DYNAMICS OF FLOW OF SCIENTISTS IN GOVERNMENT RESEARCH ESTABLISHMENTS

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Abstract

The paper reports the findings of an ongoing project on manpower modelling for a government research organisation. The flow of scientists from one grade to an other has been modelled considering recruitment, promotion and retirement policies. Age distributions of scientists have been incorporated in the formulations and it has helped in retirement calculations from various grades. Future scenarios with alternative policies are generated and discussed.

1.0 INTRODUCTION

The most important asset in an R&D organisation is its scientists and engineers. A large number of research works have been conducted on various aspects of R&D manpower. Many system dynamicists have also addressed themselves to the problems of manpower in R&D organizations. The works of Roberts (1967a; 1967b) stand unique among them.

The model presented in this paper is an outcome of a project undertaken jointly by the IIT, Kharagpur and NISTADS, New Delhi to study the evolving manpower structure in R&D laboratories under Council of Scientific and Industrial Research (CSIR).

2.0 THE APPROACH

The model attempts to

1. study the effect of existing policies of recruitment, promotion and retirement on overall manpower structure for a longterm future (20 years), and
2. attempt to recommend a suitable policy or a set of policies for recruitment, promotion and retirement or structural changes to achieve the manpower structure as might be desired.

A number of meetings with the Scientists of CSIR(HQ),

The authors gratefully acknowledge the financial support received for this research from CSIR (EMR Division).

NISTADS and NPL, and a study of various publications by CSIR related to manpowr planning in its laboratories helped in defining the scope of the investigation in the following way :

i) <u>Selection of CSIR Units for Study</u>

The investigation will be carried out in NISTADS and NPL. The decision in favour of these two organisation was taken keeping in view the contrasting situation they present in matters of their sizes, activities and the availability of years of organisational history. Two CSIR Units were selected for the purpose of the study. The first is a laboratory with a large number of scientists and a long history, while the second is an institute mainly involved in theoretical investigations and has a relatively smaller number of scientists and a history of about 9 years. The results for the first unit are given in this paper.

ii) <u>Factors Included in the Study</u>

The study investigated the long-term manpower structure of the CSIR units. The current study, being the first of its kind in the CSIR, has excluded such important manpower-related factors as productivity of scientists, reward system, research facilites, and organizational culture, etc.

iii) <u>Category of the Manpower</u>

The study was limited to Scientists (Grade B through Grade G) only.

iv) <u>Manpower Flow</u>

The existing recruitment promotion and retirement policies were considered for the purpose of modelling the manpower system. The effect of anticipated policy changes were examined. These provided the necessary inputs in suggesting new policies with regard to recruitment, promotion and retirement.

v) <u>The Methodology for Analysis</u>

System Dynamics was used as the primary methodology for structural and policy analysis because of its many desirable characteristics such as generality, ease of communication, ability to explicitly represent physical flows, and inherent capability to model nonlinearities and produce model behaviour in time, etc.

vi) <u>Computer Database</u>

Computer databases were developed for both the CSIR units not only to capture the histories of manpower but also to estimate the parameter values necessary for the system dynamics models and to generate and analyse the past behaviour of the manpower systems.

vii) Generation of Scenarios

Emphasis was give to the generation of future scenarios under different policy environments.

3.Ø DATA COLLECTION AND ANALYSIS

The discussion with the CSIR scientists was followed by a preliminary model which was later discussed with scientists of the two units. Based on the discussion and the model requirements, data on the following manpower related aspects of the two units were collected for each group of scientists:

i) number of scientists,
ii) age distribution,
iii) recruitment rate from external sources,
iv) leaving rate which included :
   a) resignations from a level,
   b) retirement rate,
   c) natural wastage, i.e., death, retirement, etc.,
v) promotion rate,
vi) minimum period of stay in a level for being eligible for promotion,
vii) age of recruitment of various levels,
viii) expected age of scientists at various levels, and
ix) age of retirement.

While searching for manpower related data in the two CSIR units the following difficulties were encountered.

1. Aggregate level data where not available in consolidated form.
2. The data for this study were not available in required form and had to be derived from a huge amount of data maintained in the personnel record of each scientist.
3. Certain personnel records were not updated properly. In such cases the data were validated by personally discussing the cases with the scientists (if on role of the Unit) or with the senior scientists in charge. A questionnaire was circulated among the scientists for providing individual data in case of the second CSIR unit.

It was decided to develop databases for each CSIR Unit in order to circumvent the above mentioned difficulties and also to help in estimating the paramter values for the system dynamics model. The details of the databases are given in Mandal et al. (199Ø).

It is seen from historical data for the first unit that the number of junior scientists (in grade B and C) has come down from 81% from 1974-75 to 74% during 1982-83 and, finally, to 65% during 1989-9Ø. This reflects existence of avenues for promotion of junior scientists (scientists in Grades B and C) to senior grades (Grades E_I, E_{II}, F, G, DRG and DIRECTOR) during the last fifteen years.

Although this is a welcome trend one is not sure of the type of manpower structure which will be obtained in future. It is necessary to construct a mathematical model and to generate the future behaviour of the manpower system in future.

4.Ø THE SYSTEM DYNAMICS MODEL

A system dynamics model has been developed for the above mentioned situation only for the Scientists group starting from Grade B onwards. In the model, the three highest grades (G, DRG and DIRECTOR) are clubbed together to form Grade H.

The system dynamics model basically models the stock of scientists in each grade and the intermediate flows. Figure 1 gives an overview of stock and flow of scientists at various grades. The value of a stock increases as flows occur into it, and decreases as flows occur out of it. The inflows to the stock of scientists consist of the following:

1. Recruitment rate,
2. Promotion from immediate low grade.

The outflows from a stock consists of

1. Wastage (Retirement/Resignation/Death),
2. Promotion to immediate higher grade.

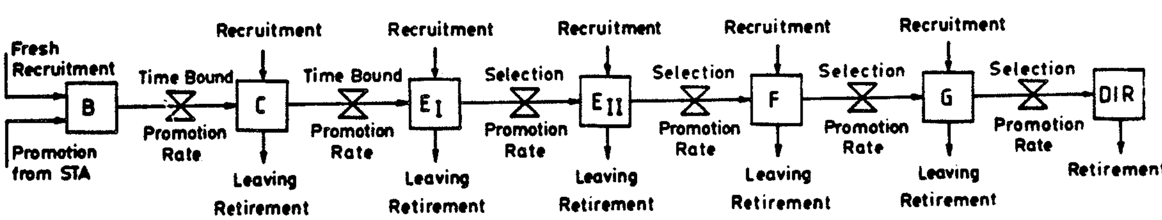

Fig. 1: Overall Flow Diagram.

Recruitment at a Grade

An analysis of the recruitment data for various grades indicates massive recruitment in B and C grades and very negligible recruitment in the higher grades. Therefore, the model assumes that recruitment takes place only at B and C grades.

Promotion from/to a Grade

Promotion from a grade to its immediate higher grade has been modelled by considering years of service for eligibility and the historical average of the fraction of such people who used to get promoted to the next higher grade.

Since the old practice of promoting technicians to Grade B is stopped for a few years now, the model does not consider such a possibility.

Wastages

Wastages include death, retirement and resignation of scientists at a particular grade.

For Grades B and C CSIR has a stated policy of 100% promotion. But the historical averages of the fractions of the eligible scientists who have actually got promotion from this grade are less than 100%. The model assumes that the remaining fractions are value of the wastages from this grade.

CSIR follows a restricted promotion policy for Grades E_I, E_{II}, F and H. Therefore, many eligible scientists will naturally continue to stay in CSIR Units in the same grade till their promotion or their retirement in the same grade at a future time. The model defines a level of eligible scientists after the completion of required years of service in a grade. Pipeline delay functions are used for this purpose. The promotion from this level is made according to the historical average of the fractions getting promotion. The retirement, however, takes place at two stages: before and after the scientists become eligible for promotion.

The mechanism of modelling for retirement is depicted in the influence diagram shown in Fig. 2. A detailed discussion of such a scheme in given elsewhere (Mohapatra et al., 1990). In a nutshell, the scheme requires computation of total age of all the scientists in a grade, expressed as a level . The value of such a level increases it with the age of incoming scientists and ageing of the existing scientists with time, whereas it reduces as scientists get promoted or retire. The average age of the scientists is computed in a group by dividing the total age of scientists by the total number of scientists in that grade. Assuming a normal distribution for the age of scientists in a group with its mean as the average age, so computed, and a reasonable value of standard deviation, the retirement rate is computed for every grade of scientists.

Model Parameters

The database created for the CSIR units helped in computing the initial values of the level variables and the different parameters needed for the system dynamics model. Data for the period 1975-1985 were used to compute the parameter values for the first CSIR unit.

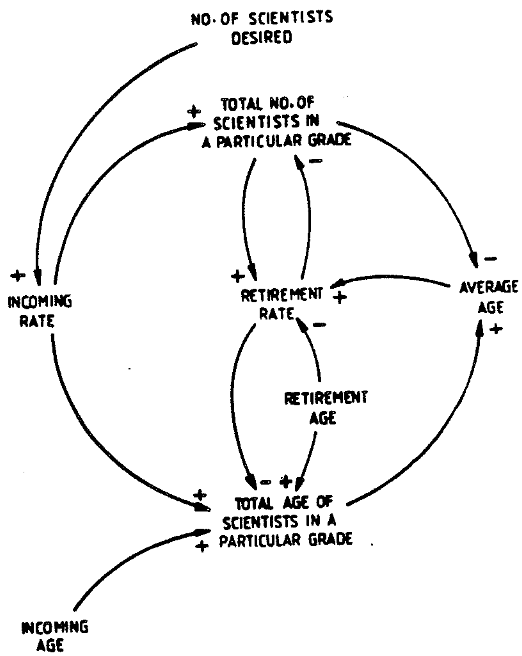

Fig. 2 : Modelling of Age.

The model has been simulated in PC-XT with the help of the PC version of DYMOSIM software package (Bora and Mohapatra, 1982). The details of the model equations are given in Mandal et al. (1990).

A validation scheme proposed by Forrester (1961), Forrester and Senge (1980) and Mohapatra (1990) has been followed to develop confidence in the model. The scheme considers validation of the following model attributes:

1) Importance of the model objectives,
2) Validation of the model structure,
3) Validation of the model behaviour, and
4) Validation of policy implications.

The details of the validation tests are available in Mandal et al. (1990). The manpower dynamics model passed through the validation tests satisfactorily and the model is considered to be reasonably good representation of reality.

The behaviour reproduction tests were carried out with the model based at 1985. To negate any propagation error occurring due to mismatch of actual and simulated values of scientists at various grades in 1989, the initial values for the manpower dynamics model were refixed at their 1989 values for the purpose of simulation, forecasting, and scenario generation.

5.0 POLICY TESTING AND SCENARIO GENERATION

For CSIR Units, like any other organisation, it is essential that the management should modify the existing manpower policies and introduce new policies, if necessary, to suit future requirements and forecast the effects of such changes in policies. Keeping this in mind different policy simulation runs were taken and results analysed. The various policies tested are given in Table 1.

TABLE 1

POLICY	DESCRIPTION
1. Reference policy	Continuation of present situation i.e. (do-nothing strategy). In this policy recruitments at Grade B and Grade C are 80% and 20% of the total vacancy. Promotions occur at 100%, 100%, 75%, 50% and 25% of the eligible candidates at Grades B, C, E_I, E_{II} and F, respectively.
2. Policy 1 (P1)	Recruitments at B, C, E_I and E_{II} grades with 40%, 30%, 20% and 10% of the vacancies respectively. Promotions as in the reference policy.
3. Policy 2 (P2)	Recruitments at B, C, E_I, E_{II} and F grades with 25%, 25%, 20%, 20%, and 10% of the vacancies respectively. Promotions as in the reference policy.
4. Policy 3 (P3)	Promotions at the rate of 82%, 55%, and 28% of the eligible scientists at E_I, E_{II} and F grades. Recruitments as in the reference policy.
5. Policy 4 (P4)	Promotions at the rate of 68%, 45%, and 22% of the eligible scientists at E_I, E_{II} and F grades. Recruitments as in the reference policy.
6. Policy 5 (P5)	Promotion at the rate of 50% of the eligible scientists at E_I grade (as per recommendation of Kailash Chandra Committee Report). Recruitments as in the reference policy.

Different performance measures that have been analysed for policy comparisons are as follows:

i) number of scientists at various grades,
ii) number of eligible scientists at various grades,
iii) average age of scientists at various grades and overall average age of the scientists in the organisation,
iv) ratio of junior scientists (Sc.B+Sc.C) to senior scientists (Sc.E_I+Sc.E_{II}+Sc.F+Sc.H),
v) number of fresh recruitments and number of promotions at a grade.

Future Scenario with Reference Policy

Fig. 3 and Fig. 4 depict the number of scientists at various levels during the 20 year period. The observations made are the following:

a) The total number of scientists in the Unit always varies between 300 and 310 and is always less than the ceiling limit of 320.

b) Number of scientists B goes on increasing from its 1989 value of 25 before stabilising at a value of about 77. This is due to the fact that, as per the present policy, 80% of the vacancy is filled by recruitment at scientist B grade.

c) Number of scientists C starts decreasing from its 1989 value of 179, reaches a minimum of 32 in 1994 and picks up again to stabilise at about 77 at the end of the simulation run. Such a behaviour is due to a higher rate of promotion at this level compared to the recruitment into this level which is just 20% of the existing vacancies. Moreover, promotions from Grade B is much less due to the small number of scientists at this grade. However, from 1994 onwards, more and more grade B scientists get promoted to grade C thus increasing the number of Grade C scientists.

d) Before finally stabilising at about 72 the number of scientists at Grade E_I fluctuates noticeably. This fluctuation occurs in a direction almost opposite to the direction of fluctuation of Grade C scientists. This is due to a higher rate of promotions to this grade from Sc.C grade (number of scientists C initially is quite high) as compared to the promotions to the grade E_{II}.

e) Number of scientists E_{II} initially increases and later decreases. This can be attributed to the higher inflow to this grade from E_I grade (initially a large number of E_I are eligible to be promoted to E_{II} grade as compared to the number of E_{II} eligible to be promoted to F grade.

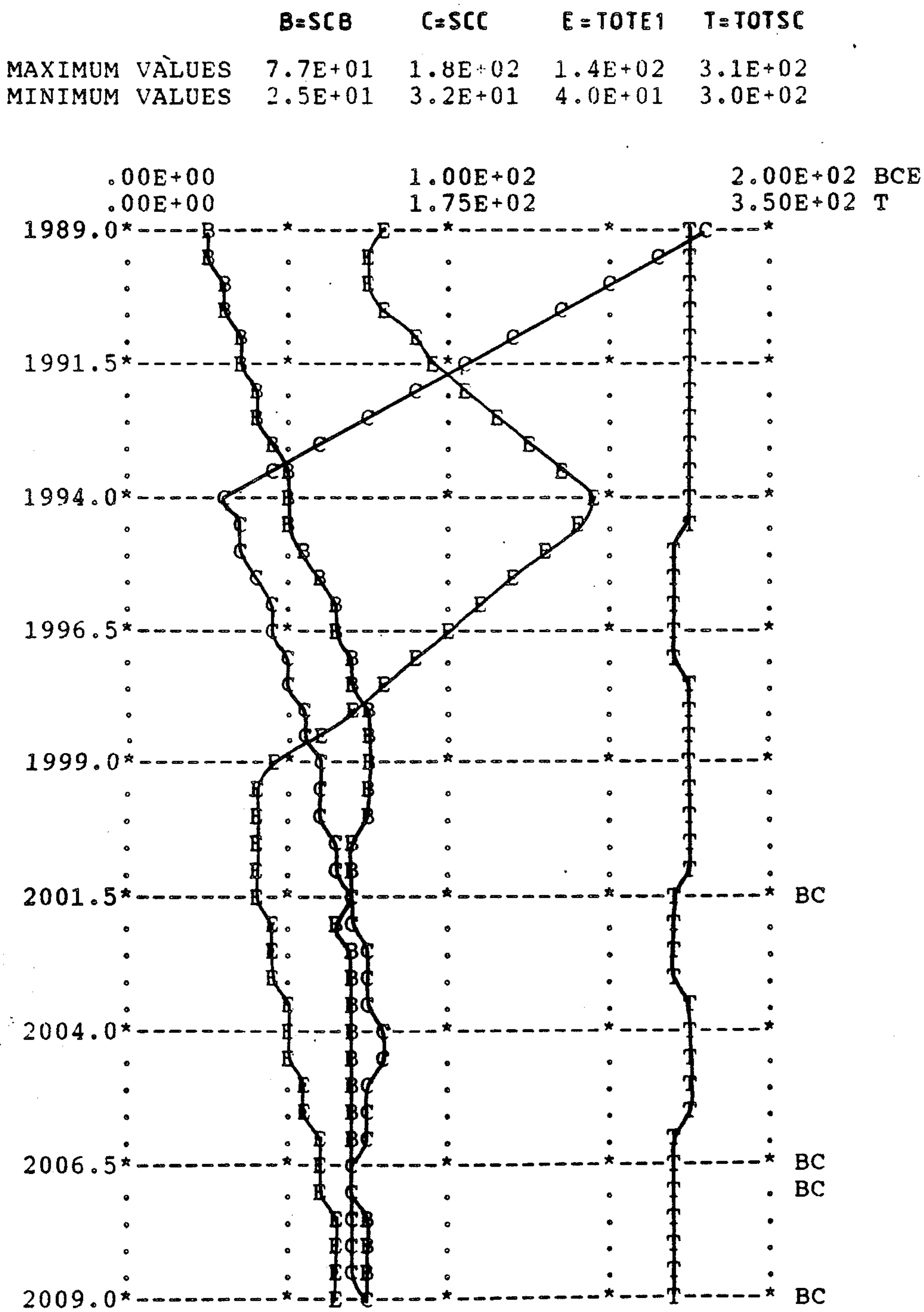

Fig.3: Dynamics of Scientists B, C, E_1 for Reference Policy.

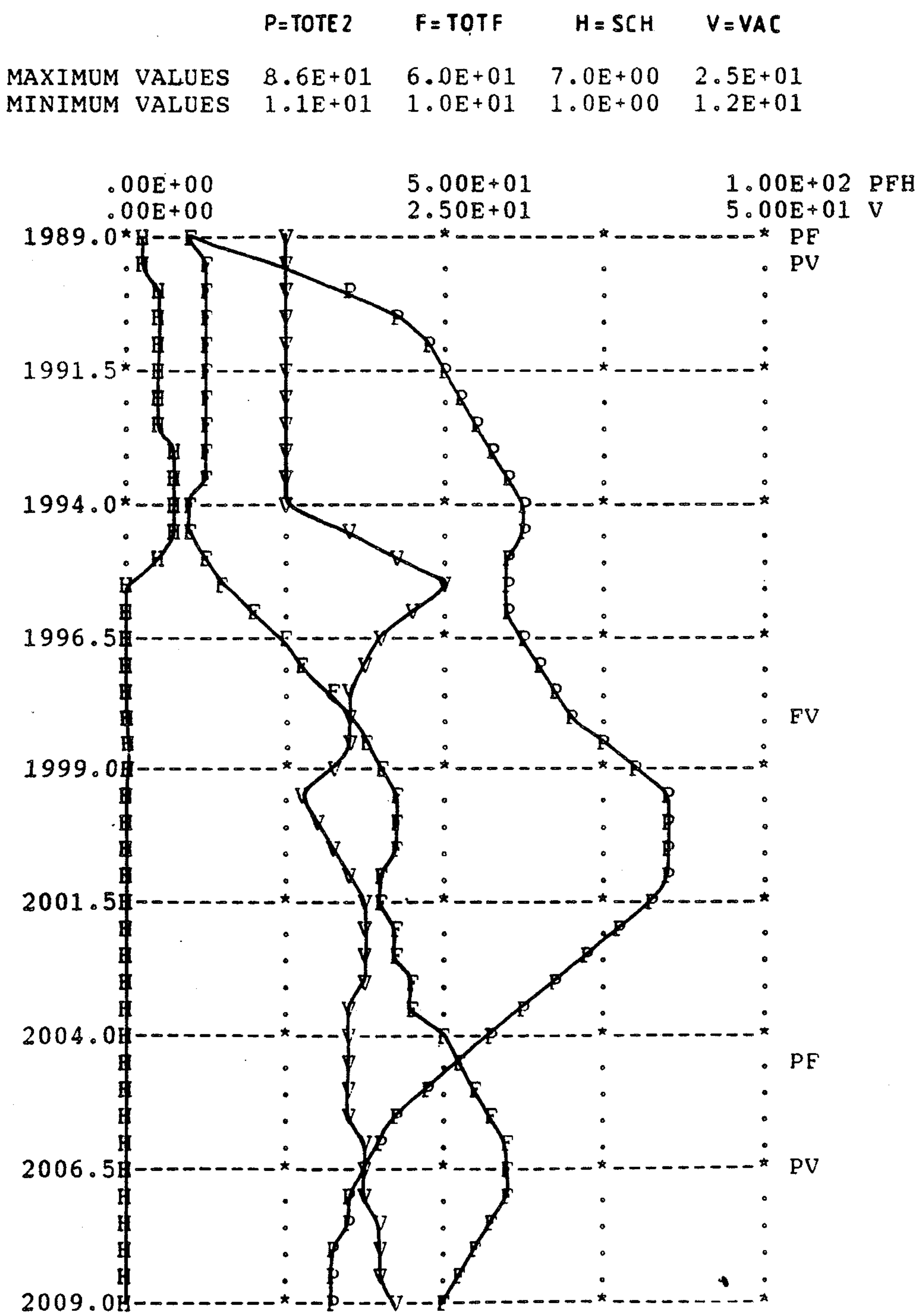

Fig. 4 : Dynamics of Scientists E_{II}, F, H and Vacancy for Reference Policy.

f) Number of scientists F starts at 11, remains almost constant at that value for about 6 years, but thereafter continues to increase with intermittent fluctuation to reach a final value of 50 at the end of the simulation run. The higher rate of promotion from E_{II} grade after the delay period of about 5 years causes this behaviour.

g) Number of scientists H (which includes scientists G, scientists DRG and Director) decreases after a slight initial increase in the initial period. This is because the scientists attain retirement age with time and also there are less promotions from F grade, due to stiff norms of promotion.

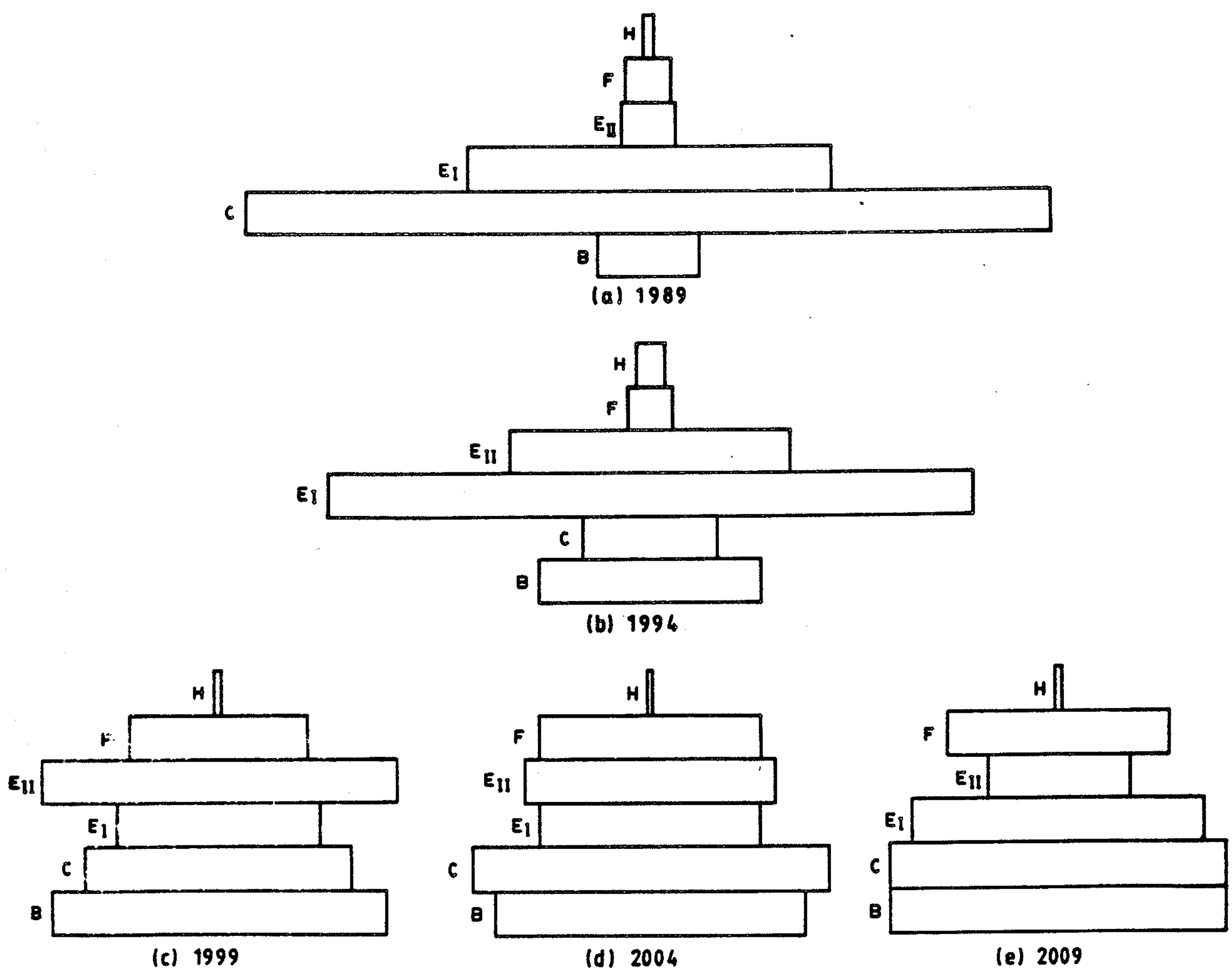

Fig. 5 : Manpower Structure for 1989, 1994, 1999, 2004 and 2009 for NPL.

Fig. 5(a) through Fig. 5(e) give the distribution of scientists at various grades during the years 1989, 1994, 1999, 2004 and 2009. It is noticed that the prevailing bulge in Grade C is progressively advancing to immediate higher grades after every five years. It has however taken about 10 years for the bulge to pass from Grade E_{II} to Grade F, presumably because of stiff promotion policy at this grade.

Thus the effect of the reference policy is to convert a bottom-heavy pyramidal manpower structure of Fig. 5(a) of 1989 to an almost cylindrical structure of Fig 5(e) in 2009.

Fig. 6 shows the behaviour of junior scientist to senior scientist ratio with respect to reference policy run. It can be observed that the ratio which is higher initially, falls during the initial 5 years and thereafter slowly rises to stabilise at the value 0.98.

Fig. 6 also shows the behaviour of overall average age of scientists with respect to the reference policy. It shows an almost continuously rising trend of average age of scientists with time. Such a rise has resulted from a relatively large number of scientists at higher grade (obviously with higher age).

Scenarios with Policy Alternatives

Table 2 shows the major outputs for new policies. Certain salient features of these policies are discussed in the subsequent sections.

TABLE 2

POLICY	(JUNIOR:SENIOR) SCIENTISTS RATIO			AVERAGE AGE OF SCIENTISTS		
	1989	1999	2009	1989	1999	2009
1.Reference	1.96	0.80	0.98	36.19	39.01	40.50
2.Policy P1	1.96	0.41	0.49	36.19	40.87	43.70
3.Policy P2	1.96	0.25	0.32	36.19	42.34	46.16
4.Policy P3	1.96	0.78	0.94	36.19	39.00	39.00
5.Policy P4	1.96	0.82	1.00	36.19	39.16	40.19
6.Policy P5	1.96	0.80	0.92	36.19	39.00	40.47

Policy P1 and P2 study the effects of alternative recruitment policies. The ratio of junior to senior scientists

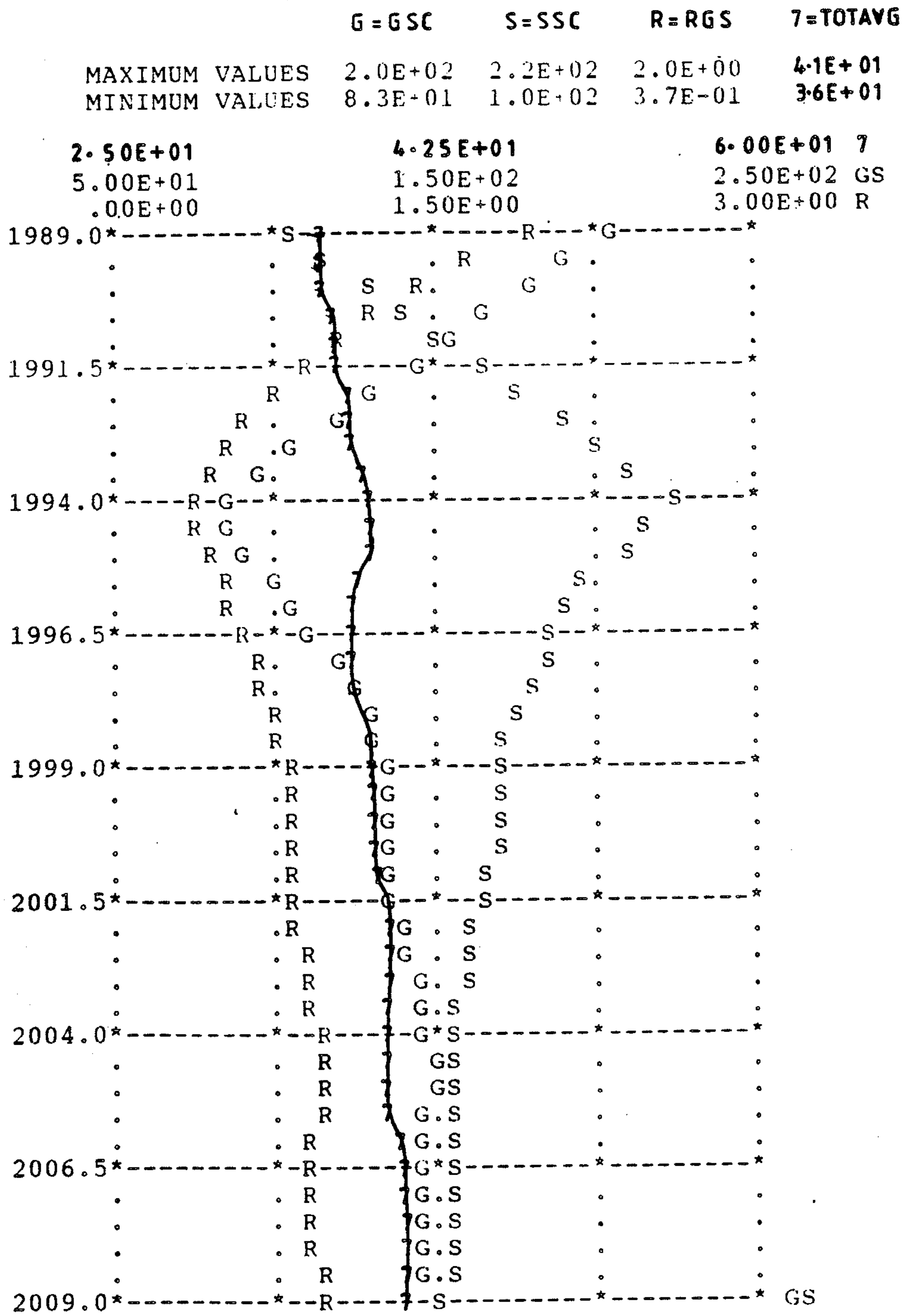

Fig. 6: Junior to Senior Scientists Ratio and Average Age for Reference Policy.

decreases with time and the decrease in case of policy P2 is more than that of policy P1. At the end of simulation run the number of senior scientists for policy P2 are about 10% more than that of policy P1. The same is attributed to the increased recruitment rate at higher levels.

During the simulation runs for P1 and P2 the average age of scientists shows an increase. The increase in case of P2 is higher because of recruitment with high incoming age at higher levels. As the recruitment rate for P2 at upper levels is higher than that of P1, there is higher increase in average age in case of policy P2 run. The comparative study can also be made from Table 2.

Policies P3, P4 and P5 are designed to study alternative promotional policies. The effects of changing norms for promotion are prominently displayed in policies P3, P4 and P5, by the changes of the number of scientists at higher grades. Because the promotions from a level subsequently effect the next higher grade, the accumulation becomes prominent at the higher grade. In policy P3 (10% more promotion than the existing policy), the increase in the promotional fractions has resulted in a decrease of the junior to senior scientists ratio, resulting in more number of senior scientists. Policy P4 (10% less promotion than the existing policy), as expected, has restricted the number of senior scientists and Policy P5 (50% promotion from E_I to E_{II} as compared to 75% in the existing policy) produced a structure with very few scientists in Grades E_{II} and above.

The policy runs, as discussed above, show different scenarios for the system. The long term behaviour predicts appreciable changes with respect to organisational structure, age of scientists, recruitment, promotion and retirement pattern with different policies. It is expected that from the analysis of these scenarios the management would be in a better position to take an appropriate decision regarding the manpower strategy.

6.0 CONCLUSION

Basic objectives of this study has been to study the manpower flow for CSIR laboratories by changing the scenario of promotion and recruitment. The model runs have been made for various policy alternatives.

One important feature of the study is the development of a consolidated database. The database has helped in estimating the parameter and the initial values of the model.

Various recruitment and promotion policies have been tested on the system dynamics model developed. The results show that a wide variety scenarios can be generated. The model can be used by the management to design and analyse the longterm effect of various policies.

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