Title: A Linear Program for Human Resource Allocation in a Design/construction Firm

Course:
Year: 1993
Author(s): D. C. Liesch

Report No: P93020

Abstract: A design/construction firm uses the talents of many skilled individuals besides engineers. The primary challenge in these firms is to attract and keep individuals with the skill sets that make them competitive in the industry. At the same time they must be able to maintain a project mix that will utilize these skill sets sufficiently so that there are few times that these people are left without chargeable work. A linear programming model was developed to better manage and forecast the match of available skill sets to fluctuating project requirements.

A Linear Program For Human Resource Allocation in a Design/ Construct Firm

David C. Liesch

EMP-P9320

EMGT 540
TERM PROJECT

A LINEAR PROGRAM FOR HUMAN RESOURCE ALLOCATION IN A DESIGN/CONSTRUCT FIRM

FROM: DAVID C. LIESCH

DATE: JUNE 2ND 1993

ABSTRACT

A DESIGN/CONSTRUCT FIRM UTILIZES THE TALENTS OF MANY SKILLED INDIVIDUALS BESIDES JUST ENGINEERS. THE PRIMARY CHALLENGE IN THESE FIRMS IS TO ATTRACT AND KEEP INDIVIDUALS WITH THE SKILL SETS THAT MAKE YOU COMPETITIVE IN THE INDUSTRY, BUT AT THE SAME TIME BE ABLE TO MAINTAIN A PROJECT MIX THAT WILL UTILIZE THESE SKILL SETS IN SUFFICIENT NUMBER THAT THERE ARE FEW TIMES THAT THESE HIGHLY SKILLED AND COMPENSATED PEOPLE ARE LEFT WITHOUT CHARGEABLE WORK. THIS BECOMES A CLASSIC PROBLEM IN RESOURCE ALLOCATION AND HENCE A LINEAR PROGRAMMING MODEL IS DEVELOPED HERE TO BETTER MANAGE AND FORECAST THE MATCHING OF AVAILABLE SKILL SETS TO FLUCTUATING PROJECT REQUIREMENTS.

A sensitivity analysis was run on the multiple-variable objective function model which revealed among other things that the solution would remain optimal within a wide range of values for both the objective fumction coefficients and the right hand side values. The wide range of values on the objective function coefficients is only on those variables which are not in the basis. The wide range on the right hand side values is due to the fact that these values are by definition the upper and lower bounds on the variables. Please note that these models do not permit the substitution of individuals across departmental lines, which would not reduce general overhead hours but might reduce the cost of these hours by substituting higher compensated people onto project work in lieu of lower compensated people. This will be more fully explained in the analysis.

The model was put together in such a way that it can be readily modified to reflect changes in project mix and sevral example of alternate project mixes are indicated here.

Further refinement of this model is still needed in order to reduce the number of simplifying assumptions and to allow for a broader time frame so as to anticipate the level of the general overhead account furher in advance. In addition the model needs to incorporate a mechanism to permit substitution across departmental lines and to impose appropriate penalties for excessive overtime or for bringing on temporary personnel. The goal programming model presented herein would easily lend itself to a penalty situation but further data is needed to come up with the appropriate penalty to assign.

The assumptions inherent in this model are as follow and where applicable are the result of historical data on a mix of projects:

1) This model does not take into account the power politics of the "matrix" organization and hence assumes that the organizational goal of minimizing general overhead will be as readily accepted by Project Managers as it is by Department Managers.

2) Project hours in any one month can be varied in any one month from the original plan without jeoparidizing the project as long as the "average" hours even out.

The Design/Construct firm under study solicits its work from clients in industry, government, and etc. These client companies come to a Design/Construct firm because they are seeking skill sets that they do not have within their own organization in sufficient number to handle the capital projects they are looking at. More often they are looking for particular experience in the process areas or building types that they are considering which they hope to receive from the Design/Construct firm due to the numerous similar projects it has already done. It is these "value added" features that can differentiate one firm from another and hence the Design/Construct firm must always attempt to keep the human resources on hand that can meet these needs.

One reason the client companies do not have sufficient numbers of people available within their organization to handle a major project is due to the cyclical nature of these projects. A large capital commitment in excess of $100,000,000 is undertaken with great caution even in large corporations except during an economic boom time and capital may even "dry-up" during periods of recession or economic problems. Companies in the same or related industries tend to experience boom and bust periods at about the same time and hence with a few exceptions their capital expansion projects are occuring in relatively the same time periods and hence "staffing up" during those times is difficult since they are all competing for the same resources.

The problems listed above for companies that perform capital projects are also experienced within Design/Construct firms. These firms are likewise subject to the vicissitudes of the economy. How can these Design/Construct firms maintain and attract the type of skill sets that are desired by their client companies while at the same time stay profitable during periods of decreased activity without having massive fluctuations in the workforce that are not conducive to the goals set out above?

The models presented here are more on the order of strategies than mathematical models but the goal in this case is not one of maximizing or minimizing but rather to give a framework that permits focusing resources involved in employee selection where they will do the most good.

Jones and Kwak (2), present a goal programming model for allocating resources to FDA Laboratories in keeping with the FDA's ***Good Laboratory Practice Regulations.*** This is a good example of a goal programming model being applied to a resource allocation problem. In their words;"We would argue that the goal programming model solution aids in planning and allocation of human resources, thus acheiving the goals of the organization." The purpose of the model is not only to assign available workhours to each of the priorities but to insure that the resources are allocated in such a way that the competing goals of analyzing drug samples and implementing the Good Laboratory Practice Procedures can both be met with existing resources. This can serve as a general framework for the goal programming formulation of our model

Ritzen and Winkler (3), developed a model for looking at the allocation of resources in the production of human capital. In particular they were interested "in developing a model for the allocation of limited school resources over time when schools have the objective of maximizing the human capital embodiment of pupils at the end of a specified schooling period." This model utilizes a Cobb-Douglas function and optimal control theory as well as differential equations and hence is too theoretical to be of practical use for the managers in a Design/Construct firm. The model does go on to indicate that present funding strategies in education are in keeping with the results of the model (increased funding with increasing grade level) a weakness of the model is a lack of information on the production function of cognitive learning which prevents the authors from identifying the models' output as optimal.

We also know from a historical basis approximately what the average % of total project hours is for each functional department. (See figure 1)

We have decided to develop a model for minimizing the General Overhead Account as opposed to a profit (contribution) maximization model. This decision was made due to the increased number of factors that contribute to profit (added complexity). General overhead has the biggest single impact on contribution.

MODEL FORMULATION:

$$
\begin{aligned}
\text{MIN } Z = \; & 28X11 + 28X12 + 28X13 + 42X21 + 42X22 + \\
& 42X23 + 50X31 + 50X32 + 50X33 + 17X41 + \\
& 17X42 + 17X43 + 18X51 + 18X52 + 18X53 + \\
& 50X61 + 50X62 + 50X63 + 40X71 + 40X72 + \\
& 40X73 + 29X81 + 29X82 + 29X83
\end{aligned}
$$

(XIJ, WHERE I=DEPARTMENT I;I=1,8 AND J=MONTH J; J=1,3)

SUBJECT TO:

	$X11+PS1 \geq 1822$ (LOWER BOUND)
PS(i)=PROJECT SUPPORT	$X11+PS1 \leq 3036$ (UPPER BOUND)
i= MONTH(i);1-3	$X12+PS2 \geq 1822$ (LOWER BOUND)
	$X12+PS2 \leq 3036$ (UPPER BOUND)
	$X13+PS3 \geq 1822$ (LOWER BOUND)
	$X13+PS3 \leq 3036$ (UPPER BOUND)
	$X21+PE1 \geq 841$ (LOWER BOUND)
PE(i)=PROJ. ENGNR.	$X21+PE1 \leq 1400$ (UPPER BOUND)
i= MONTH(i);1-3	$X22+PE2 \geq 841$ (LOWER BOUND)
	$X22+PE2 \leq 1400$ (UPPER BOUND)
	$X23+PE3 \geq 841$ (LOWER BOUND)
	$X23+PE3 \leq 1400$ (UPPER BOUND)
	$X31+PM1 \geq 841$ (LOWER BOUND)
	$X31+PM1 \leq 1400$ (UPPER BOUND)
PM(i)=PROJECT MGMT.	$X32+PM2 \geq 841$ (LOWER BOUND)
i= MONTH(i);1-3	$X32+PM2 \leq 1400$ (UPPER BOUND)
	$X33+PM3 \geq 841$ (LOWER BOUND)
	$X33+PM3 \leq 1400$ (UPPER BOUND)

These constraints simply state that the project charges per month by department must add up to no greater than the total projected hours per department for that department. This allows us to vary the amount of project charges per department in any one month by any extent as long as we average out to the projected total at the end of three months.

The above model is a multiple-decision variable, linear programming model to determine how to minimize the amount of general overhead for a three month period for any given project mix.

The above model was reformulated into a goal programming model as well since our literature search revealed this was an excellent type of format to use for this application.

GOAL PROGRAMMING FORMULATION OF MODEL

MIN Z= X11N

SUBJECT TO:

PS1+X11N-X11P=	1822
PS2+X12N-X12P=	1822
PS3+X13N-X13P=	1822
PE1+X21N-X12P=	841
PE2+X22N-X22P=	841
PE3+X23N-X23P=	841
PM1+X31N-X31P=	841
PM2+X32N-X32P=	841
PM3+X33N-X33P=	841
PC1+X41N-X41P=	561
PC2+X42N-X42P=	561
PC3+X43N-X43P=	561
PA1+X51N-X51P=	468
PA2+X52N-X52P=	468
PA3+X53N-X53P=	468
PP1+X61N-X61P=	981
PP2+X62N-X62P=	981
PP3+X63N-X63P=	981

These constraints define the upper bound ox XijP as 50% of available hours per month, where i=Department (i=1-8) and j= Month (j=1-3). The RHS values are 50% of the departments available hours.

ADDITIONAL CONSTARINTS:

PS1+PS2+PS3<=	4514
PE1+PE2+PE3<=	5406
PM1+PM2+PM3<=	3604
PC1+PC2+PC3<=	3154
PA1+PA2+PA3<=	1352
PP1+PP2+PP3<=	4505
PR1+PR2+PR3<=	3154
PT1+ PT2+PT3<=	24726

These last constraints are identical to the linear programming formulation and insure that monthly charges by department to projects even out over the period in question to be less than or equal to the scheduled hours. This permits a department to add staff to projects or remove staff from projects on a monthly basis in reaction to their projected monthly general overhead charges.

The goal programming model requires several iterations. The first iteration will give the value of X11N, which is then added to the constraints and the program is run again for MIN Z=X12N and solved. For each iteration a new decision variable is included and the value obtained for the previous variable is added to the constarints until the program is run for all XijN (i=1-8, j=1-3).

In addition the multiple-decison variable, objective function, linear program was run for three different project mixes to see what impact the change in project mix would have on the value of General Overhead. Please refer to the appendix for detailed print-outs for each run of the model. In addition there will be further discussion of changes in project mix under the discussion of sensitivity analysis.

For the decision variables this shows that only those with zero reduced cost are in the basis and those not in the basis would have to have coefficients of zero or less to enter the basis. This basically means that for these X(ij) variables, their department I has more project hours than hours availble and hence cannot influence the General Overhead Account unless the coefficient becomes non-positive. All non decision variables had positive values and zero reduced costs since they do not enter the objective function.

Looking at the dual prices for the constraint rows we find that only rows containing basic variables have non-zero dual (shadow) prices. This should be no surprise nor should the fact that these dual prices are negative be a surprise. For example:

Row 2: X11+PS1>= 1822 (Lower bound) Shows zero slack and a dual price of -$28. This means that by reducing the RHS of Row 2 to 1821 we would decrease Z by $28. This makes sense since reducing the RHS by one hour means the department has one less hour available for either project work or general overhead. Looking at Row 3 we can see that we have a surplus of 1214 hours before we reach our upper bound. We could increase our RHS value up to this point and not affect Z, however it might impact us in the following months since we will not have as many surplus project hours in our department when we need them. See further discussion of reducing the lower bound and the implication of the shadow price at the conclusin of project mix 3. Please refer to the Appendix to see the detailed print-out of this model solution.

We notice that 26 iterations were required to find the optimal solution to this linear program.

PROJECT MIX 2:

Z=$19,208=(686* $28)

DECISION VARRIBLE	VALUE	REDUCED COST
X11=	0.0	0.0
X12=	686	0.0
X13=	0.0	0.0
X21=	0.0	42

PROJECT MIX 3: (CONTINUED)

DECISION VARIABLE	VALUE	REDUCED COST
X13=	783	0.0
X21=	0.0	42
X22=	0.0	42
X23=	0.0	42
X31=	234	0.0
X32=	0.0	0.0
X33=	0.0	0.0
X41=	0.0	17
X42=	0.0	17
X43=	0.0	17
X51=	0.0	0.0
X52=	468	0.0
X53=	78	0.0
X61=	0.0	0.0
X62=	0.0	0.0
X63=	82	0.0
X71=	0.0	40
X72=	0.0	40
X73=	0.0	40
X81=	310	0.0
X82=	0.0	0.0
X83=	0.0	0.0

This solution is for a project mix that does not provide many project hours in excess of available hours and hence even though we have minimized ,(this is the optimal solution), our General Overhead Account for this situation it is still significantly higher than the previous examples. Once again our reduced costs indicate that for non-basic variables to enter the basis their coefficients must become non-positive.

Our dual or shadow prices for this mix show that there are lots of opportunities to further decrease our Z value by reducing the lower limit on our available hours. In the Design/Construct Business this is normally done via reductions-in-force. This is something we would like to prevent but these shadow prices can be used to establish a cost/benefit analysis.

SENSITIVITY ANALYSIS:

A sensitivity analysis was done for the three trial runs of the multiple-variable, objective-function model. A sensitivity analysis for the goal programming formulation is not meaningful.

RANGE ON OBJECTIVE FUNCTION COEFFICIENTS: The range on objective function coefficients for all decision variables that were not in the basis ranged from zero to infinity which means that these coefficients could be of any value and would not change the optimality of the objective function unless they became non-positive as was stated before in our discussion of reduced cost. This makes sense because under the previous discussion they would have to be non-positive to enter the basis. For those decision variables in the basis the allowable range on the objective function coefficients ranged from their present value to zero. This means the model is not sensitive to the cost of a general overhead hour and looks only at allocation of work hours irrespective of the cost. This is true for all three trial runs although the decision variables forming the basis change from project mix to project mix.

RANGE ON RIGHT HAND SIDE:

The right hand side values on the constraints are for the most part the upper and lower bounds on the available hours per department. The sensitivity analysis for the three trial runs indicates the range for which the right hand side values can change and yet leave the solution optimal.

PROJECT MIX 1: The RHS values for the upper bounds can of course increase to infinity without changing the optimality of the solution. In all cases the upper bound and lower bounds can increase over quite a range. This appears to be the case because we allow wide fluctuations within any one month that can be made up within the next months. It is interesting to note that for rows 50 and up the RHS side value is the total project hours for the particular department over the time period in question. The upper bound on these hours is infinity except for those constraints that are not satisfied.(Xij <= 0).

EXTENSIONS:

The limitations on this model were first raised in the Executive Summary. Any extension of this model should address those limitations. Goal programming has proven to be a very useful model in many other applications and I believe that by modifying our formulation we can extend the scope and effectiveness of our model.

It was touched on previously that it is undesireable to have excessive charges to the general overhead account. Likewise there are problems with having too great a surplus of project hours that must be addressed either by overtime and/or bringing on temporary help. There is a penalty of some sort associated with either extreme. We addressed excessive general overhead by minimizing this within the objective function . We did not address the "penalty" associated with bringing on temporary help or with excessive overtime. Overtime was partially addressed by putting a cap on it. The goal programming formulation would most readily be able to handle the penalty situation. Let us assume that for a particular department, if an hour of general overhead costs the organization $29 then an hour of overtime or the addition of a temporary employee might cost the department a portion of this perhaps $20. The new goal programming formulation would then become for that particular constaraint:

PT1+ 29X81N-20X81p=4204.

This would cause the program to look slightly more favorably at an hour of overtime than an hour of general overhead.

One of the other limitations that was raised earlier but which would be a good extention of the model is to incorporate a means of substituting personnel across departmental lines so as to keep the total dollar value of general overhead down even if the total hours remain the same. It is not obvious at this time how this can be achieved within the formulation of this model.

VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
X11	28.000000	INFINITY	.000000
X12	28.000000	.000000	28.000000
X13	28.000000	INFINITY	.000000
X21	42.000000	INFINITY	42.000000
X22	42.000000	INFINITY	42.000000
X23	42.000000	INFINITY	42.000000
X31	50.000000	INFINITY	50.000000
X32	50.000000	INFINITY	50.000000
X33	50.000000	INFINITY	50.000000
X41	17.000000	INFINITY	17.000000
X42	17.000000	INFINITY	17.000000
X43	17.000000	INFINITY	17.000000
X51	18.000000	INFINITY	.000000
X52	18.000000	.000000	18.000000
X53	18.000000	INFINITY	.000000
X61	50.000000	INFINITY	50.000000
X62	50.000000	INFINITY	50.000000
X63	50.000000	INFINITY	50.000000
X71	40.000000	INFINITY	40.000000
X72	40.000000	INFINITY	40.000000
X73	40.000000	INFINITY	40.000000
X81	29.000000	INFINITY	29.000000
X82	29.000000	INFINITY	29.000000
X83	29.000000	INFINITY	29.000000
PS1	.000000	.000000	28.000000
PS2	.000000	28.000000	.000000
PS3	.000000	.000000	28.000000
PE1	.000000	42.000000	.000000
PE2	.000000	42.000000	.000000
PE3	.000000	42.000000	.000000
PM1	.000000	50.000000	.000000
PM2	.000000	50.000000	.000000
PM3	.000000	50.000000	.000000
PC1	.000000	17.000000	.000000
PC2	.000000	17.000000	.000000
PC3	.000000	17.000000	.000000
PA1	.000000	.000000	18.000000
PA2	.000000	18.000000	.000000
PA3	.000000	.000000	18.000000
PP1	.000000	50.000000	.000000
PP2	.000000	50.000000	.000000
PP3	.000000	50.000000	.000000
PR1	.000000	40.000000	.000000
PR2	.000000	40.000000	.000000
PR3	.000000	40.000000	.000000
PT1	.000000	29.000000	.000000
PT2	.000000	29.000000	.000000
PT3	.000000	29.000000	.000000

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	1822.000000	861.000000	961.000000
3	3036.000000	INFINITY	1214.000000
4	1822.000000	1214.000000	961.000000
5	3036.000000	INFINITY	1214.000000
6	1822.000000	861.000000	961.000000
7	3036.000000	INFINITY	1214.000000

PROJECT MIX #2

MIN 28 X11 + 28 X12 + 28 X13 + 42 X21 + 42 X22
+ 42 X23 + 50 X31 + 50 X32 + 50 X33 + 17 X41
+ 17 X42 + 17 X43 + 18 X51 + 18 X52+ 18 X53
+ 50 X61 + 50 X62 + 50 X63 + 40 X71 + 40 X72
+ 40 X73 + 29 X81 + 29 X82 + 29 X83

**OBJECTIVE FUNCTION VARIABLES X_{IJ}, WHERE I=DEPARTMENT (1-8)
OBJECTIVE FUNCTION COEFFICIENTS ARE LOADED HOURLY WAGES.
(INCLUDES FRINGES).**

SUBJECT TO:

2) X11 + PS1 >= 1822--LOWER BOUND
**PROJECT SUPPORT HOURS MONTH 1
X11=GENERAL OVERHEAD HRS. IN
DEPARTMENT 1 FOR MONTH 1'**
3) X11 + PS1 <= 3036--UPPER BOUND

4) X12 + PS2 >= 1822--LOWER BOUND
**PROJECT SUPPORT HOURS MONTH 2
X12=GENERAL OVERHEAD HRS. IN
DEPARTMENT 1 FOR MONTH 2.**
5) X12 + PS2 <= 3036--UPPER BOUND

6) X13 + PS3 >= 1822--LOWER BOUND
**PROJECT SUPPORT HOURS MONTH 3
X13=GENERAL OVERHEAD HRS. IN
DEPARTMENT 1 FOR MONTH 3.**
7) X13 + PS3 <= 3036--UPPER BOUND

8) X21 + PE1 >= 841
9) X21 + PE1 <= 1400
10) X22 + PE2 >= 841
11) X22 + PE2 <= 1400
12) X23 + PE3 >= 841
13) X23 + PE3 <= 1400
14) X31 + PM1 >= 841
15) X31 + PM1 <= 1400
16) X32 + PM2 >= 841
17) X32 + PM2 <= 1400
18) X33 + PM3 >= 841
19) X33 + PM3 <= 1400
20) X41 + PC1 >= 561
21) X41 + PC1 <= 935
22) X42 + PC2 >= 561
23) X42 + PC2 <= 935
24) X43 + PC3 >= 561
25) X43 + PC3 <= 935
26) X51 + PA1 >= 468
27) X51 + PA1 <= 780
28) X52 + PA2 >= 468
29) X52 + PA2 <= 780

O
GO.
P OPTIMUM FOUND AT STEP 25

OBJECTIVE FUNCTION VALUE

1) 19208.000

VARIABLE	VALUE	REDUCED COST
X11	.000000	.000000
X12	686.000000	.000000
X13	.000000	.000000
X21	.000000	42.000000
X22	.000000	42.000000
X23	.000000	42.000000
X31	.000000	50.000000
X32	.000000	50.000000
X33	.000000	50.000000
X41	.000000	17.000000
X42	.000000	17.000000
X43	.000000	17.000000
X51	.000000	18.000000
X52	.000000	18.000000
X53	.000000	18.000000
X61	.000000	50.000000
X62	.000000	50.000000
X63	.000000	50.000000
X71	.000000	40.000000
X72	.000000	40.000000
X73	.000000	40.000000
X81	.000000	29.000000
X82	.000000	29.000000
X83	.000000	29.000000
PS1	1822.000000	.000000
PS2	1136.000000	.000000
PS3	1822.000000	.000000
PE1	841.000000	.000000
PE2	841.000000	.000000
PE3	841.000000	.000000
PM1	841.000000	.000000
PM2	841.000000	.000000
PM3	841.000000	.000000
PC1	561.000000	.000000
PC2	561.000000	.000000
PC3	561.000000	.000000
PA1	468.000000	.000000
PA2	468.000000	.000000
PA3	468.000000	.000000
PP1	981.000000	.000000
PP2	981.000000	.000000
PP3	981.000000	.000000
PR1	438.000000	.000000
PR2	438.000000	.000000
PR3	438.000000	.000000
PT1	4204.000000	.000000
PT2	4204.000000	.000000
PT3	4204.000000	.000000

ROW	SLACK OR SURPLUS	DUAL PRICES

YES
YES

ANGES IN WHICH THE BASIS IS UNCHANGED:

OBJ COEFFICIENT RANGES

ARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
X11	28.000000	INFINITY	.000000
X12	28.000000	.000000	28.000000
X13	28.000000	INFINITY	.000000
X21	42.000000	INFINITY	42.000000
X22	42.000000	INFINITY	42.000000
X23	42.000000	INFINITY	42.000000
X31	50.000000	INFINITY	50.000000
X32	50.000000	INFINITY	50.000000
X33	50.000000	INFINITY	50.000000
X41	17.000000	INFINITY	17.000000
X42	17.000000	INFINITY	17.000000
X43	17.000000	INFINITY	17.000000
X51	18.000000	INFINITY	18.000000
X52	18.000000	INFINITY	18.000000
X53	18.000000	INFINITY	18.000000
X61	50.000000	INFINITY	50.000000
X62	50.000000	INFINITY	50.000000
X63	50.000000	INFINITY	50.000000
X71	40.000000	INFINITY	40.000000
X72	40.000000	INFINITY	40.000000
X73	40.000000	INFINITY	40.000000
X81	29.000000	INFINITY	29.000000
X82	29.000000	INFINITY	29.000000
X83	29.000000	INFINITY	29.000000
PS1	.000000	.000000	28.000000
PS2	.000000	28.000000	.000000
PS3	.000000	.000000	28.000000
PE1	.000000	42.000000	.000000
PE2	.000000	42.000000	.000000
PE3	.000000	42.000000	.000000
PM1	.000000	50.000000	.000000
PM2	.000000	50.000000	.000000
PM3	.000000	50.000000	.000000
PC1	.000000	17.000000	.000000
PC2	.000000	17.000000	.000000
PC3	.000000	17.000000	.000000
PA1	.000000	18.000000	.000000
PA2	.000000	18.000000	.000000
PA3	.000000	18.000000	.000000
PP1	.000000	50.000000	.000000
PP2	.000000	50.000000	.000000
PP3	.000000	50.000000	.000000
PR1	.000000	40.000000	.000000
PR2	.000000	40.000000	.000000
PR3	.000000	40.000000	.000000
PT1	.000000	29.000000	.000000
PT2	.000000	29.000000	.000000
PT3	.000000	29.000000	.000000

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE

DISTRIBUTION OF PEOPLE BY DEPARTMENT

DEPARTMENT	NO. OF PEOPLE IN DEPARTMENT	AVG. LOADED WAGE/HR OF G.O.	% OF DEPARTMENT ON G.O. PER WEEK
SUPPORT SERVICES X1	13	$ 28/HR	
PROJECT ENGINEERING X2	6	$ 42/HR	
ADMINISTRATION	3	$ 38/HR	100%
PROJECT/CONSTR MANAGEMENT X3	6	$ 50/HR	
MARKETING	2	$ 48/HR	100%
CLERICAL X4	4	$ 17/HR	
ACCOUNTING X5	3	$ 18/HR	
PROCESS STAFF X6	7	$ 50/HR	
PURCHASING X7	3	$ 40/HR	
TECHNICAL X8	30	$ 29/HR	

Ignore administration and marketing for the purpose of this model since none of their time is chargeable.

FIGURE 1

BIBLIOGRAPHY:

1) Boivin, Yvan and Carroll Malenfant. (1992),"Allocating Human Resources Among The Services of a Health Care Organization" *Journal of Health Care Marketing,* 12 (September),pp 65-70.

2) van Hee, K. M.(1984),"Sharing Profits And Liabilities of a Pool of Dockers". *Europeon Journal of Operational Research.,* 15 (March), pp 297-301.

3) Jones, Lawrence and N. K. Kwak.(1982), "A Goal Programming Model For Allocating Human Resources For The Good Laboratory Practice Regulations." *Decision Sciences,* 13 (January),pp 156-166.

4) Ritzen, J. M. and D.R. Winkler.(1979). "On The Optimal Allocation of Resources in The Production of Human Capital". *Journal of The Operations Research Society,* 30 (January),pp 33-41.

5) Sproule, C.F. "A Strategy for Resource Allocation in Public Personnel Selection". *Public Personnel Management Journal,* 9 (3),pp 116-124.