)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} bd_{ij}D_{ij} + \sum_{i=1}^{n}\sum_{j=1}^{m} bs_{ij}S_{ij} + \sum_{i=1}^{n}\sum_{j=1}^{m} bsa_{ij}SB_{ij} + \sum_{i=1}^{n} bt_i TP_i^s + \sum_{i=1}^{n} bo_i TU_i \le P_i; i = 1,...,n; s \in S \quad (19)$$

$$DA_{ij}, S_{ij}, SB_{ij}, TBP_i, TP_i, TU_i \ge 0 \quad \text{and integer} \quad (20)$$

FEASIBLE NEIGHBOURHOOD SEARCH

Step 1 Solve the relaxed problem, To get the optimal continuous solution

Step 2. Find the row index in which occur integer infeasibility from the continuous solution/

Step 3 Do a pricing operation as in simplex method for linear programming problem. .

Step 4. Calculate vector $\sigma_{ij} = v_{i*}^T a_j$

With *j* can be found from $\min_j \left\{ \left| \frac{d_j}{\sigma_{ij}} \right| \right\}$

If none, take the other non-integer nonbasic or superbasic *j*

Step 5. Find the step size

$\alpha_{j*} = B^{-1}\alpha_{j*}$

i.e. solve $B\alpha_{j*} = \alpha_{j*}$ for α_{j*}.

Step 6. Do ratio test for maintaining the

step 7. Exchanging basis

Step 8. Stop whenever no more integer infeasibility. Otherwise repeat from step 2.

CONCLUSIONS

This paper provides a model of capacity management for nursing staff under uncertainty. The outcome model would be a massive-scale issue, depending on the number of scenarios. To solve the integer model, we suggest a direct search approach.

REFERENCES

1. Pierskalla W.P, Brailer D. 1990. *Application of Operations Research in Health Care Delivery*. In: Pollock S, Barnett A, Rothkopf M (eds) Beyond the profit motive: public sector applications and methodology. Handbooks in OR&MS, vol 6. North-Holland, New York.
2. PierskallaW.P, Wilson D. 1989. *Review of Operations Reserach Improvements in Patient Care Delivery Systems*. Working paper, University of Pennsylvania, Philadelphia.
3. Smith-Daniels VL, Schweikhart SB, Smith-Danielsn DE. *Capacity management in health care services*. review and future research dirresctions Decis Sci, Vol. 19, 1988, pp. 899-918.
4. Hurst K. 2003. *Selecting and Applying Methods for Estimating the Size and Mix of Nursing Teams*. Leeds, Nuffield Institute for Health, pp. 1-19.
5. Halloran EJ, Vermeersch PEH. 1987. Variability in Nurse Staffing Research data Collection and the Method of Reporting. *Journal of Nursing Administration,* pp. 17:26-34.
6. Siferd SP, Benton WC. 1992. Workforce Staffing and Schedulling-Hospital Nursing Specific Models. *Eur J Oper Res*, Vol. 60, pp. 233-246.
7. Brusco MJ, Futch J, Showalter MJ. 1993. Nurse Staff Planning Under Conditions of a Nursing Shortage. *J Nurs Adm*, Vol. 23, pp. 58-64.
8. Kao EPC, Tung GG. 1981. *Aggregate Nursing Requirement Planning in a Public Health Care Delivery System*. Socioecon Plann Sci, Vol. 15, pp. 119-127.
9. Abernathy WJ, Baloff N, Hershey JC, Wandel S. 1073. *A Three-Stage Manpower Planning and Schedulling Model-A service Sector Example*. Oper Res, Vol. 21, 1973, pp. 693-711.
10. Brown LE, Lewin BA.1982. *Supplemental Staffing Agencies: Friend or Foe?*. Nurs Manage, Vol. 13. pp. 37-47.
11. Bordoloi SK, Weatherby EJ. 1999. *Managerial Implications of Calculating Optimum Nurse Staffing in MedicalUnits. Health Care*. Manage Rev, Vol. 24, pp. 35-44.
12. Wright PD, Bretthauer KM, Cote MJ. 2006. *Reexamining the Nurse Scheduling Problem: Staffing Ratios and Nursing Shortages*. Decision Sciences, Vol. 37, pp. 39-70.
13. Van der Vlerk M.H, Haneveld W.K.. 1999. Stochastic Integer Programming: General Models an Algorithms. *Annals of Operations Research*, Vol. 85, pp. 39-57.
14. Prasad, D., Kabir, Z., Dash, A., Das, B.Abdominal obesity, an independent cardiovascular risk factor in Indian subcontinent: A clinico epidemiological evidence summary (2011) Journal of Cardiovascular Disease Research, 2 (4), pp. 199-205. DOI: 10.4103/0975-3583.89803