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Research Article

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Sensitivity Analysis of Large-scale Medical Equipment Allocation

Xiaoqing Lu[1], Shuming Guan[2] and Wenyi Zhang[3]

College of Science Hebei United University TangShan, China

ABSTRACT

Focusing on the problems of large-scale medical equipment allocation in medical institutions, such as improper allocation , high rate of capital employed, unfairness and so on, based on the data collected related to the operating frequency of five-type large-scale medical equipments, apply the linear programming of operational research into the analysis of the operating frequency of equipments. On the basis of daily available time of equipment, monthly average testing number of patients, non-negativity of decision variable as well as other factors, list the corresponding constraint conditions, and then establish the linear programming model of profit maximization for hospital. Employ EXCEL to obtain the solution of the model, raising the proposal concerning the standard of large-scale medical equipment allocation referring to the result of sensitivity analysis. Aim: provide a scientific and reasonable management method to the hospital administrators, improving the feasibility and practicability of the management plan.

Key words: Medical equipment; linear programming; sensitivity analysis

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INTRODUCTION

With the development of modern science and technology, improving standards of living, people have made health care increasingly high quality of service requirements. On the one hand, large medical equipment in medical and health services play an increasingly important role; On the other hand, with many hospitals unplanned purchase of medical equipment and blindly, the idle rate, turn to be a clear upward trend in share capital. Caused by a misconfiguration, management control, there is, no doubt that the hospital administrators and management are in the introduction of proposed new research. Linear programming is an important branch of operations research, it is a widely used for industrial, military, health management and other areas of quantitative analysis method, which aims to help managers to achieve organizational goals, under conditions of limited resources optimally and provide a theoretical basis for decision-makers [1].

This article aims to use linear programming to the four hospitals of several major medical equipment to analyze the situation, establish profit-maximizing linear programming model to determine the boundary constraints; then use the computer to solve the model and the results and sensitivity analysis, the results of the analysis can help put forward reasonable suggestions.

CASE AND ANALYSIS

Case: Now on the A, B, C, D our four comprehensive hospitals of the five large-scale equipment CT, MRI, DSA, ultrasound, X-ray machine costs and equipment usage data collection, and the list is as follows[1][2]:

Tab.1: Five kinds of equipment costs and utilization

	CT	MRI	DSA	Ultrasound	X-ray machine
The average examination time per person（Hours / times）	0.25	0.33	1.08	0.33	0.30
Can start on time	24	10	15	15	15
The average check per person profit	50	20	10	50	18
Average cost of each device（Ten thousand yuan）	550	1500	324	150	300

Tab.2: The hospital equipment usage and attendances

Hospital	CT	MRI	DSA	Ultrasound	X-ray machine	Acceptable number of average monthly check（Person / month）
A	0.42	0.42	0.38	0.85	0.36	12000
B	0.54	0.53	0.43	0.67	0.85	12536
C	0.52	0.68	0.45	0.70	0.48	14200
D	0.73	0.47	0.72	0.58	0.92	17520
To accept the check number（Person / month）	x_1	x_2	x_3	x_4	x_5	

Analysis: in solving such practical problems, linear programming model should be concerned about the three major components:

- Decision variables. The system in the unknowns to be determined, but also decision-making system in the controllable factors need to be achieved according to the purpose of factors' affect .and find the decision variables. The problem of decision variables is accepted to check the monthly number of respectively x_1、x_2、x_3、x_4、x_5 (see table above) that.

- The objective function. By the decision variables and objective to be achieved between the function of the target function. Linear programming objective function is a linear function of the target to achieve maximum or minimum. Such as maximum profit, minimum cost or the largest number and so on. The purpose of this case raised is about a reasonable configuration device, the hospital's profit-maximizing [6].

- Constraints. It means that the decision variables determine the conditions and limitations of the decision variables to satisfy the known conditions. In practical problems, the linear programming variables should be positive, that is non-negative constraints, because practical problems are represented by physical variables, can not be negative. This case should be based on available boot time, the number of average monthly check and accept the non-negative decision variables listed in the corresponding constraints[6].

THE ESTABLISHMENT OF THE HOSPITAL TO OBTAIN THE MAXIMUM PROFIT LINEAR PROGRAMMING MODELS

With four hospitals received monthly CT, MRI, DSA, ultrasound, X-ray examination of the numbers were:

x_1、x_2、x_3、x_4、x_5.

A linear programming model for the:

The objective function $\max Z = 50x_1 + 20x_2 + 10x_3 + 50x_4 + 18x_5.$

Constraints

① $0.25\,x_1 \leq 720$

② $0.33\,x_2 \leq 300$

③ $1.08\,x_3 \leq 450$

④ $0.33\,x_4 \leq 450$

⑤ $0.30\,x_5 \leq 450$

⑥ $0.42\,x_1 + 0.42\,x_2 + 0.38\,x_3 + 0.85\,x_4 + 0.36\,x_5 \leq 12000$

⑦ $0.54\,x_1 + 0.53\,x_2 + 0.43\,x_3 + 0.67\,x_4 + 0.85\,x_5 \leq 12536$

⑧ $0.52\,x_1 + 0.68\,x_2 + 0.45\,x_3 + 0.70\,x_4 + 0.48\,x_5 \leq 14200$

⑨ $0.73\,x_1 + 0.47\,x_2 + 0.72\,x_3 + 0.58\,x_4 + 0.92\,x_5 \leq 17520$

⑩ $x_i \geqslant 0$, x_i are Integer (i=1,2,…,5）

FOR SOLVING LINEAR PROGRAMMING MODEL

Solving linear programming problems using EXCEL with powerful and intuitive features, and has been widely used management practice. Specific steps are as follows:

1. In the Excel menu bar select "Tools / Add-Ins", then in the pop-up dialog box, select "Solver" and left-click "OK".

2. In electronic form a linear programming model .
(1) The issue of data collection and data entry spreadsheet data cells.
(2) To determine the need to make decisions, and specify the variable cells display these decisions;
(3) To determine the limits of these decisions (constraints conditions), and the data is limited and decisions that result into the output cell;
(4) Select the target cell to enter data in decision-making and decision-making that goal [7].

In fact, in electronic form a linear programming model, the key is to find good data cell, changing cells, output cells and target cells. The data in this case the input data in the cell (see table below) where the target cell for the I16 (total profits), decision variable (the monthly checks received five kinds of medical equipment, the number of people)in the changing cells B17: F17 in , cell I20 to balance the time required,G2:G5 and D9: D13 for the output cell. Cell E9: E13, I2: I5 in the "≤" constraint was.

	A	B	C	D	E	F	G	H	I
1	hospital	CT	MRI	DSA	Color Doppler ultrasound	X-ray machine	Total demand		Available resources
2	A	0.42	0.42	0.38	0.85	0.36		≤	12000
3	B	0.54	0.53	0.43	0.67	0.85		≤	12536
4	C	0.52	0.68	0.45	0.7	0.48		≤	14200
5	D	0.73	0.47	0.72	0.58	0.92		≤	17520
6									
7									
8			Time demand	Total demand		Available time			
9		CT	0.25		≤	720			
10		MRI	0.33		≤	300			
11		DSA	1.08		≤	450			
12		Color Doppler ultrasound	0.33		≤	450			
13		X-ray machine	0.3		≤	450			
14									
15		CT	MRI	DSA	Color Doppler ultrasound	X-ray machine			Total profits
16	Unit profits	50	20	10	50	18			
17	Decision variables								
18									
19							Total cost		Withdraw cost time
20	Equipment cost	5500000	15000000	3240000	1500000	3000000			

3. In the output cell and target cell enter the formula. The formula used in the case [4] [5]:

G2 =SUMPRODUCT(B2:F2,B17:F17)

G3 =SUMPRODUCT(B3:F3,B17:F17)

G4 =SUMPRODUCT(B4:F4,B17:F17)

G5 =SUMPRODUCT(B5:F5,B17:F17)

D9 =MMULT(C9,B17)

D10 =MMULT(C10,C17)

D11 =MMULT(C11,D17)

D12 =MMULT(C12,E17)

D13 =MMULT(C13,F17)

I 16 =SUMPRODUCT (B16:F16,B17:F17)

4. Solver

In the Tools menu, select "Solver" command, the pop-up "Solver parameters" window. In the dialog box, select the target cell I16, the problem type "Max", select the variable cells B17: F17. Click the "Add" button, then "add binding" dialog box, according to the model, adding a total of three constraints:
B17:F17=integer, D9:D13<=F9:F13, G2:G5<=12:15.
Then click on "Options" button, "Solver Options" dialog box, the "linear model" and "assume non-negative," the two selected, then click "OK", "solve" button .

The optimal solution of linear programming (2880, 909, 416, 1363, 1500), hospitals receive a total monthly income of 26.1490 million Yuan.

LINEAR PROGRAMMING SENSITIVITY ANALYSIS [4]

EXCEL cannot finish the sensitivity analysis for integer programming, now "B17: F17 = integer" to remove this constraint, and then make a sensitivity analysis, some results in Table 3:

Tab.3: Linear programming sensitivity analysis

Cell	Name	Final Value	Shadow Price	Constraint R.H.Side	Allowable Increase	Allowable Decrease
D9	CT Total demand	720	200	720	3764.434624	720
D10	MRI Total demand	300	60.60606061	300	4960.760294	300
D11	DSA Total demand	450	9.259259259	450	18779.12727	450
D12	Color Doppler ultrasound Total demand	450	151.5151515	450	3319.861176	450
D13	X-ray machine Total demand	450	60	450	2869.827807	450

Provide the amount of business is located five kinds of instruments, respectively y1、y2、y3、y4、y5 the five kinds of equipment, the shadow price of effective use of time zone are 0≤y1≤4484.43，0≤y2≤5260.76、0≤y3≤19229.13、0≤y4≤3769.86、0≤y5≤3319.83 Column from the shadow price can be seen when the CT volume of business provided in [0, 4484.43] changes within each increase (decrease) a person, the total profit will be a corresponding increase (decrease) 200; Similarly you can get the other four devices shadow price analysis[5].

CONCLUSION

We can also get average cost of each device and according to the hospital we can obtain the total monthly income to calculate the hospital through 9 years to recover the cost, and general machine service life of 6-8 years, which resulted in hospital financial loss.

Based on sensitivity analysis results, resulting in fewer hospital revenue is mainly due to machinery and equipment idle. Therefore, under the conditions of the existing resources, it is necessary to increase the amount of patients treated, extending the working hours of medical equipment, improve equipment utilization, so as to improve the economic efficiency of the hospital. According to the data provided by linear programming hospital administrators formulate a scientific and rational management plan, and then management plan will be able to enhance the feasibility and practicality, avoid the blindness caused by work experience.

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