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A Goal Programming Model for Reallocation of Hospitals' Inpatient Beds

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Abstract: Due to changing patient loads and demand patterns over time, assigning bed complements for various medical services in a hospital is a recurring problem facing the administrators. We present a goal programming approach for reallocating beds to wards. In this study, important constraints of beds allocation were identified through the review of literature and interview with experts and objective function were determined based on constraints. Finally, the presented model was solved by GAMS Software. The important constraints included the total number of beds, nursing work hours, waiting time, the definite bed allocation to patient, the definite bed allocation to ward. The main goals were distinguished: maximum the use of human resources, minimizing the number of empty beds, reducing the waiting time, definite bed allocation to patient and definite bed allocation to ward then the model solved based on the MIP solver in GAMS. The results related that goal programming model was presented suitable framework for bed reallocation and optimum use.

Key words: Goal programming · Inpatient bed · Hospital

INTRODUCTION

A hospital is an institution for health care, which is able to provide complex service and satisfaction patient [1]. Hospitals include numerous medical units specializing each in a different area of medicine, such as internal, surgery, intensive care, obstetrics and so forth. In most of the large hospitals there are several similar medical units operating in parallel. Our nation's health care providers - physicians, nurses, hospitals and others - work hard to provide life-saving and life-improving care of people. The rising cost of health-care services has been a subject of mounting importance and much discussion health care system. Ample explanations have been proposed. Yet, regardless of their cause, rising costs impose and rightly so, pressures on health-care providers to improve the management of quality, efficiency and economics of their organizations. Hospitals play a central role in the provision of health services that managerial aspect of providing health services to patients in hospitals is becoming increasingly important. Hospitals want to reduce costs and improve resource allocation. Hospital departments are striving to minimize inappropriate resource use by adopting new strategies and tools or by optimizing existing ones. Limited bed availability and the need to contain rising health costs have intensified the search for alternatives to conventional hospitalization [2]. Hospital faced with increasing economic pressures, limited resources and unlimited needs of population in health system. This issue makes the specific situation for hospitals in health economics. The health system must be respond to the growing trend of patients to receive appropriate services. On the other hand, they always face with limited resources and budgets [3]. Hospitals costs have dramatically increased and at the same time, hospitals have been under pressure to provide increased quality of care for their patients. The challenge to improve

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healthcare quality, reduce medical errors, increase efficiency and deliver appropriate evidence-based health services is stronger than ever. These challenges generate significant interest in how resources can be utilized to maximize patient throughput and minimize patient wait time without incurring additional costs [4]. Discussions of hospital quality, efficiency and nursing care often taken place independent of one another. Activities to assure the adequacy and performance of hospital nursing, improve quality and achieve effective control of hospital costs need to be harmonized [5].

Definition of the Problem: Busy hospital systems constantly provide new challenges to their managers and decision-makers due to high demands for service, high costs, limited budget and healthcare resources. As a result, decision-makers are continuously studying efficacy and efficiency of existing hospital systems and must be able to evaluate the outcomes of any changes they make to these systems [6]. Hospitals today are faced with several pressures such as increasing equipment costs, a shortage of qualified healthcare professionals and limited hospital facilities [7]. Bed shortage or improper bed distribution can be increase waiting times, patient displacement and distrust of bed management [8]. Hospital bed capacity planning accuracy is important to satisfy patients' needs, organize departments and improve the quality and amount of service provided. Health care management thus should aim to optimize activities within the imposed [9]. The management of hospital beds is an important subtask. Various approaches have been proposed, involving the computation of efficient assignments with regard to the patients' condition, the necessity of the treatment and the patients' preferences. However, these approaches are mostly based on static, unadoptable estimates of the length of stay and etc [10].

Suggestion for Solve Problem: Inappropriate use of hospitals resources in considerable important challenge, in an attempt to overcome this problem requires to correct management of processes and hospital resources. The success of such units hinges on both efficient administration and management and the active involvement of physicians and nursing staff in the goal of improving the quality of care. The efficiency of the hospital delivery system and the minimization of costs of the services have positive effects on performance hospitals that we reach to these goals through behavior predict of system using simulation model [11]. Simulation studies focusing on healthcare delivery networks are mainly based on modeling care processes, patient flows and available resources within healthcare supply chains and facilities such as hospitals, clinics and care units. Efficient allocation of resources is very critical when applied to health industry. It is a matter of life and death when supply cannot meet the demand of the patients in the right time and in the right amount. Utilization of hospital beds is often inefficient and hospital administrator's effort is to increase efficiency and Patient care improve and optimum bed allocation [12]. Models can provide a simplified interpretation of reality that preserves the essential features of the situation being examined and can be used as a tool to investigate decision-making options, particularly in complex environments such as the healthcare sector. As one potential approach to facilitate decision-making in the healthcare sector, goal programming modeling can be used to model decisions about hospital bed allocation [13].

Goal Programing: One of the most promising techniques for multiple objective decision analysis is Goal Programming. Goal Programming is a powerful tool which draws upon the highly developed and tested techniques of Linear Programming, but provides a simultaneous solution to a complex system of competing objectives. Goal Programming can handle decision problems having a single goal with multiple sub goals. In Goal Programming, instead of attempting to maximize or minimize the objective function directly as in the Linear Programming, the deviations between goals and what can be achieved within the given set of constraints are minimized. Three steps of goal programming model include define the decision variables, define the goals, define the deviational variables [14].

The general goal programming model can be mathematically. expressed as:

Minimize $Z = £Wi (dpi, dni)$
$i = 1, 2, 3, \ldots, n$

Subject to:
$£aijXj + dni – dpi = bi$
$Xj, dni, dpi \geq 0$

Xj= Decision variables, Wi = weight goals, dpi= positive deviations, dni = negative deviation, bi = resources, aij= technical coefficients, Z = Total weight deviation.

The deviational variable is represented in two dimensions, both the positive and the negative deviations from each goal or subgoal. Then the achievement function becomes minimization of these deviations based on the relative importance or priority assigned to them [15].

Literature Review: Most work on bed allocation planning has used simulation and goal programming approach. G. Joey presented a goal programming model for determining the optimal allocation of drugs to different rural health centers. The model aims to balance the allocation of anti-TB drugs to each health center and achieve a higher cure rate of patients afflicted with tuberculosis (TB). The model developed considers the medication requirements for the treatment patients [16].V.M. Trivedi has developed a MIGP model for expense budgeting in a hospital nursing department. Objectives are based on cost and quality nursing care considerations. The results reported such as justice of budget distribution, promotion services and job motivation [17]. M.N. Azaieza *et al*. has developed a computerized nurse-scheduling model is developed. The model is approached through a 0-1 linear goal program. The model aims including satisfy a number of important criteria for efficient scheduling, to balanced schedules, fairness considerations and nurses'preferences, in addition to ergonomic considerations and staffing requirements both in quality and size [18]. J. Ruzzakiah proposed a cyclical nurse scheduling model using a 0-1 goal programming that would help the head nurse or nurse manager to have less effort on building new schedules periodically. The result obtained from this model gives an optimal solution where all goals are achieved. The model also provides an unbiased way of scheduling the nurses and thus leads to an overall higher satisfaction and fairness to the nurses and the hospital management [19]. Moores *et al*. have formulated the student nurse allocation problem using also a 0-1 GP. The problem was to produce a 3-year schedule for student nurses to comply with the minimum practical and theoretical standards while being used as part of the hospital work force [20]. A.Rajabi surveyed optimal allocation of resources by goal programming model for hospital. He expressed using of goal programming model to increase use of resources (human, physical and financial resources). Inadequate access to various resources was one of hospital constrains. This model identified performance bottlenecks and shortage resources [21]. It is concluded that appropriate planning for allocation bed must consider both structural and qualitative service requirements.

Global researches have showed that modeling is one of the most common approaches for assessment the current status and future projects. In this study, we introduced a framework for reallocation pattern of inpatient beds by using goal programming approach.

Methodology and Model Structure: In this study, important constraints of beds allocation identified through the review of literature and interview with experts. Objective function determined based on constraints. The model contains 5 constraints. The sets of constraints are given below.

The first set of constraints is beds have distributed. The second set of constraints is nurse work hours in month per ward that this constraint include minimum of nurse work hours, maximum of nurse work hours. The third set of constraints is patient waiting time per ward. The fourth set of constraints is definite allocation bed to ward. The fifth set of constraints ensures is definite allocation bed to patient. The objective function of the formulation consists of five terms. The objective function minimizes the total goals are given below.

The first term indicates minimize the number of empty Bed. The second term indicates maximum use of human resources. The third term contains Reduced waiting time. The fourth term indicates definite allocation bed to patient. The fifth term indicates definite allocation bed to ward. Finally, the presented model solved based on the MIP solver in GAMS. The following features are included in the simulation model. To develop a GP model, the symbols used and the model components (system constraint, goal constraint and achievement function) are explained below:

Model constraints

Constraint 1: Total beds:

$$\Sigma x_{ij} + d1^- + d+1 = h$$

j=ward symbol i=Bed symbol h= Total number of beds

⊠Constraint 2: Nursing Hours:

$$\Sigma tsjXij + d2^- + d+2 \geq c$$

j=ward symbol i=Bed symbol s = nursing hours each bed c= Total nursing hours in month

Constraint 3: Waiting time:

Σ twiXij + d+ 3 $\leq$ f

j= ward symbol i= Bed symbol $_{tw}$=Average waiting time for patients in each ward f=Total waiting time for patients

Constraint 4: Definite allocation bed to patient:

ΣXij+ d+4+d-4=1

j= ward symbol i= Bed symbol

Constraint 5: Definite allocation bed to ward:

ΣXij> 0

j= ward symbol i= Bed symbol

Goal function:

- Maximum use of human resources

Min = Σ (d- 1 + d+1)

- Minimize the number of empty Bed

Min = Σ (d+2)

- Reduced waiting time

Min =Σ (d+ 3)

- Definite allocation bed to patient

Min =Σ (d+4+d-4)

- Definite allocation bed to ward

Min =Σ (d^+_5+d^-_5)

Min = Σ (d^-_1 + d^+_1) + Σ (d^-_2) + Σ (d^+_3) +Σ (d^+_4+d^-_4)+ Σ (d^+_5+d^-_5)

Simulation Model: In presenting our method, it is assumed that a general Hospital is used as a case study to demonstrate our modeling approaches with the following characteristics:

Symbols:

Ts = Average nursing hours
tw =Average optimal waiting time
I = Number of beds
J = Number of ward

Formulating Model Constraints: Before we formulate the objective function, let us first declare the various sets and parameters that will be used in the formulation.

Constraint 1: Total beds:

Σ x i j +d_1^- + d_+^1=361

⊠Constraint 2: Nursing Hours:

ts1:4.16 ts2:2.30 ts3:2.40 ts4:10.26 ts5: 9.66 ts6:5.72 ts7:1.83 ts8:8.06 ts9:2.51 ts10: 4.40 ts11:1.46 ts12:1.88 ts13:1.98 ts14:2.93 ts15: 1.05 ts16:2.20 ts17:2.47 ts18: .80 ts19:1.14 ts20:1.25 ts21:1.46

Σ4.16Xi1+Σ2.20Xi2+Σ2.40Xi3+Σ10.26Xi4+Σ9.66Xi5+Σ5.72Xi6+Σ1.83Xi7+Σ8.06Xi8+Σ2.51Xi9+Σ4.40Xi10+Σ1.46Xi11+Σ1.88Xi12 + Σ1.98Xi13+ Σ2.93Xi14+ Σ1.05Xi15+Σ2.20Xi16+Σ2.47Xi17+Σ.80Xi18+Σ1.14Xi19 +Σ1.25Xi20 + Σ1.46Xi21 +d_2^- + d_+^2≥ 1238

Σ4.16Xi1+Σ2.20Xi2 + Σ2.40Xi3+ Σ10.26Xi4 + Σ9.66 Xi5+Σ5.72Xi6+Σ1.83Xi7+ Σ8.06Xi8+ Σ2.51Xi9 + Σ4.40Xi10+Σ1.46Xi11+Σ1.88Xi12 + Σ1.98Xi13+ Σ2.93Xi14+Σ1.05Xi15+Σ2.20Xi16+Σ2.47Xi17+Σ.80Xi18 +Σ1.14Xi19 +Σ1.25Xi20 + Σ1.46Xi21 + d_-^2 + d_+^2≥1518.40

Table I: Hospital general characteristics

Number of beds	361 (number)
Number of wards	21 (ward)
Maximum hour of nursing with most overtime	1238.43(hours)
Minimum hour of nursing with the Least overtime	1518.40(hours)
Average length of stay	46.33 (average day in month)
waiting time	7476 (hours)

Table II: The number of beds before and after model solving

Unit	Number of Beds before model solving	Number of Beds after model solving	unit	Number of Beds before model solving	Number of Beds after model solving
The internal part 4	20	15	Internal Emergency	20	15
Nephrology	15	15	Emergency Surgery	22	69
General Surgery	29	15	Neurosurgery	15	15
Surgical super specialty	16	15	ICUG	12	19
Neurosurgery	16	15	CCU	10	15
ENT	11	15	POST CCU	24	15
Orthopedics1	23	15	ICUOH	6	18
Orthopedics2	21	15	Subspecialty of internal	28	15
Burn	15	15	Angiography	11	15
Neurology of internal	14	15	ICUN	5	15
Infectious Disease Internal	27	15			

Constraint 3: Waiting time:

tw1:6 tw2:6 tw3:12tw4:6 tw5:6 tw6:6 tw7:6 tw8:6 tw9:12 tw10: 12 tw11:12 tw12:12 tw13:12 tw14:12 tw15: 12 tw16:12 tw17:12 tw18:12 tw19:12 tw20:12 tw21:12

$\Sigma 6Xi1 + \Sigma 6Xi2 + \Sigma 12Xi3 + \Sigma 6Xi4 + \Sigma 6Xi5 + \Sigma 6Xi6 + \Sigma 6Xi7 + \Sigma 6Xi8 + \Sigma 12Xi9 + \Sigma 12Xi10 + \Sigma 12Xi11 + \Sigma 12Xi12 + \Sigma 12Xi13 + \Sigma 12Xi14 + \Sigma 12Xi15 + \Sigma 12Xi16 + \Sigma 12Xi17 + \Sigma 12Xi18 + \Sigma 12Xi19 + \Sigma 12Xi20 + \Sigma 12Xi21 + d+ 3 \leq 7476$

Constraint 4: Definite Allocation Bed to Patient:

$\Sigma xij + d+4+d-4=1$

Constraint 5: Definite Allocation Bed to Ward:

$\Sigma xi1 > 0\ \Sigma Xi2 > 0\ \Sigma Xi3 > 0\ \Sigma Xi4 > 0\ \Sigma Xi5 > 0\ \Sigma Xi6 > 0\ \Sigma Xi7 > 0\ \Sigma Xi8 > 0$

$\Sigma Xi9 > 0\ \Sigma Xi10 > 0\ \Sigma Xi11 > 0\ \Sigma Xi12 > 0\ \Sigma Xi13 > 0\ \Sigma Xi14 > 0\ \Sigma Xi15 > 0\ \Sigma Xi16 > 0$

$\Sigma Xi1 > 0\ \Sigma Xi17 > 0\ \Sigma Xi18 > 0\ \Sigma Xi19 > 0\ \Sigma Xi20 > 0\ \Sigma Xi21 > 0$

The Goal function is then as follows:
goals

- Maximum use of human resources

$\text{Min} = \Sigma (d^-_1 + d^+_1)$

- Minimize the number of empty Bed

$\text{Min} = \Sigma (d+2)$

- Reduced waiting time

$\text{Min} = \Sigma (d+ 3)$

- Definite allocation bed to patient

$\text{Min} = \Sigma (d+4+d-4)$

- Definite allocation bed to ward

$\text{Min} = \Sigma(d^+_5+d^-_5)$

$\text{Min} = \Sigma (d^-_1 + d^+_1) + \Sigma (d^-_2) + \Sigma (d^+_3) + \Sigma (d^+_4+d^-_4) + \Sigma(d^+_5+d^-_5)$

After the solve model by Software, beds distribution by using goal programming brought in Table II

DISCUSSION

Based on modeling and compared output with input the results showed using goal programming caused optimum allocation of resources. Efficient allocation of hospital beds has large impact on health management.Efficient use of limited resources particularly hospital beds is an important issue. Many managers try to optimize the number beds of hospital to improve care and satisfaction patient. Simulation studies and forecast status is necessary for prevention of loss capital and setting priories in programs [22]. coordinated framework of hospital bed management including the management of all admissions in hospital, length of stay, discharge and handling (within the hospital or another hospital).Principled processes management of beds is such as a committee to distribute bed, focus on distribution, distribution of bed in 24 hours a day [23]. As identify, the number of beds change influence the resources such as staff source, budget and etc. Factors that might be considered high priority in bed distribution included: bed occupancy rate, waiting time patient, staff resource. M. Colin used a model for estimating the number of beds in the delivery room base

on bed occupancy rate but other effective factors are such as the number of doctors and nurses, unit equipment and length of stay [12]. Patient waiting is undesirable, limiting waiting times is an important objective when designing a healthcare system. Patient waiting times reflects poor management, lack of coordination and insufficient resources. The research showed that waiting time is one of the factors affecting patient satisfaction and distribution of hospital bed of service quality which is offered [24]. S. Ajami *et al*. reported that patient waiting time is also important to examine hospitals and their efficiency.in this study, The result showed that waiting time patients is important factor on satisfaction patient but also one of the indicators will count for quality assessment of service [25]. Bed occupancy rate is effective factor for bed distribution. Cohen *et al*. demonstrated that in spite of high demand for hospital beds, improper management and planning may cause that a large number of hospital beds remain useless. Since bed occupancy percent of hospital ward can be affected by administrational policies, So It is suggested to consider a hierarchy system for a ward hospital to recommend possible changes in occupancy bed rate to manage the effective factor on bed distribution in hospitals [26]. Human resource is the most critical element for resources allocation in the Health Sector. A. Barnard *et al* reported that costs influenced of nurses number. The results showed that the number of appropriate nurses for hospitals bed caused decreased length of stay, decreases effects side and better care of patient [27]. MA. Ahmed *et al*. conducted optimization simulation for emergency department. In this simulation, the appropriate mix of resources showed 28 percent increase in efficiency staff and 40 percent reduction in waiting time [28]. Optimum bed allocation in hospitals should be consider to the improve quality. J. B. Lin *et al*. proposed and evaluated a number of models for building surgery schedules and they developed a number of mixed integer programming based heuristics and a met heuristic to minimize the expected total bed shortage and present computational results [29]. Y. Tütüncü and D. Newlands showed that hospital beds planing and management was effective factor for Increase Patient Satisfaction and effectiveness units [30]. The purpose of planning and control of hospital beds obtained satisfied patient, optimize efficiency and increase productivity. The goals of healthcare processes improvement are to enhance the effectiveness. That this study attempted for optimum bed reallocation that its result was full use of hospital resource.

CONCLUSION

- In the present study the lack of some goal objection records was main problem to do bed reallocation using goal programming. It is suggested to collect data regularly to prevent problem in data analysis.
- Education is required to ensure health care professionals become conversant with more sophisticated modeling techniques that should lead to better decision making.

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