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TECHNOLOGY TRANSFER UNDER VARYING RATES
OF KNOWLEDGE GENERATION

Francis C. Spital and Thomas J. Allen[*]

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Introduction

The purpose of this analysis is to examine the effect of the rate of
change of the knowledge base from which engineers are working on the infor-
mation gathering process they use, with specific attention to the role of
the technological gatekeeper. In the model of Galbraith (1969), a high
rate of change of the knowledge base implies high uncertainty, which in turn
requires a high level of information processing for effective performance.
Is this theory supported here? How is high level of information processing
evidenced? This paper argues that the existence of the technological gate-
keeper, as defined in the past, is a reaction to a highly dynamic knowledge
base and is itself evidence for a high level of information processing.
Research dealing with a stable knowledge base requires a less specialized
information processing system and the technological gatekeeper may be irrele-
vant or at least must be empirically redefined.

DATA ANALYSIS

Previous research has demonstrated that the communication behaviour
of engineers and scientists significantly affects their performance on
technical problem solving, (Allen, 1969). Though we will review the liter-
ature more completely when the results are presented; it will be well to
briefly summarize it here. Allen has shown that higher preforming indivi-
duals communicate more with organizational colleagues, both within their own
functional specialty and in other functional specialties. Allen also found
that sources outside the individual's department were used more often than
sources inside, even though the outside sources tended to produce ideas of
poorer quality than do sources within the department. In support of previous
research, Allen finds a negative relation between personal contact with

sources outside the organization and the quality of the solution of the technical problem. This negative relationship is explained as being due to the average technologist not being able to communicate effectively with the technical world outside his department, i.e., there is a barrier to effective communications at the organizational boundary. Thus arises the importance of the technological gatekeeper. The technological gatekeeper mediates between the research organization and the outside technical environment. Gatekeepers communicate broadly and effectively with the external technical environment, while also maintaining a strong network of communications within the laboratory, thus they gather information from the environment and disseminate it within the organization. The method by which the research group obtains the information it needs for organizational survival is therefore a two step process, mediated by the technological gatekeeper.

Research Setting.

The scientists and engineers in this study work in a U.S. government research facility. The original sample was selected from three departments at the facility on the basis of technical area of expertise. The original objective of the research was to explain the introduction of a formal, computerized, on-line information retrieval system and the effect of this introduction on the informal information gathering techniques of the people in the organization. The sample was therefore chosen to be those people for whom the data bases on the information retrieval system would be useful. The sample contains the chemists, chemical engineers, and sanitary engineers from the three departments chosen. The original sample size was 61 people; 19, 29, and 13 from the respective departments. Upon analysis it was found that in one group our sampling criterion had resulted in our drawing a few engineers from very large groups: their communication pattern showed significantly fewer contacts internal to our sample, and significantly more con-

tacts with other people at the facility but not in our sample. Since this was an artifact attributable to our sampling criterion, this group was excluded from our later analyses to avoid the bias that would otherwise result.

The data were gathered over two time periods of ten weeks each. Comparison between the two time periods will allow us to check for the stability in the gatekeeper role, and other communication patterns. Our sample size in the first period of data-analysis was 48 scientists and engineers, and in the second period was 45; the difference being due to job mobility and retirement.

<u>Measurements</u>.

All measurements were taken in both laboratories, with the exception of individual performance ratings which were available in only one.

The principal variable in this study is communication frequency. This was measured in four domains:

1) communication with other professionals in the sample;

2) communication with others at the same facility, i.e. at the same geographic location, but not in the sample;

3) communication with others working for the same U.S. government agency, but not at the same geographic location;

4) communications with others external to the agency.

Communication with people in these domains was all measured on a single page questionnaire administered on a randomly chosen day once per week for a period of ten weeks for each data period. The questionnaire contained the names of all the people in the sample and required only that a number be written in the appropriate space to report the number of communications with any one person on the particular sampling day. Contacts outside our sample were reported in a similar way, except that the names had to be entered by the respondent.

Other data on the level of education of the respondents, the number of papers presented at professional society conferences, and the number of professional society conferences attended in the last two years were gathered by means of a questionnaire administered prior to the start of the communications data gathering.

Performance measures, which were taken in only one group, were assigned by the subjective rating of the department director. The limitations of such subjective measures are granted, but the tasks of the individuals differed and their output was in different forms and not directly comparable. The director's performance ratings were based upon actual performance, subjectively evaluated, relative to the individual's task and expected output. One of the directors pointed out the inapplicability of single objective performance measures, and doubted the ability to measure R&D performance objectively at all. One of the reasons why Allen (1969) used parallel R&D projects, (i.e. two organizations each attempting to solve the same problem) was the difficulty of objectively evaluating R&D performance. The rate of change of the knowledge bases with which the separate groups were working was also subjectively evaluated by each department director. After examining the data on that given by the directors we saw that one department was in general dealing with a faster rate of change of knowledge base than the other, and upon feeding back this data to the directors we were told that this was accurate.

Statistics.

Analysis of the data was done using non-parametric statistics, because the underlying distributions of the communications data are almost certainly non-normal; in fact, they would be positively skewed. In addition many of our measures are ordinal. The tests used are Mann-Whitney U tests. Corrections

for ties are used where appropriate (Siegel, 1956). Significance levels are
for one tailed tests. The Kolmogorov-Smirnoff test was used in testing
stability of the communication networks over time.

RESULTS

Analysis of the stability of the internal communication networks over
time, presented later in this paper, shows that the networks are stable at
$p < .01$. Since the data from the two time periods gives essentially identical
results in the rest of the analysis the data periods have been combined in
the interests of a clearer exposition of results. There remain instances,
however, where the analysis concerns the periods separately and in these
cases the data is presented for both periods individually.

Responses to the individual questionnaires, are aggregated over the
20 week period to obtain measures of the variables of interest. The mea-
surement of internal communication, i.e. communication with other people
in the sample, was performed in the following manner: questionnaires
from the 20 sampling days (one per week for 20 weeks) were totaled to
determine the number of times each individual communicates with each other
individual. Some frequency of communication is then arbitrarily picked
as being representative of regular contact, in this study a frequency of
twice per week was used, and all communication bonds which meet this cri-
terion are included in the communication network. This measure is adjusted
for individual response rate; thus if a person sent back ten questionnaires
he must report talking to another person four times for that bond to be included
as regular, if he had only sent back five questionnaires an absolute fre-
quency of two reported communications with another person would justify the
bond as regular. Only these regular contacts are included in the analysis.
The modal individual response rate in each time period was ten.

Internal Communication.

Allen, Gerstenfeld and Gerstberger (1968), in agreement with the results of Pelz and Andrews (1966), found that high performing individuals consulted organizational colleagues more than low performing individuals. In the present case, performance was reported by the department chief using a five point scale for each individual. Based on the distribution of performance scores, a rating of four or five is considered "high", while three or less will be taken as "low". Median performance is 3.0. Considering scores at the median as low, results in a situation in which approximately one-third of the respondents are considered high performers, the remainder low performers. Shifting the break-point to include scores of three as "high" would classify more than half of the respondents as high performers. Shifting in the other direction and considering only scores of five as high results in too few high performers for meaningful comparison. The results are shown in Table I.

Table I

Internal Communication by High and Low Performing Individuals

| | median number of communications reported by: | | |
	high performers (n=9)	low performers (n=20)	p
first period	6.0	5.0	0.02
second period*	4.5	4.0	N.S.

*Number of high performers in period two is 8, since one individual was absent. Number of low performers remains the same.

Results are in the direction expected from earlier work, although in the second time period the difference is not statistically significant. Communication, in fact, dropped considerably between time periods, due to some seasonal variation in the work. This may possibly account for the weak results in the second time period.

External Communication.

Several studies (Allen, 1964; 1966; Shilling & Bernard, 1964) have found a significant inverse relation between personal contact with people external to the department and performance. External contact is measured in two domains in this study: contact with other engineers within the agency but not at the facility, and contact with other people not within the agency. The somewhat surprising results are shown in Table II. The results shown are all in the opposite direction and are highly significant statistically.

Table II

External Communication by High and Low Performing Individuals

| | median number of communications per day | | |
	high performers (n=9)	low performers (n=20)	p
Outside the department but within the same government agency			
first period	0.90	0.05	0.01
second period*	0.58	0.06	0.01
Outside the agency			
first period	1.10	0.11	0.01
second period*	1.28	0.11	0.01

*Only 8 high performers in period 2.

It should be noted that the three studies cited above were not done in situations exactly equivalent to this. The department, in the present study is dealing with technologies that are probably not changing as rapidly as those in the earlier studies. Nonetheless, these results were not expected. The conclusion drawn from them is that the engineers in this agency can communicate effectively with the external technical environment, and therefore they can effectively import information into the organization. Given this, the traditional model of the gatekeeper may be irrelevant in this organization since they are not the sole source to the organization of information from the external environment.

Network Stability over Time.

In this study we have communications data gathered at the same organization during two different time periods, separated by six months, and can therefore examine stability of the communications networks over time.

The degree of overlap between the internal communication network measured in period one and that of period two can be tested using methods originally developed by Allen and subsequently described by Ritchie (1974), from which much of this description is drawn. For any individual who reports regular communication with X individuals in one period and Y individuals in the other period (Y<X), the number of overlaps R, assuming that the engineer is equally likely to communicate with any other person in the laboratory, is given by the hypergeometric distribution:

$$\frac{\left(\begin{array}{c} X \\ R \end{array} \right) \left(\begin{array}{c} N-X \\ Y-R \end{array} \right)}{\left(\begin{array}{c} N \\ Y \end{array} \right)}$$

where:

R = number of overlapping choices, 0, 1, 2...Y.

and   N = the number of professionals in the laboratory

This distribution may be used to generate the expected (at random) number of overlaps between the two communication networks. This expected number is then compared with the observed number. It is obvious from Figure 1, that the observed degree of overlap far exceeds chance expectation in both departments. In other words, the networks are highly stable over time, even after a period of almost six months they retain essentially the same configuration.

Gatekeeper.

The concept of the technological gatekeeper was first presented by Allen and Cohen (1969). Allen (1966; 1964), Allen et. al (1968), Pelz and Andrews (1966), and Baker et.al (1967) all found that information needs of R&D members were most satisfactorily met by organizational colleagues. Allen and Cohen found that a few of these colleagues were used most heavily, and labelled them "internal stars"; defined as those people who had more contacts than one standard deviation above the mean for the department. Noting the previous research that had shown an inverse relation between external contact and performance and hypothesising that this was due to the inability of most technologists to communicate with the external environment effectively, they found a few engineers in the department who apparently could bridge the organizational boundary and communicate broadly and effectively with the environment. Individuals who had more than one standard deviation above the mean for the department in external contact were then labelled "external stars". The process of importing information into the organization was therefore seen as a two step process. Technological gatekeepers were defined as those people who were both internal and external stars. The gatekeepers scanned the environment while at the same time keeping in contact with many people in the organization, thus they gathered the information from the technical environment and disseminated it to their colleagues in understandable
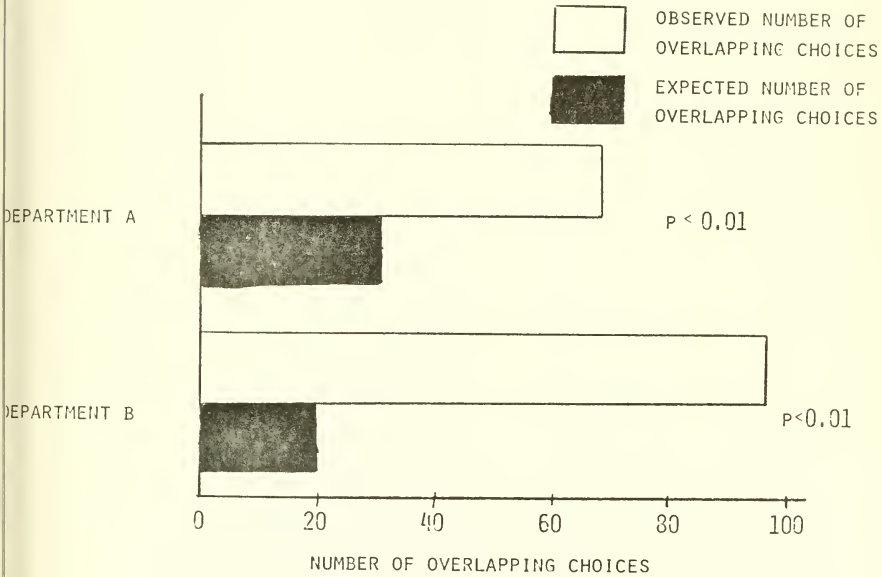
FIGURE 1. OVERLAP BETWEEN TECHNICAL DISCUSSION CHOICES IN
PERIODS ONE AND TWO

form. In the department examined in the present study, however, the engineers apparently have less need of gatekeepers since they can themselves communicate with the external environment.

In fact, however, there are some apparent gatekeepers in this organization. There do exist some individuals who are unusually high in both their internal and external communication activities. These are shown in Figure 2 and 5, which show the communication networks for both departments during the two time periods.

A disturbing fact will be noticed in viewing Figures 2 through 5. The identification of gatekeeper roles is unstable over time. There were six apparent gatekeepers in the first period, and only four in the second. Furthermore, only two individuals were gatekeepers in both periods. In other words while a total of eight individuals met the operational definition of a gatekeeper in one or the other of the two periods, only two of the eight had a sufficient level of communication in both periods.

This is a puzzling situation, because the gatekeeper role has always been seen in other organizations to be a relatively stable phenomenon. Gatekeepers tend to retain this identity over fairly long periods of time. One would certainly expect this to be the case in an organization in which the communication patterns remained so stable over time.

Let us look to the characteristics of these eight individuals to see whether there might be some clue to explain their transitory nature. Gatekeepers have been found to be consistently among the highest performing and most productive workers in their departments. The data in Table III show this to be generally the case for these eight individuals. They received significantly higher evaluations by their management and produced a significantly greater number of publications. So they certainly look like gatekeepers in this respect.
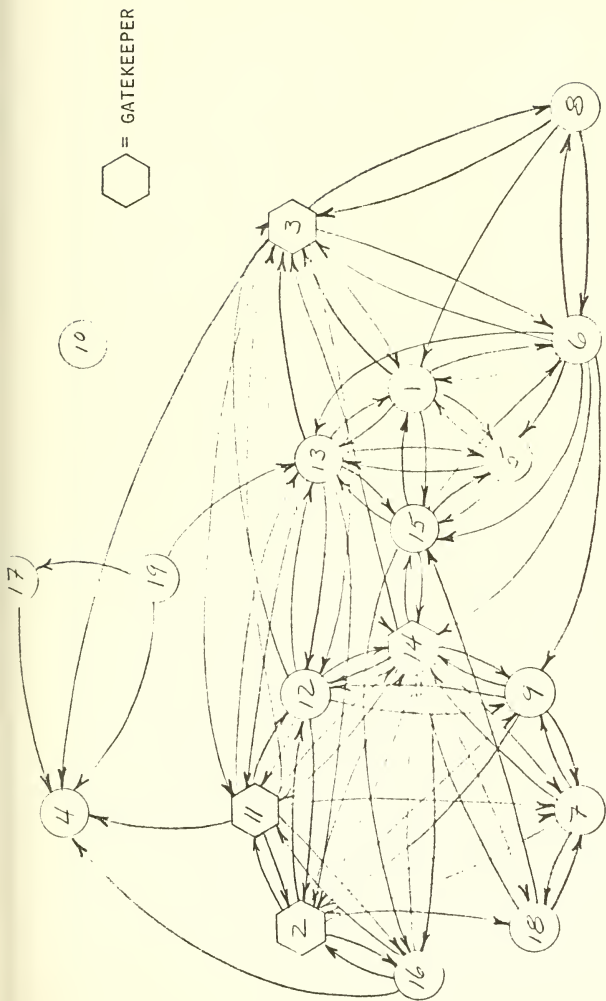
12.

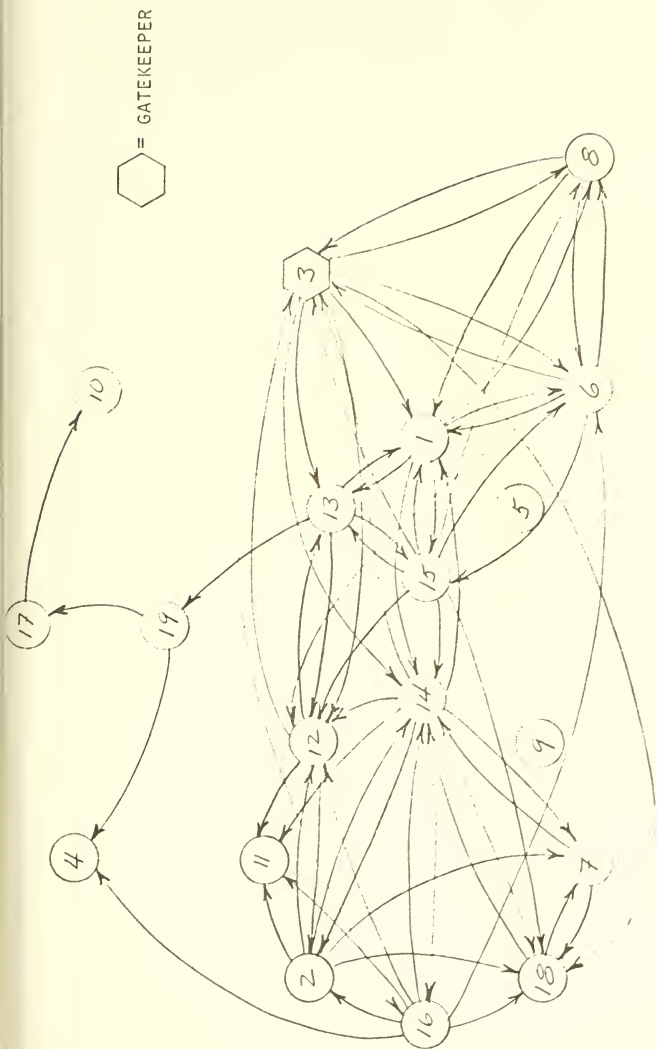FIGURE 2. COMMUNICATION NETWORK FOR DEPARTMENT A, DURING PERIOD 1.

◯ = GATEKEEPER

= GATEKEEPER

FIGURE 3. COMMUNICATION NETWORK FOR DEPARTMENT A, DURING PERIOD 2.

14.

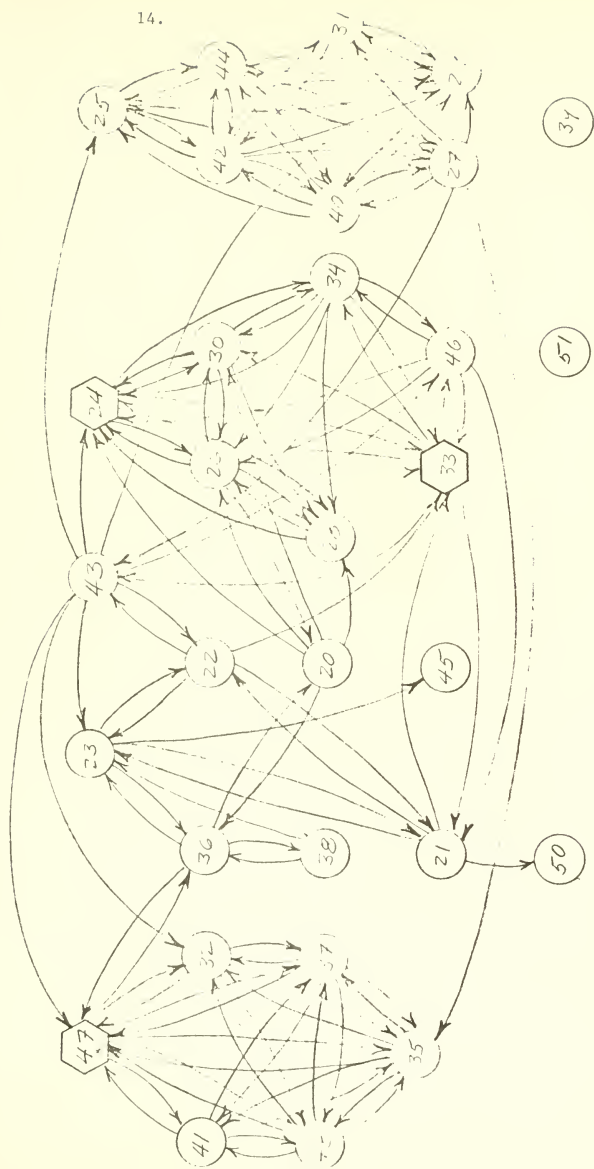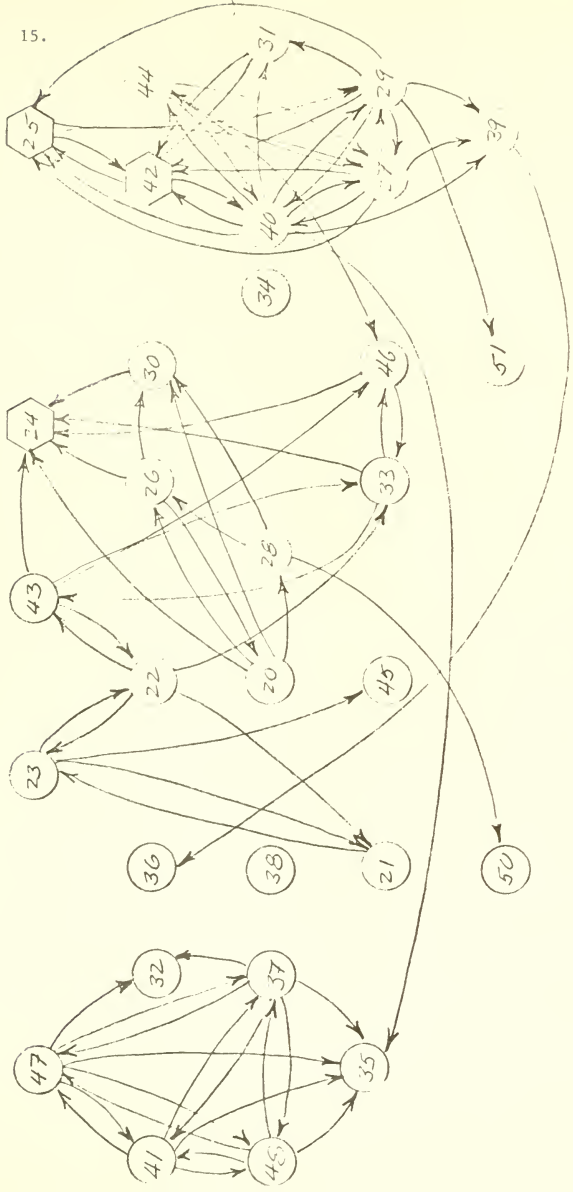FIGURE 4. COMMUNICATION NETWORK FOR DEPARTMENT B, DURING PERIOD 1.

◯ = GATEKEEPER

15.

◯ = GATEKEEPER

FIGURE 5. COMMUNICATION NETWORK FOR DEPARTMENT B, DURING PERIOD 2.

Table III

Performance of Apparent Gatekeepers

| | mean level for: | | |
	apparent gatekeepers	others	p
management evaluation (one department only)*	3.75	3.08	0.05
papers published (per year)	1.51	0.65	0.03
conference papers (per year)	1.10	0.06	0.05

*Management evaluations of performance were available in only one of the two departments. Score is based on a five point scale with the highest score being 5.

The eight apparent gatekeepers attend conferences somewhat more frequently than their colleagues, although the difference falls short of statistical significance.

Table IV

Conference Attendance by Apparent Gatekeeper

	mean level for:		
	apparent gatekeepers	others	p
professional conferences attended in the previous two years	3.38	2.37	0.13

Reasons for Variation in Role. Since there are two components, internal and external, to the gatekeepers definition let us see which of these was primarily responsible for the change in status of the six individuals. Judging from the evidence in Table V, it is contact within the organization that is primarily responsible for the change in role. The apparent gatekeepers maintained their contact outside of the organization during both periods but were evidently consulted more by colleagues in one period than in the other.

Since they were high performers and maintained their contact outside of the organization during both periods, they were potentially available for gatekeeping at both times. The fact that they weren't used in both periods might indicate a situation in which the organization was less

Table V

Reasons for Variation in Gatekeeper Status
Between Periods

change in amount of communication	proportion*
within the organization	83%
outside of the organization	33

* Proportions sum to more than 100 percent because one individual
varied in both internal and external contacts.

dependent on gatekeepers for contact with the outside world. This possibility
is reinforced by the earlier discovery (Table II) of a strong positive cor-
relation between external contact and performance.

Environmental Impact.

One would expect that with an increasing rate of environmental change,
communication outside of the organization should increase. As the environ-
ment becomes more dynamic, increased communication is required to remain
abreast of environmental status. In fact, Tushman (1976) has found in many
cases just the opposite is true. Tushman's counterintuitive results show
that some technical groups actually decrease their mean level of interaction
with the environment when that environment begins to change more rapidly.
This is not true for all technical groups, however. Some increase their
mean level of communication with increasing environmental change. This is

particularly true for technical service groups, which are fairly remote
from the research end of the R&D spectrum. Research groups, on the other
hand decrease their mean level of environmental contact, but develop more
specialized roles (gatekeepers) to perform this function. External communi-
cation is then funnelled through these gatekeepers. In the case of technical
service groups the gatekeeping function is not so essential since the average
individual is capable of keeping abreast of his environment. With reseach
groups, this is more difficult, and so the burden falls on those few who
are capable of keeping abreast and then informing their colleagues.

In the present study, environmental change was measured by asking mana-
gers to indicate, on a special form (Figure 6), their estimate of the rate
of change in the knowledge base of each technical group in the two departments.

On the special form, a performance index for fairly well-known fields
(computers and machine tools) is plotted against time for the period from
1960 to 1970, with the slope representing the rate of change of the technology
$(\frac{dK}{dt})$. Managers were asked to sketch in the line representing the particular
field in question, which generally fell somewhere between the two fields
given as examples. Managers were generally quite comfortable doing this.

In this manner, groups were divided according to the rate of change
of their knowledge base (or environment) and then compared in terms of
external communication (Figure 7).

High performing groups appear more responsive to their environment,
but both increase their communication as the environment changes more
rapidly. This would indicate that the groups are more similar to Tushman's
technical service groups, than research groups, and may explain the ephemeral
nature of the gatekeeping role in this organization.
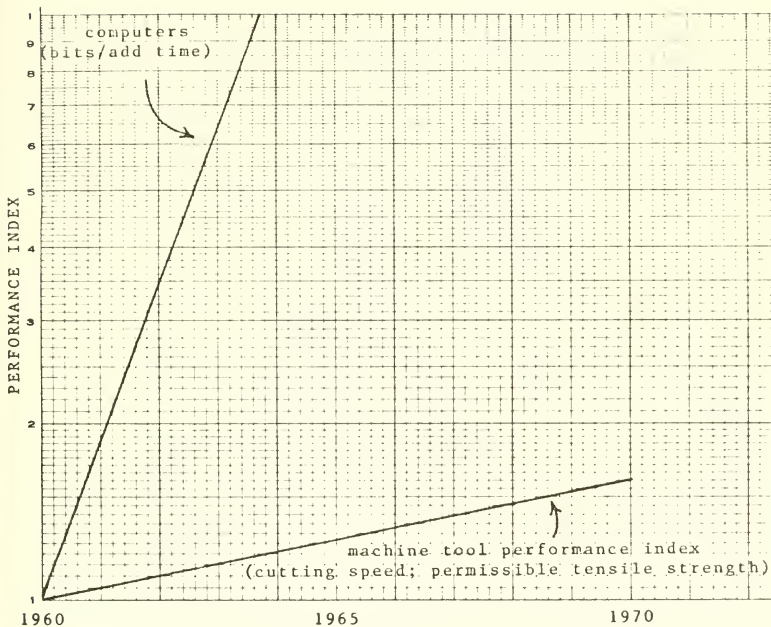
Figure 6

Figure 6. Form Used for Obtaining Estimates of $(\frac{dK}{dt})$. Managers are asked to sketch their field relative to the two shown.
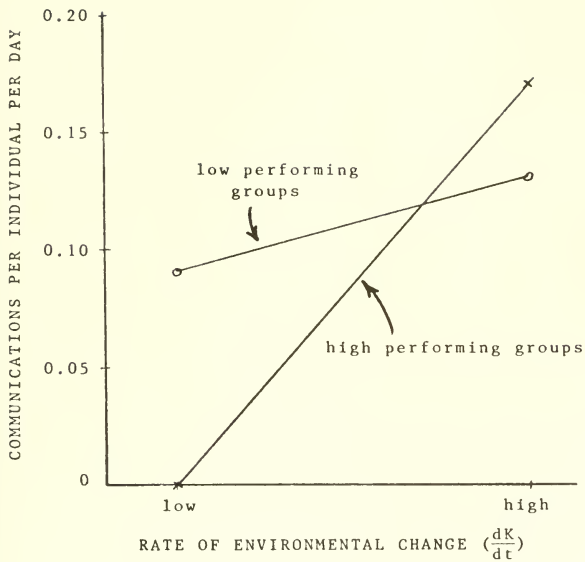
Figure 7

Figure 7. External Communication as a Function of Environmental Change.

Support for this contention is found in comments by the directors of the two departments. One stated that external contacts at his laboratory were often due to outside people seeking information from the department in response reading the Technical Newsletter or another publication of the department. The other director stated that 60% of their work consisted of monitoring outside contracts. These laboratories are not doing purely R&D work, the nature of the task is partly that of a service organization. What effect will this service aspect of the organization have on communication patterns and their relationship to performance?

External contacts will often be initiated by the external correspondent and will be relatively short lived, the communications data support the latter assertion, though it would be expected that this will be less true with respect to the monitoring of outside contracts. In either case the traditional definition of a gatekeeper will confuse the issue since the external communications are not necessarily importing information into the organization, rather vice versa.

This organization should have relatively less need to import information from the external environment since its work deals with relatively stable fields. The average value of $\frac{dK}{dt}$ is 0.84, compared with 2.16 for computers and 0.16 for machine tools.

DISCUSSION

It would certainly appear from the present results that there are factors which strongly condition the need for gatekeepers. Paramount among these is the nature of the technologies underlying the work of the laboratory. As technologies become more dynamic, the gatekeeper rises in importance. But for the laboratory dealing with technical service type work, which itself is making little contribution to advances in the state-of-the-art, there

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