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Rigidity, lack of drive, stereotypic problem-solving efforts, the drying up of creativity, and the disappearance of self-confidence, are some of the descriptors of the process of aging which one might apply to an acquaintance. Such adjectives and the syndrome name, aging, can be used to describe an organization as well, not so much as an anthropomorphic analogy but simply as a shorthand tag for the joint occurrence of these descriptors. An organization so described must not necessarily be inefficient and ineffective in carrying out its task, so long as it operates in a relatively static environment; however if the task of the organization is to change the environment, as in the case of a research or a research & development operation, probably no set of symptoms are more indicative of an organization that is failing in its mission.

It is the intent of the present research effort to explore the conditions which produce organizational aging in the context of a particular R&D organization which has shown at least some of the aging symptoms to an important degree, to build a theoretical approach to utilizing the information gained in the study of this organization and then to develop strategies aimed at the mitigation of the various weaknesses which occur in the aging syndrome. Clearly this would be a large undertaking if one were to consider all possible causes of aging and all remedies. This study will be limited by consideration of personnel policies which determine the acquisition, movement within the organization, and separation of employees. Such a partial analysis has limited value in its own right, but gains importance when it also permits a method of separating out the set of phenomena attributable to the personnel policies from those other phenomena central to the

purpose of the organization, and thereby to aid those investigations undertaken by others who have tackled the problem of R&D management from relatively more sophisticated viewpoints. Partialling out the effects of aging of the staff, of staleness occassioned by familiarity, of the rigidity which is developed to protect the weaker staff members and simplify the work of administrators, will provide a data base in which the magnitude of other significant forces in the research environment can be more accurately assayed.

The Personnel Approach

In the exploratory interviews with personnel at the facility in which this study is being conducted, a great many of the problems which face the manager and the scientist and engineer were brought out. Many of these problems are common to other facilities as attested to by the now extensive literature on the management of creative scientists and engineers, and in the more general topic of allocating scarce resources for projects of uncertain return.* Among those mentioned were: the restrictiveness of the budget for developing project designs; the rigidity of federal and contractual accounting procedures; the selection of personnel; the selection of projects to support; the relation between the professional and the management; the maintenance of a creative climate; the responsiveness of the organization in which the R&D effort is embedded; and the effectiveness (and necessity) of

* A catalogue of much of the ongoing research (as of the early 1960's) in R&D management was compiled by A.H. Rubenstein of Northwestern University. This listing will serve as entre to this area of research. A Directory of Research-on-Research, College of Research and Development of the Institute of Management Sciences. 1964.

information retrieval and interlab communication. In any definitive study of the R&D management problem each of these factors will require some consideration and any integration one can achieve will be of significant aid in the design of such operations, because at the moment much of the research has concentrated on one of these (and other) significant issues to the exclusion of others.

In addition to, and in an important sense, before we conduct relatively sophisticated studies from the viewpoints mentioned above, we ought to look at the simple data regarding the individual members of the organization in terms of their age, training status, and length of service in the facility and in the area of concentrated activity. The 'partialling' analysis which is planned in the present investigation looks at the distribution over time of these individual data for the professional populations, i.e., the scientists, engineers, and their immediate administrators, of the R&D facility to answer such questions as: What are the changes in average age and status over the life of the organization? What is the change in distribution of chances for promotion as a function of age and place in the organization? And what have been the patterns of hiring and separation in terms of the backgrounds and relative quality of the involved persons?

The tool to be utilized in this partialling analysis is one already common to mobility studies; transition analysis with the assumption of Markovian properties. Using this approach to organize the empirical data will sharpen the ability to correlate changes in organizational product with changes in the personnel who bring about such productivity. But more importantly

it is also a tool which can be used to design policies based on what has been found to be desirable characteristics for the organization of R&D activities.

In this introductory paper, I will not attempt to lay out the technical detail either of the empirical data reduction stages or of the methods for selecting the most attractive personnel policies. I will confine the technical exposition to that which will be suggestive of the direction and to provide the basis for analysis of empirical data reported in the final section of this paper.

Attempts to make practical application of transition mathematics to organizational studies has seldom been successful because of the inability of the investigator to identify clearly states of the system and because of the frequent occurrence of exogenous shocks to the system. However, the subject organization in the present study is characterizable by the existence of a discrete, identifiable and ordered, set of status levels into which all the professionals are classified and by an unusual degree of isolation from forces which would change its size and internal structure. With such ideal conditions for a formal analysis we can establish models containing elements which have easily identified referrants in the subject world, and which are computationally convenient.

The manning table of such an organization as we are studying can initially be represented by a vector

M_t, indicating the number of employees in each of the n status levels. In extensions of the preliminary analysis, this vector will be refined to include age, skills and organizational

position.

H_t is a similar vector indicating the number of employees hired during the year t, according to their incoming status.

A is a transition matrix, the elements, a_{ij}, of which are the portion (or likelihoods) of the individuals remaining in the status they occupied at the beginning of the year for i = j, for being promoted, i < j for being separated, i = s; or for being demoted, i > j.

M_t is a datum of the organization for values of t in the past; for future values it is a projection or a desired vector. Similarly H_t and A can represent historical data. Or they may be used as policy variables, for the most part controllable by the organization though hiring and separation are somewhat dependent on market forces and mortality as well. For example, a policy form of the hire vector H_t might be chosen to maintain the present status distribution in the organization. Thus

$$H_{it} = M_{it-1} - M_{it-2} \text{ for } i = 1, 2, \ldots, n$$

Or the policy selected might be to maintain a near constant employment, M^0, and hire to make up the deficits due to separations according to some pattern given by a distribution vector, h,

$H_t = \alpha(M^0 \xi - M_{t-1} \xi)h$ where α is a 'smoothing' constant with a value between 0 and 1, chosen to cushion the shock of an unusually large separation rate.

(ξ is a column vector with all n entries equal to 1).

Or, H_t might in part be determined by a budget constrained function such that the carrying cost of new employees would not exceed $C_t(H)$. Thus:

H_t is a member of the set of hire schedules such that $H_t c \leq C_t(H)$ where c is a vector of costs incurred by employing a person at each level 1, 2, ..., n.

Similarly A for future years can be explicity selected by management. An example of a policy matrix is one in which transition probabilities for status, age and years in a given status level are specified such that for each status age and year in status on transition is always to retirement. High turnover, thus high influx of new employees, could be obtained by selecting appropriately early retirements. The later phases of this study will consider the effects of a great variety of policies. A may also be used as an estimate of operations in previous years. Viewed as an estimate of previous personnel policy is provides a compact method of stating the previous behavior of the system, a projection mechanism if management policy remains constant, and as a vehicle to test for stability in the behavior of the organization.

More significantly than either the direct specification of a future policy or the estimation of past performance, the use of the transition matrix approach allows us to isolate and study the transiency effects in the past performance or in the installation of new policies. One of the ideas which persistently appears in the study of creative successes is that the newness and excitement of working in a rapidly changing organization is an essential

aspect of the achievement of a creative output,* Thus one of the possible approaches to the problem of R&D management is to create a new organization every time one wishes to achieve an R&D breakthrough.[2] Effective as this route might be it fails to take into account the requirement of predictability and stability required by the employees and the institutions as shepards of physical and organizational capital. By searching for policies which provide for a constant under-structure but psychologically appropriate transients we may be able to design an environment which on the average is effective for research and development activities.

The 'Lab'; a first look at the data

The brief characterization of the laboratory and test facility introduced here is limited to that necessary to understand this first look at the empirical data which will later be more extensively analyzed.

The 'lab' is a government research and development facility which has existed in one location for over twenty years. During that period its rather narrowly defined mission has been gradually modified, but apparently at a rate just appropriate to the changing scientific environement. In part because of the logistics of the site and in part as a matter of policy, the total personnel at the site has been limited to a size attained

* See R.A. Howard, Dynamic Programming and Markov Processes, Wiley (1960) for techniques to be used in handling the transients.

during the early 1960's. This overall limitation has been applied specifically to the professional component with the result that the number of scientific and engineering personnel in the facility has remained nearly constant over the past ten years. The number declined slightly during the late fifties, partially through consolidation of part-time employment into full-time appointments; since 1961 there has been a slow increase in the professional staff at the expense of some support operations which have been 'contracted out.' These changes have been sufficiently small and gradual that it is reasonable to say that the facility has had a constant employment over the past ten years, plus or minus a small random component.

The professionals are classified according to civil service ratings ranging from GS 5 to GS 15 with a few administrative senior men in the open appointed class which is labelled (for the public law under which such employees are appointed) 'PL.' As in other civil service all the ratings are not in current use; almost no one is hired or moved to the ratings 5,6 or 10.

Hiring into the facility occurs at all levels. To date, most of the separations from the facility are due to resignation or transfer. Few employees have reached retirement age and separation 'for cause' among the professionals is rare.

The personnel records which are now maintained on magnetic tape, provide full employment records of all professionals who have been at the lab during the past 8 years, though it appears to be seriously incomplete prior to 1961. This limits our

working basis to the most recent five years. However, a great variety of statistics were collected during the 1950's and summary data is available against which to test various propositions arising out of analysis of the recent full information. The available data on the individuals currently or recently on the payroll includes all promotional data, training and relevant skills, organizational assignments, and, where applicable, the cause of separation. Special studies of a small subset of the professionals have also provided a detailed record of scientific accomplishments, publications, recognitions, etc. So far, only the age and promotional data has been utilized in this study.

One of the significant facts which emerge from the initial look at the distribution of employees by their GS classification is that the organization clearly does not fit the idealized triangular organizational form in which the number of employees at ~~each~~ rank decreases with increasingly elevated rank. At the moment, the middle GS grades are by far the most populous. The distribution over recent years averages

Classification	# of Professionals
P[illegible]	less than one
15	[illegible]
14	[illegible]
13	17
12	[illegible]
11	10
9 & 10	8
7 & 8	8
5 & 6	1

The professional component of the research organization is, of course, only a part of the total organization. If we looked at the whole structure we may again find a broad base of more or less skilled blue-collar employees. However, the purview of the research scientist does not include this component any more than the university professor is essentially concerned with the non-academic personnel outside of his immediate work space. The R&D activity takes place in an organization within an organization. Nevertheless, it is the phenomena of the inner organization with which we must be concerned, and as more functions are automated or contracted out, the inner organization with its 'football' shape will become increasingly the significant one for top management and the organizational student.

A second statistic which emerges immediately is that the median classification has been increasing over the period for which data is available (Figure I).

FIGURE I

Percent of the Professional Employment in GS Classification

At beginning of year	Hire	Classification 5&6	7&8	9&10	11	12	13	14	15	PL
1981	8	2	14	11	19	23	15	6	2	0
1982	11	1	7	13	20	25	15	6	2	1
1983	11	1	6	7	20	28	17	7	3	1
1984	10	1	7	7	18	28	18	7	3	1
1985	8*	1	5	7	16	30	21	9	4	1

* 1/2 year

There are two obvious sources for such a trend; one is the inflation in the 'currency of rank' which accompanies the upward push in salaries for the scarce research scientists; the other is the maturing process in the personnel 'mix' up. Unless new ratings are created at the upper end of the scale, promotion will eventually be curtailed. It is the effects of such curtailment and other manifestations of maturity towards which this investigation is directed.

The Employment Transition Matrix

Over the past five years the hiring, promotional and separation patterns have held remarkably constant. In fact, on a statistical basis one can conclude the hypothesis that most elements in the employment structure have not changed. Figure 11 displays the estimate of the employment transition matrix. (The data are only an approximation at this time as we have found that the personnel records failed to take notice of a portion of the separations; until this element is corrected, more refined work and full statistical treatment are not warranted).

FIGURE 11

Estimate of the Transition matrix over the years 1960-65

		TO										
		Hire	"8"	"9"	"10"	11	12	13	14	15	PL	S
FROM	Hire	0	.03	.43	.13	.24	.12	.06	.02	.01	.00	0
	"8"	0	.57	.27		.08						.08
	"9"	0		.35	.54	.07						.04
	"10"	0			.34	.18	.02					.06
	11	0				.58	.31	.01				.10
	12	0					.72	.18				.10
	13	0						.76	.19			.05
	14	0							.80	.15		.05
	15	0								.89	.06	.05
	PL	0									.95	.05
	S	0	0	0	0	0	0	0	0	0	0	1

Entries in the transition matrix represent the portion of those individuals beginning the year in one classification, as represented by their location in a given row, ending the year in the same or other status. The most common occurrence is that the individual remains in the same classification. Thus, the main diagonal contains the dominant proportions. The "hire"

row indicates the distribution of those hired during the year. None remain in the simple classification 'hired' and by definition no one was separated from an initial hire status, though some few have been separated within the same year they joined the facility; the portion is small enough to ignore at this level of refinement. Demotion occurs too infrequently to be considered, 0.1% of total employment. The unit entry in the separation row simply indicates for sake of completeness that all persons separated in a given year are regarded as having not returned within that year. In later stages of this analysis, the classification 'separation' will be expanded to include the various causes, of which resignation, retirement and 'for cause' are of greatest interest for a general study of R&D management.

We can take advantage of the empirical fact of constant size to simplify the employment matrix in a way which violates reality in an obvious but harmless way. We can simplify the analysis by simply assuming that those hired come from the ranks of those separated, in abstraction from the other personal characteristics of the separated individuals. Since, to maintain constant employment, the total separation must equal the total hire, Figure II can be rewritten as it is in Figure III.

FIGURE III

Modified Transition Matrix

FROM \ TO	"6"	"8"	"10"	11	12	13	14	15	PL	S
"6"	.57	.27	.00	.08						.08
"8"		.35	.54	.07						.04
"10"			.34	.56	.02					.05
11				.58	.31	.01				.10
12					.77	.16				.10
13						.76	.15			.09
14							.30	.15		.05
15								.89	.05	.06
PL									.95	.05
Hire	.03	.48	.14	.14	.12	.06	.02	.01	.00	0

In this form, the process is defined entirely by endogenous events. If we assume A to be constant (as it appears to have been) the recent history of the organization and its near future can be studied as an example of a finite markov process. Such analysis allows us to detect previous de facto employment and promotion policies and changes thereof, if there were any; it allows us to predict the future distribution of professionals according to status, the retirement rates, the mean years to promotion at each level, and the transient effects of any change in policy selected by the familiarity or forced on them by the aging and inflationary processes.

The final distribution, assuming no change in policy, is given by the 'limiting state vector' π (or P in matrix form). This vector, obtained from A by finding π such that $\pi A = \pi$, is approximately:

$$\pi = \begin{pmatrix} 6 & 8 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & S \\ .01 & .04 & .05 & .10 & .16 & .14 & .10 & .15 & .18 & .07 \end{pmatrix}$$

Since $H_t = S_t$ by definition, π_S is the hire rate as well. Note the large portion of the personnel in the upper levels, GS 15 and PL. This is a pattern found in established universities,

but not in industry or in most governmental bodies. In later analyses, which take into account, age and present retirement rules, the portion in the higher levels will certainly be reduced. Then, when we begin to understand what is the ideal organization form and what are appropriate rate of personal progress to maintain the best psychological climate for creation and development, we will be able to look for new retirement (and other personnel) policies which effect the desired organisational parameters.

Another use of this estimate of the matrix $\underline{A}$ is to test whether in fact $\underline{A}$ has in fact held for each of the years of the sample. If it has we should be able to find some vector M_o (t_o = 1960) such that when $\underline{A}$ is applied repetitively a close approximation is obtained to the actual data for the following years' distribution, M_1, M_2, . . . Such a finding gives evidence of an implicit or explicit policy which has had a constant impact on the personnel disposition over the years considered. That such constancy could be found in actual environments may seem unlikely; similar constancy has been observed in commercial firms over periods up to 25 years (McWhinney, 1965). Wildavsky (1964), in his book on the budget process in the government, gives a very reasonable explanation of the existence of such observed consistencies.

Further Explorations

When the source data is 'cleaned up' a number of statistical studies will be made of the complex transition data by age and professional speciality as well as of GS level. On a somewhat

gross level analysis is also possible on data classified by the departmental and research or development assignments.

Based on these analyses, projections will be made of the various significant statistics. As is already evident, such projections will undoubtedly indicate distributions which by statute, design of mission and simply common sense will be considered inappropriate. Thus, the organization will have to introduce policies which will maintain the desired distribution. Considerable exploration will be required to locate policies which will provide both the psychologically required opportunities for change and a conscionable retirement scheme - or more succinctly, which will overcome organizational aging.

The final stage of this investigation is expected to involve the integration of the various factors mentioned above (page 9) into a general personnel model out of which policy recommendations can be generated. While such recommendations will have particular reference to facilities similar to the subject laboratory, the properties of constrained size and constrained budget will probably come to plague a great many of our R&D facilities in the near future and therefore the model should have wider applicability.

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