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# Aggregate Manpower Planning - A Goal Programming Approach

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**Abstract:** The combination of a manpower supply model and objective programming with preemptive needs gives a helpful instrument to adding to a future year labor arrange under clashing Socio-economic-authoritative goals. Effective usage obliges a nearby administration inclusion in altering probabilities and indicating objectives, needs and looming approach changes. Such a methodology is exhibited in this paper and is kept straightforward, yet point by point and brought together, with the goal that it is effectively seen by specialists and understudies of operational examination/administration science.

**Keywords:** Goal Programming, Manpower Planning, Transition Probability Matrix (TPM)

## 1. Introduction

The issue of labor wanting to focus the quantity of individuals by kind of increase, staying and misfortune that outcomes from the exertion of an association to best meet its component needs in the light of clashing Socio-economic-authoritative destinations and limitations. Markov procedures have been utilized to model the stream of individuals through indicated evaluations as well as loss states [3]. This enables one to predict the number of people by grade and type of loss that would result in future years, given a company policy for personnel hiring, promotion, etc. These models however, cannot consider costs, restrictions and conflicting objectives that exist in a real situation. It seems therefore natural to combine Markov analysis with mathematical programming in order to develop more realistic manpower planning models. Surprisingly however, this approach is not widely known or used in the field of operational research/management science and certainly not in personnel management. A few such models have been developed for the Office of Civilian Manpower Management in the U.S. Navy [4, 5, 7]. Similar models were developed for the Canadian Air force and the Iron & Steel Industry Training board in U.K. [9]. Most of these efforts were published only in manpower planning books, thus preventing a wider dissemination.

The manpower planning problem may be at the marcolevel [6] ormicro level [4,5]. The Markov transition probabilities are usually considered constant [4] but models have been suggested to modify them with variable personnel transition or treat them deterministically as controlled decision variables. The manpower planning models cited previously are if an ordinary linear programming [9] or a weighted linear (goal) programming form [4,5,6]. The latter seems more attractive for handling real-world manpower planning problems, where conflicting goals always exist. However, determination of proper weights for thousands of goal deviations is a formidable task and must be entirely or partially repeated each time some goals are added to or deleted from the model. It may also be very difficult or even impossible to find proper weights for non-commensurable goals. Furthermore, the final solution can be rather sensitive to the choice of weights for goal deviational variables of similar order of magnitude.

Objective programming with preemptive needs and perhaps weighted commensurable objectives inside of the same need gives a more adaptable and practical apparatus for labor arranging issues. Another promising technique is multiple objectives LP with interval criterion weights and filtering as employed by Steuer and Wallace in their non-markovian manpower micro model. This paper presents a markov chain/preemptive goal programming sequential approach for solving manpowermarcoplanning problems under various restrictions and conflicting objectives.

## 2. Data of the Problem

This study was carried out by means of large chemical industry in Hyderabad. Projections of future engineering employee requirements for industrial organizations are based on forecasts of workloads. Workloads vary with time because of industry growth or decline as well as business cycles. This imposes a need to change the size and composition of work force in a way that will not conflict with social and industrial concerns.

In general, a company alters its work force by changing the flow people through one of three processes: entrance (e.g. hiring), staying (e.g. promotions) and wastage (e.g. layoffs, retirements, etc.). In large, well established companies, first alternative is usually preferred to altering existing promotion and retirement policies or laying –off professional employees. The lay-off option is enforced during periods of company crisis with undesirable losses in know-how and social goodwill. A strategy followed by many industrial organizations is to use contract professionals during peak work load periods and thus provide better stability for their own work force.

At the end of the year and manpower plans are needed for the coming year in the engineering department of a large chemical company. The number of contract engineers and additions to the department professional personnel need to be determined based on next year's work load projections. Additions may come from hires, rehires, transfer-in (from other departments) and advancements from non-exempt payroll to salary professional status. The department has four levels of professionals employees called AA, A, B and C. Manpower losses for the department are in the form of quits, retirements (early and regular), company action (firing), transfers-out, to non-exempt payroll, leave of absence, and death or disability. Historical annual transitions of personnel among states were used to estimate the Markov Transition Probability Matrix (TPM). This is presented in the companion paper along with some difficulties and procedures for developing, validating and using the Markov model for short and long range forecasts.

The estimated total people requirements (at departmental efficiency) to meet next year's needs under three different anticipated work loads are:

*Case I-1850 Case II-1295 and Case III-1195*

The first case represents an increase and the other two a decrease from the current year's total of 1765. The end of the current year people count is given the following.

***Table 1.*** *Yearly People Count.*

| AA | A | B | C | Total | Contract | Adjusted workforce |
|---|---|---|---|---|---|---|
| 30 | 208 | 384 | 543 | 1165<br>56 | 600(900) | 1765 |

***Table 2.*** *Yearly Cost Matrix (Relative Costs).*

| | Q | R65 | RE | CA | TO | NE | DD | AL | AA | A | B | C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AA | 45 | 15 | 45 | − 15 | 15 | −15 | 45 | 15 | 30 | 26 | — | — |
| A | 33 | 11 | 33 | − 11 | 11 | −11 | 33 | 11 | 26 | 22 | 19 | — |
| B | 26 | 9 | 26 | −8 | 9 | −8 | 26 | 9 | — | 19 | 17 | — |
| C | 20 | 7 | 20 | −6 | 7 | −6 | 20 | 7 | — | — | 15 | 13 |
| H | — | — | — | — | — | — | — | — | — | 23 | 17 | 13 |
| RH | — | — | — | — | — | — | — | — | — | 23 | 17 | 13 |
| TI | — | — | — | — | — | — | — | — | 27 | 21 | 18 | 15 |
| NE | — | — | — | — | — | — | — | — | — | — | 9 | 7 |

The adjustment incorporates the company's estimate that a contract engineer's efficiency is about 2/3 of company's engineers (and his cost 50% higher than B's cost).

### *2.1. Model Goals and Assumptions*

Once the forecasts of future people requirements have been made, the problem becomes how best to satisfy them, while recognizing the existence of conflicting Socio-economic-organizational goals. The following goals were identified:

(a) Get the work done even if contract engineering must be used.
(b) Keep costs as low as possible.
(c) The number of contract engineers should not be less than 100 in order to maintain a good relationship with the contracting agency.
(d) The department manpower growth should not exceed 10%. This moderate growth will permit adequate training of new employees and reduce the risk of overstaffing if a downturn occurs.
(e) Hire at least 40 college "fresh-outs" to maintain a reasonable college recruiting image.
(f) Re-hires should be kept to 5 or a few more.
(g) Transfers-in from other departments should be 20 or a few more. This rotation will allow adequate training with little disruption.
(h) Non-exempt employee promotions should be 30 or less. Such promotions are usually rewards for obtaining a college degree.
(i) Keep the employee ratio of A's to AA's between 6 and 8; the ratio of B's plus C's to A's between 5 and 8, and the ratio of B's to C's between 1 and 2. These ratios will allow adequate supervision at reasonable cost.
(j) The number of contract engineers should not exceed the number of department engineers; otherwise coordination and supervision problems will occur.

In addition to specific goals, management needs to concur with the cost and other assumptions used in the model. For example, in this study the following assumptions were made:

i. The transition probability matrix elements---especially losses, gains and promotions are reasonable & with minor modifications can be used for forecasting future year transition. Management will make such adjustments to the TPM if deviations from historical patterns are anticipated.
ii. Accounting estimates can be obtained for the annual cost for each grade level and other costs such as employee moving expenses and requirement.
iii. Contract engineering is less efficient and requires one and one half as many people for the same work that is done by department engineers, and the cost of a contract engineer is one and half times the cost of a department B-level employee.
iv. The cist of losses is a subjective estimate and assumes that losses occur mid-year. For quits, early retirement, death and disability a cost of one and one half times annual salary is used. For company action and losses to non-exempt a credit of one half years salary is used. The yearly salary includes the cost of “fringe benefits”, therefore pension and lay-off costs are not included in the loss numbers. (See Table 2).

This problem input highlights the proliferation of conflicting goals and the necessity of involving management, not only in defining goals but also in the subsequent step of determining goal priorities.

### *2.2. Model Development*

At this point the problem reduces to determining the new entrants:

$X_1$ = Number of new hires
$X_4$ = Number of promotion from non-exempt
$X_2$ = Number of rehires
$X_5$ = Number of contract engineers
$X_3$ = Number of transfers-in from other departments that will best satisfy the previous conflicting goals.

$$\begin{bmatrix} X_{AA} \\ X_A \\ X_B \\ X_C \end{bmatrix} = \begin{bmatrix} AA & A & B & C & Gains \\ 30 & 208 & 384 & 543 & X_1, X_2, X_3, X_4 \end{bmatrix} * \begin{array}{c} \begin{matrix} AA & A & B & C \end{matrix} \\ \begin{bmatrix} 0.8929 & 0.0119 & 0 & 0 \\ 0.0180 & 0.8889 & 0.0135 & 0 \\ 0 & 0.0696 & 0.8527 & 0 \\ 0 & 0 & 0.1033 & 0.7988 \\ 0 & 0.0043 & 0.0775 & 0.9117 \\ 0 & 0.0513 & 0.3333 & 0.6154 \\ 0.0474 & 0.2133 & 0.4076 & 0.3318 \\ 0 & 0 & 0.0119 & 0.9881 \end{bmatrix} \end{array}$$

or

$$\begin{bmatrix} X_{AA} \\ X_A \\ X_B \\ X_C \end{bmatrix} = \begin{bmatrix} 30.531 + 0.0474X_3 \\ 211.975 + 0.0048X_1 + 0.0513X_2 + 0.2133X_3 \\ 386.337 + 0.0775X_1 + 0.3333X_2 + 0.4076X_3 + 0.0119X_4 \\ 433.748 + 0.9177X_1 + 0.6154X_2 + 0.3318X_3 + 0.9881X_4 \end{bmatrix} \quad (1)$$

This problem is modeled using linear goal programming (LGP) with preemptive priorities. To develop the goal equations, total costs and people counts must be expressed as functions of the unknown number of new people. The expected No. of company employees at the end of new year are obtained by multiplying the starting employee count & unknown gains by the stay-and-gain portion of TPM.
which yields

$$X_{AA}+X_A+X_B+X_C=1063+X_1+X_2+X_3+X_4 \quad (2)$$

The constant people count (1063) lags the required total work force by 787,232 and 132 for cases I, II and III respectively and the desired growth level by 1.1(1165-1062)=219 new employees.

The expected cost of each employee transition is obtained as the inner product of the corresponding entries of the TPM & yearly Cost Matrix (Table-2), and is shown in Table-3. Next the expected total costs of losses, stays and gains is obtained by multiplying the start of year count vector[ $30,208,384,543,X_1,X_2,X_3,X_4$ ] by the expected cost matrix. This produces the following costs:

$$\text{Cost of all losses} = \begin{bmatrix} Q & R65 & RE & CA & TO & NE & DD & AL \\ 644 & 48 & 207 & -29 & 376 & -24 & 130 & 43 \end{bmatrix}$$

$$\text{Cost of continuing people} = \begin{bmatrix} AA & A & B & C \\ 901 & 4585 & 6462 & 5638 \end{bmatrix}$$

$$\text{Cost of all Gains} = \begin{bmatrix} H & RH & TI & NE \\ 13{,}358X_1 & 14{,}846X_2 & 18{,}073X_3 & 7{,}024X_4 \end{bmatrix}$$

Adding them to the contractor costs, $26X_5$, yields

$$\text{Total Cost} = 18{,}981+13{,}358\,X_1+14{,}846\,X_2+18{,}073X_3 + 7{,}024\,X_4+26X_5 \quad (3)$$

The variable component of which is to be minimized.

### *2.3. The Goal Programming Model*

With the information given in the previous two selections the following linear goal programming model was developed.

| Priority | Goals |
|---|---|
| 1 | Impose Lower Limit on New Hires<br>$X_1+n_1-p_1=40$ |
| 1 | Maintain at Least 100 Contract Employees<br>$X_5+n_2-p_2=100$ |
| 1The Achievement Function for This Model | No. of Contract People not to Exceed Dept People |
| 2 | Number of Re-Hires to be 5 or a Few More<br>$X_2+n_4-p_4=5$ |
| 2 | Keep Transfer-in at 20 -- or a Few More<br>$X_3+n_5-p_5=20$ |
| 2 | Non-Exempt Promotions to be 30 Less<br>$X_4+n_6-p_6=30$ |
| 3 | Satisfy the Forecast Future Year People Required<br>$X_1+X_2+X_3+X_4+2X_5/3+n_7-p_7=787,232,132$ |
| 4 or 5 | Limit Department Growth Rate<br>$X_1+X_2+X_3+X_4+n_8-p_8=219$ |
| 5 or 4 | Minimize Labor Costs<br>$13.358X_1+14.846X_2+18.073X_3+7.024X_4+26X_5+n_9-p_9=0$ |

| Priority | Goals |
|---|---|
| | Satisfy Position Level Ratio Goals |
| 6 | $0.0048X_1 + 0.0513X_2 - 0.1659X_3 + n_{10} - p_{10} = 32.273$ |
| 6 | $-0.0048X_1 - 0.0513X_2 - 0.0711X_3 + n_{11} - p_{11} = 28.789$ |
| 6 | $0.9568X_1 + 0.5383X_2 - 0.9670X_3 + X_4 + n_{12} - p_{12} = 875.715$ |
| 6 | $0.9712X_1 + 0.6922X_2 - 0.3271X_3 + X_4 + n_{13} - p_{13} = 239.79$ |
| 6 | $0.7627X_1 - 0.0512X_2 - 0.4834X_3 + 0.9643X_4 + n_{14} - p_{14} = 338.926$ |
| 6 | $-0.8402X_1 - 0.2821X_2 - 0.0758X_3 - 0.9762X_4 + n_{15} - p_{15} = 47.411$ |

### *2.4. Objective Function*

The priorities listed on the left side of the goal formulations are an example of the priority decisions that must come from management. Goals can be grouped within the same priority where there is no strong preference between goals. The 'must goals" are given first priority to assure satisfaction. In this, the higher cost of contract employees creates a major conflict between the goal limiting department growth and the goal to minimize labor costs. To test the importance of the priority selection of these two goals, alternative solutions were obtained by reversing the priority level of these goals.

$$\text{Minimize } \bar{z} = \{\underbrace{(n_1 + n_2 + p_3)}_{1^{st}\text{ Priority}}, \underbrace{(n_4 + n_5 + p_6)}_{2^{nd}\text{ Priority}}, \underbrace{(n_7 + p_7)}_{3^{rd}\text{ Priority}}, \underbrace{(p_8), (p_9)}_{4^{th}\ 5^{th}\text{ Priority (or reversed)}}, \underbrace{(p_{10} + p_{11} + p_{12} + n_{13} + n_{14} + p_{15})}_{6^{th}\text{ Priority}}\}$$

## 3. Result and Analysis

The solution will be obtained by using QM for WINDOWS package as follows. The solution results for three cases are shown in the Table-4. Reversing priorities 4 and 5 did not make any difference in the last two cases. The cost goal pushed the use of contract personnel to its minimum and the department growth was still below the 10% ceiling (negative growth in case III). In case I, however, the large workload made a difference when reversing the cost and growth priorities. In Run1, the higher priority cost goals cut variable expenses in half by dropping contract people to the minimum 100 and allowing the lower goal priority growth rate swell to an unrealistically high 53%. As expected, the opposite trends are observed in Run 2; the higher priority growth limit of 10% is attained by using many more (852) contract employees to cover the remaining workload, thus doubling the lower priority variable costs and shifting the violated supervision ratio from a high C/B (Run-1) to a low (B+C)/A (Run-2 and cases II and III).

It should be noted that the above results can be made more realistic by revising personnel promotion and wastage probabilities as linear regression functions of accumulated annual change in total employment. This will be necessary when a significant change in the department's growth rate is anticipated. Organizations experience higher wastage and fewer promotions during decline periods, while growth has the opposite effect.

It any case, the final choice of a plan rests upon management, which sooner or later will ask various "what-if" questions that LGP so conveniently can handle. For example, they may want to reconsider some of the supervision ratio priorities or keep ratios in the same priority, but aasign them different weights to give some preferential treatment. This "what-if" interaction sharpens the decision maker's understanding, thus making him able to select the most satisfactory plan.

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