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Optimum Allocation of Computer Resources through Goal Programming

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Abstract: **Allocation of computer resources is becoming an increasing problem both within and outside of computer centre, with budgets fixed and demands increasing system analyst and designers are looking for ways to more effectively and efficiently utilize existing hardware and to design better system. Goal programming model was designed to allow optimization of multi-criteria as needed in this process. This paper deals with application of goal programming to system analysis and design phase of computer implementations and usage.**

Key Words: **Goal Programming, Computer Resources, Fuzzy Goal Programming Modal.**

I. INTRODUCTION

Public pressure and limited quantities of natural resources necessitate development of more reliable decision making techniques. Modern natural resource managers are rapidly becoming aware of new decision aiding techniques which are capable of reviewing, utilizing, and organizing vast quantities of resource data. During the past decade, many models utilizing operation research techniques have been developed to aid range and other resource managers.

Decision makers realize, however, that linear programming models are single objective or single goal systems; the objective has commonly been profit maximization or cost minimization. Linear programming has been modified in order to allocate resources when multiple conflicting goals are present. The procedure is called goal programming. The traditional method of solving multiple goal problems has been to define all goals in a common unit. Managers and most economists have been highly critical of this procedure as all goals cannot be translated into strictly economic terms. In goal programming, there is no requirement that the objectives be defined in the same value, terms. The only requirement in goal programming is that the manager can attach ordinal priorities or rankings to the goals that reflect the importance of each goal. Once goals have been defined and ranked according to importance, a solution via goal programming can be obtained. The decision maker can then change the goal priorities, and by examining the solutions, he can obtain an estimate of the tradeoffs between goals. The results of the goal program have been compared to the results of a linear program. The concept of goal programming evolved as a result of unsolvable linear programming problems and the occurrence of conflicting multiple goals.

Ana Barcus [1] have developed Supporting the allocation of software development work in distributed teams with multi-criteria decision analysis, Aouni B [2] have described decision-makers preferences modeling in the stochastic goal programming, Blahe [3] have developed a goal programming approach to strategic resource allocation in acute care hospitals, Dominique[4] et al. have developed Multiple criteria decision analysis of treatment and land-filling technologies for waste incineration residues, Hodgkin J have described [7] European Supporting the Intelligent MCDA user: a Case Study in Multi-person Multicriteria Decision Support, Juliana Regueira Abath et al.[10] have developed Outsourcing multicriteria decision model based on promethee method, Liu D [12] have described Object-oriented decision support system modeling for multicriteria decision making in natural resource management, Mishra S [15] have described a fuzzy goal-programming model of machine-tool selection and operation allocation problem in FMS: a quick converging simulated annealing-based approach, ODDOYE JP [16] have described a multi-objective model to determine efficient resource levmedical assessment unit, Yaghoobi M [22] have described weighted additive models for solving fuzzy Goal Programming problems.

II. DATA OF THE PROBLEM

If better allocations of computer resources can be made in the purchase/installation phase, then the system will perform better, satisfy it's more hardly, and the organization will get more utility for its purchase Rupees. This, in turn, will allow political benefits to accuse to the administration of the organization for having been so wise to have made such a good purpose-political benefits from both lower and higher levels of management; lower will be delighted that something "works as advertised" as their computing needs are met, and higher levels will be delighted that a system was finally purchased that doesn't need a multi-million dollar "system upgrade" every year or so. Simply speaking, the problem is this: Since there are only a few heuristics dealing with allocation of computer resources, build a goal programming model for allocation of college/university computing resources, taking into account the priorities and goals of the institution.

The data for this study were gathered at a small [i.e., enrollment of less than 3,000], college in Hyderabad in India, and four-year state college which is presently in the process of installing a new computer system. This new system is primarily for administrative computing, so no attention has been paid to constraints dealing with faculty, instructional, or research computing needs. The sole focus of the study is restricted to the perceived administrative mission of the computer. Prior to a detailed discussion of the model itself, its development and the run protocol rationale will be discussed. The Dean of Finance, and the Director of the Computer Center, the following allocations, in priority order, was stated as critical;

(1) Terminal allocation

(2) Allocation of computer "core time"

(3) Allocation of printer time

(4) Allocation of disk space

An exploratory model was build, having four priority levels and 218 constraints, modeling the four areas of concern noted above. Examination of the preliminary results from this model showed both computer " core time" and printer capacity resources as having surpluses [i.e., there was excess capacity greater than 6 hours and greater than 5000 lines per day, respectively] : therefore they could not be defined as "scarce resources" .Accordingly, these constraints were not incorporated in any but the preliminary exploratory models. This left two primary concerns: terminal allocation and allocation of secondary storage space. The required information is seen below:

Table1: Three Sets of Groups

Set	Terminals	Drives	Weight Scheme
1 (runs 1-4)	50	1	A,B,C,D
2 (runs 5-8)	50	2	A,B,C,D
3 (runs 9-12)	61	2	A,B,C,D

In the first run of each set, all weights were given a value of one, despite briefings by the model builder. This led to a second run, using a two-tier weighting scheme, yielding more acceptable results. In a search for greater optimality, a five-level weighting system was then used, with the weights inversely proportional to the number of terminals allocated per office [i.e., an office with five terminals requested received a weight of one while an office with a request for one terminal received a weight of five], this was done to guarantee the smallest offices got at least some resources, albeit at the expense of the larger offices. Finally, a direct proportionality of requests to weights was used to guarantee the heaviest users.

Table 2: Run Numbers and Weighting Scheme Used

Modification	Weighting scheme			
	A	B	C	D
1	Run 1	Run 2	Run 3	Run 4
2	Run 5	Run 6	Run 7	Run 8
3	Run 9	Run 10	Run 11	Run 12

[Modification 1 = 50 terminals and, 1 disk drive, Modification 2 = 50 terminals,2 disk drives , Modification 3 = 61 terminals, 2disk drives]

Table 3: Weighting Schemes

Scheme				
Office	**A**	**B**	**C**	**D**
1	1	1	1	5
2	1	2	5	1
3	1	1	1	5
4	1	1	3	3
5	1	2	5	1
6	1	1	1	5
7	1	1	4	2
8	1	2	5	1
9	1	1	4	2
10	1	1	2	4
11	1	2	5	1
12	1	1	3	3
13	1	2	5	1
14	1	2	5	1
15	1	1	4	2
16	1	1	4	2
17	1	1	2	4
18	1	2	5	1
19	1	1	4	2
20	1	2	5	1
21	1	1	3	3
22	1	1	2	4
23	1	2	5	1
24	1	2	5	1
25	1	2	5	1
26	1	2	5	1
27	1	2	5	1
28	1	2	5	1
29	1	2	5	1

Table 4: Offices and Corresponding Data

Modifications		1		2		3	
Office Number	**Title**	**Terminals**	**Storage space**	**Terminals**	**Storage space**	**Terminals**	**Storage space**
1	Computer center	5	766124	5	1262406	5	1262406
2	Information	1	4600	1	9200	1	9200

	office						
3	Registrar	5	17466	5	108879	5	108879
4	Admissions	3	4600	3	17210	3	17210
5	Business manager	1	4600	1	9200	1	9200
6	Business office	5	5300	5	32531	5	32531
7	Accountant	2	33314	2	155808	2	155808
8	Logistics	1	4600	1	9200	1	9200
9	President	2	4600	2	9200	2	9200
10	Provost and ext campus	4	4600	4	9200	4	9200
11	Student services	1	4600	1	9200	1	9200
12	Financial aid	3	31346	3	107268	3	10726
13	Alumni	1	12018	1	16618	1	16618
14	Foundation	1	5300	1	9200	1	9200
15	Administrative services	2	4600	2	9200	2	9200
16	Public relations	2	4600	2	9200	2	9200
17	Budget and finance	4	4600	4	9200	4	9200
18	Security	1	4600	1	9200	1	9200
19	Residence life	2	4600	2	9200	2	9200
20	Advising	1	4600	1	9200	1	9200
21	Library	3	4600	3	9200	3	9200
22	Education	4	4600	4	9200	4	9200
23	Applied science	1	4600	1	9200	1	9200
24	Business	1	4600	1	9200	1	9200
25	Helper	1	4600	1	9200	1	V
26	Math/science	1	4600	1	9200	1	9200
27	Fine arts	1	4600	1	9200	1	9200
28	Humanities	1	4600	1	9200	1	9200
29	Social sciences	1	4600	1	9200	1	9200
System constraints		50	879000	50	1758000	61	1758000

III. GOAL PROGRAMMING MODEL

A goal programming model may be expressed in general terms as

Minimize $Z = \sum_{k=0}^{K} \sum_{i=1}^{m} w_{ki} \, P_k \, (d_i^- + d_i^+)$

Subject to $\sum_{i=1}^{m} a_{ij} \, X_j + d_i^- - d_i^+ = b_i \quad (j = 1,2, \dots \dots \dots .., n)$

$X_j, d_i^-, d_i^+ \geq 0 \quad \forall \; i = 1,2, \dots, m; \quad j = 1,2, \dots .., n.$

Where:

$Z =$ the sum of the weighted deviational variables

$w_{ki} =$ the relative weight assigned to k priority level for the ith goal constraint

P_k= the kth preemptive priority

d_i^-= a negative deviational variable describing under achievement of the ith goal

d_i^+= a positive deviational variable describing over achievement of the ith goal

a_{ij} = technical coefficient for the decision variable X

X_j= the jth decision variable X

b_i= the right-side value for the i th goal constraint

Because the different goals are sometimes incompatible or only partially compatible with one another (e.g., marketing: make as many as possible so we won't have stock outs vs. production: build only to order on customer demand), the priority levels prevent filling a lower-level priority until the higher–order priorities are all filled; at this point lower priorities are attended to, but never at the expense of a higher priority. In addition, the weighting of different goals at the same level allows the same kind of fulfillment within a single priority level.

Because of these goal conflicts, the objective function is stated so as to minimize the underachievement (d_i^-) or overachievement (d_i^+) of goal. If underachievement or overachievement is acceptable, then the goal programming objective function may be adjusted accordingly, together with the constraints.

Preliminary analysis showed two primary concerns: terminal allocation and secondary storage space allocation. Therefore, the computer/goal programming model is built in two major subsections, each with two subdivisions. The first subsection contains the model constraints, with one division for each concern (i.e., terminal distribution and secondary storage allocations). The subsection deals with" system constraints", guaranteeing that each of the twenty-nine offices get a minimum of each of the two scarce resources: again the system constraints have subdivisions dealing with each of the two concerns above. In addition, there are two " overall system constraints", ensuring that overall parameters are not exceeded(i.e., no more terminal are allocated than are purchased and no more blocks of disk drive space are allocated than are available). This yields a model of fifty-eight variables and 118 constraint equations. The objective function is written with two priority levels with, at most, five weights. The priority levels are allocated into the two constraints sections mentioned above; in conferences dealing with the construction of this model, these priorities were agreed upon by the relevant administrators. The weighting inside of the priority levels were likewise fixed by consensus of the group, going through an evolutionary process.

Goal Constraint

The constraint set is divided into two major subsets, each subset having two divisions. The first subset contains the model constraints with the second subset being "system constraints" within each subset are two divisions, one dealing with terminal allocation and secondary storage space allocation.

Constraint Set One: Terminal Allocation

The total number of terminals requested on campus in the original contract talks was fifty. The variable X_j in constraints one through twenty-nine is defined as the number of terminals assigned to office i . These constraints provide an assignment of terminals to offices [a list of the offices and their functions may be found in table 4]. The right-hand side values used is the result of current assignments intentions, based on interviews with the relevant administrators. Factional terminals assignments are usable, simply meaning that one terminal is shared by two or more offices.

Constraint Set Two: Disk Space Allocation

The initial contract talks specified a single disk drive with a capacity of 879,000 blocks of 512 bytes/blocks. Disk volumes used as the right-hand-side variables, measured in blocks, are the result of both measurement (actual counts of block volumes from the disk drive directories) and estimates [4,600 blocks for the academic divisions and offices without present disk space], the estimate is from the director of the computer center. Constraints Thirty through Fifty-eight are phrased so that X_i assigns j blocks of disk storage space to office.

The System Constraints

There were system constraints that had to be met as well as the model constraints. These are modified in constraints 59 through 118. The first subset specifies that each office must receive at least one terminal and the second that at least 4600 blocks (9200 blocks in runs 5-12) of secondary storage space be allocated to each office. Constraints 117-118 model the upper limits of each resource, the 'not to be exceeded" limitations of 509in runs 1-8) or 61 (in runs 9-12) terminals and 879,000 blocks/drive (1,758,000 in runs 5-12) of secondary storage.

This formulation allows for reiteration of the model with different configurations and allocations, such reiteration will allow the generation of multiple options, each based on particular scenario. Indeed, this was the approach used, varying the weights four times for each o0f the three modifications made, allowing the administrators both comparative portraits of trade-offs necessary to meet each scenario.

The Objective Function

Minimize $Z = wP_1 \, d_i^- + wP_2 d_j^-$

Where $w =$ weight used$i = 1 \; to \; 29, \; j = 30 \; to \; 58$.

Subject to

Equation numbers	General form
(1-29)	$X_i + \, d_i^- - d_i^+ =$ RHS i $\; (i = 1 \; to \; 29)$,
(30-58)	$X_j + \, d_j^- - d_j^+ =$ RHS j $\; (j = 30 \; to \; 58)$,
(59-87)	$X_i \; \leq 1 \quad (i = 1 \; to \; 29)$,
(88-116)	$X_j \leq$ 4600/9200 $\quad (j = 30 \; to \; 58)$,
(117)	$\sum_{i=1}^{29} X_i \; \leq 50/61$,
(118)	$\sum_{j=30}^{58} X_j \; \leq 879{,}000/1{,}758{,}000$,

$X_i \, , X_j \, , d_i^-, d_i^+ \, , d_j^- - d_j^+ \; \geq 0$

Where

1. Where two RHS values are shown (i.e., x/y), these represent the value used in different runs.

2. Equations 1-29 assign terminals to office i

3. Equations 30-59 assign secondary storage space to office i

4. Equations 59-116 guarantee at least minimal resource assignment (*i.e.*, terminals under storage space) to each office.

5. Equations 117-118 place upper limits on assignments to be made, guaranteeing that no assignment is made for which there are no resources.

6. Runs 1-4 assumed 50 terminals and one disk drive, Runs 5-8 assumed 50 terminals and two disk drives, runs 9-12 assumed 61 terminals and two disk drives

7. Four different weighting schemes were used for each model modification. These may be found in Table 2

8. RHS values used for each modification are shown in Table 4

9. The RHS values for Equation (117) come from the initial and subsequent contract negotiations; the figure of fifty terminals was that the college initially requested, which was later raised to sixty-one terminals.

IV. RESULT AND ANALYSIS

Three modifications of the base model, containing four "sub runs' each, were accomplished to give the decision makers a series of scenarios upon which to base their decisions. The first series of runs was done with an assumption of fifty terminals and one disk drive, as called for in the initial contract talks. When this revealed a tremendous shortage of disk drive storage space, a second series of runs were accomplished, factoring in parameters for a second disk drive. The third series of runs factored in not only the second disk drive but eleven additional terminals, the number required for each office to attain its terminal request. The model was solved by using QSB$^+$ computer software. Table 5 shows the solution for the modification –1 and we can find the solution for the remaining two modification

Table 5: Result Analysis

RHS		A	d^-	B	d^-	C	d^-	D	d^-	
Office	Terminals									
1	5	5		5		2	3	5		1
2	1	1		1		1		1		2
3	5	5		5		1	4	5		3
4	3	3		3		3		3		4
5	1	1		1		1		1		5

6	5	5		5		1	4	5	1	6
7	2	2		2		2		1		7
8	1	1		1		1		1		8
9	2	2		2		2		2		9
10	4	4		4		4		1	3	10
11	1	1		1		1		1		11
12	3	3		3		3		1	2	12
13	1	1		1		1		1		13
14	1	1		1		1		1		14
15	2	1	1	2	1	2		1	1	15
16	2	1	1	2	1	2		2		16
17	4	1	3	4	3	4		1	3	17
18	1	1		1		1		1		18
19	2	1	1	2	1	2		1	1	19
20	1	1		1		1		1		20
21	3	1	2	3	2	3		3		21
22	4	1	3	4	3	4		4		22
23	1	1		1		1		1		23
24	1	1		1		1		1		24
25	1	1		1		1		1		25
26	1	1		1		1		1		26
27	1	1		1		1		1		27
28	1	1		1		1		1		28
29	1	1		1		1		1		29

Table 6: Result Analysis (Continued)

RHS		**A**	**d^-**	**B**	**d^-**	**C**	**d^-**	**D**	**d^-**	
Office	**Drive storage blocks**									
1	766124	750200	15924	742082	24042	686622	79502	750200	15924	30
2	4600	4600		4600		4600		4600		31
3	17446	4600	12846	4600	12846	4600	12846	4600	12846	32
4	2321	4600		4600		4600		4600		33
5	4600	4600		4600		4600		4600		34
6	5300	4600	700	4600	700	4600	700	4600	700	35
7	33314	4600	28714	4600	28714	3314		4600	28714	36
8	4600	4600		4600		4600		4600		37
9	4600	4600		4600		4600		4600		38
10	4600	4600		4600		4600		4600		39
11	4600	4600		4600		4600		4600		40

12	31346	4600	26746	12018	26746	31346		4600	26746	41
13	12018	4600	7418	5300		12018		4600	7418	42
14	5300	4600	700	4600		5300		4600	700	43
15	4600	4600		4600		4600		4600		44
16	4600	4600		4600		4600		4600		45
17	4600	4600		4600		4600		4600		46
18	4600	4600		4600		4600		4600		47
19	4600	4600		4600		4600		4600		48
20	4600	4600		4600		4600		4600		49
21	4600	4600		4600		4600		4600		50
22	4600	4600		4600		4600		4600		51
23	4600	4600		4600		4600		4600		52
24	4600	4600		4600		4600		4600		53
25	4600	4600		4600		4600		4600		54
26	4600	4600		4600		4600		4600		55
27	4600	4600		4600		4600		4600		56
28	4600	4600		4600		4600		4600		57
29	4600	4600		4600		4600		4600		58

V. CONCLUSION

Goal programming has been proven to be a valid, widely applied managerial tool for decision making, taking into account, as it does both managerial preference and environmental constraints. Computers have become an essential and indispensible tool for management; indeed, with the advent of large-capacity, relatively inexpensive microcomputers, these tools are commonly placed. However, with more hardware and software options available than ever before, computer resources acquisition and distribution is as large a problem as ever. The purpose of building this model was threefold: to explore the applicability of goal programming as a computer resources allocation tool, to explore the constraint construction necessary to better allocate computer resources while meeting multiple objectives, and to provide college administrators a model for decision making vis-a-vis such a problem.

Given the demand for courses demanding computer resources, coupled with the expense of these resources, such a model is of both real and immediate value, especially in light of shrinking budgets. With the "traditional" student base decreasing, but MIS/CIS/DP enrollment growing, with constituent demand that such training be provided, with increased integration of computer course work and usage across all majors, there seems little possibility that these problems will decrease in stature any time in the near-term future. An effective and efficient allocation of budget dollars and computer resources in particular, is a requisite to good administration of a college or university, now and definitely more so in future. This model is a beginning step to such allocation. These problems, facing most college Deans and university Presidents, simply must be met. Most administrators facing with these problems have access to computer facilities; therefore, it is suggested that they use these facilities in order to help solve these pressing problems. This model may provide a "base line" or core model that may be modified to suit a particular institution in order to provide accurate and timely data for computer resources allocation.

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