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R&D PROJECT PERFORMANCE AS A FUNCTION OF
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WP 936-77   May 1977

INTRODUCTION

The evidence (Allen, 1964; 1966; 1970; Baker, et. al., 1967; Goldhar, et. al., 1976) that internal communication is strongly related to R & D project performance is, to state it mildly, overwhelming. One study after another lends support to the proposition that the best source of information for an R & D engineer is a colleague within his own organization. Good internal communication, therefore, assumes a paramount importance for the management of an R & D organization.

Other studies (Allen, 1964; 1966; Allen, et. al., 1977; Hagstrom, 1965) have shown the relation between project performance and communication outside of the laboratory to be a function of whether the project involves research, development or technical service activities. In fact, the relation shifts from a positive to a negative one, depending on the nature of the project.

Given these results, it is logical to inquire whether the nature of a project's task might affect the importance of internal communication, as well. It is entirely conceivable that internal communication might be more important for development of technical service projects, than research projects, for example.

The present research is a first attempt to differentiate among the internal communication requirements of projects in research, development, and technical service.

RESEARCH SETTING & METHOD

Organizational Setting

The organization studied was the central R&D laboratory of a medium to large size American corporation in a technology-based industry. Manufacturing and marketing are decentralized in the company, with facilities located in different parts of the country. R&D, however, is centralized and the facility is geographically separated from the rest of the organization. The laboratory's activities cover basic research and development of new products and technologies, as well as the assistance of marketing and manufacturing areas in product development and engineering. All of the company's products are related in that they share a common technological core. The basic technology facing the company may be characterized as being relatively mature and the laboratory has been a leading developer of that technology.

The laboratory consists of seven groups or divisions, one of which is located about five miles from the main facility. Two of the divisions cover more basic research and advance development, and are funded by corporate headquarters, while the other five are funded through the various marketing and manufacturing areas.

Each division is further organized according to project areas, each with a supervisor or head. Each project area focuses on specific problems or technologies Also, the project areas within each division are usually work related in that they face similar market and manufacturing constraints and often work in joint tasks. It should be pointed out that these project areas are not short term project groups in the team/task mission sense, although within any given project area there may be several short-term tasks.

The total R&D laboratory employs about 735 people, about half of whom are in various support roles. This study focuses only on the members of the technical staff and thereby limits the population to about 345 professionals. The seven divisions average about 40 professionals per division, although one of the divisions is much larger than the others (107 professionals). There are 63 project areas in the laboratory distributed throughout the different divisions. The projects average about 5.3 members, with a range of 2 to 15 members. Because of transfers and reorganization, data from two projects were eliminated from the study.

Data Collection

A survey methodology was used to sample all work related communications over a period of fifteen weeks. Data were collected via questionnaires which were distributed on randomly selected days. The sampling days were chosen so that there would be an equal number of each of the different weekdays in the sample. At the end of each sampling day, every professional staff member in the laboratory was asked to recall each work-related communication contact, both within and outside the organization. Each respondent was asked not only to write down the names of those persons with whom he had work discussions, but also to check off the content of the conversation (i.e., problem definition or evaluation, idea generation, information location, and administrative matters). The first three of these categories will be aggregated as technical communication for the purposes of the present paper. As a result of travel, absences, etc., there was an average of 10 returns per respondent. After accounting for absences, the response rate was about 90 percent.

Measurement of the Dependent Variable-Communication

The self-reported (raw) communication data were first aggregated over the 15 weeks. Missing data (e.g., vacation, sickness, out-of-town, non-returns, etc.)

were adjusted by normalizing the reported communications to an average frequency per 10 (sampling) days. Within the laboratory, communications were measured between (ordered) pairs of individuals. In order to facilitate the analysis, aggregate measures of communication were classified according to the affiliations of the discussion partners, i.e., the different internal organizational areas.

More specifically, internal communications were categorized according to progressively larger but mutually exclusive organzational units; i.e,   .

i) Project Communication: Communications with other professional members within one's immediate project.

ii) Intra-Divisional Communications: Communications with other professional members outside of one's project but within the same division.

iii) Inter-Division Communication: Communications with professional members in other divisions (i.e. within the laboratory but outside of one's division).

iv) Communication with Other Parts of the Firm: Communications with people in the organizational operating units (i.e., people who are outside of the laboratory but within the company). Organizational communication is further broken down into:

- marketing communications

- manufacturing communications

- miscellaneous organizational communications (i.e. communications with people in organizational areas other than marketing and manufacturing).

The classification of communication measures by organizational location is shown schematically in Figure 1.

For intra-organizational communication inside the laboratory, the average frequency between pairs of individuals may be represented by communication networks

(i.e. di-graphs). These communication linkages may also be represented in the following matrix forms: i.e.

Let C_{ij} represent the (adjusted) frequency of communication between person i and person j, as reported by person i. (Note that in general C_{ij} does not necessarily equal C_{ji}.)

The <u>Project Communication Matrix</u>, <u>P</u>, representing the communication flows within the project, consists of elements C_{ij}; i,j = 1,....n

where n = number of people in the project

and $C_{ii} \doteq 0$ i = 1,....n

The <u>Division Communication Matrix</u>, <u>D</u>, representing the communication flows inside the division, consists of a partitioned matrix with sub-matrices $\underline{P}_{ij}$, i,j = 1...k

where $\underline{P}_{ii}$ is the project communication matrix for project i

$\underline{P}_{ij}$ is the inter-project communication matrix between project i and project j (for data as reported by people in project i), i,j = 1,....1 i ≠ j

k is the number of projects in the division
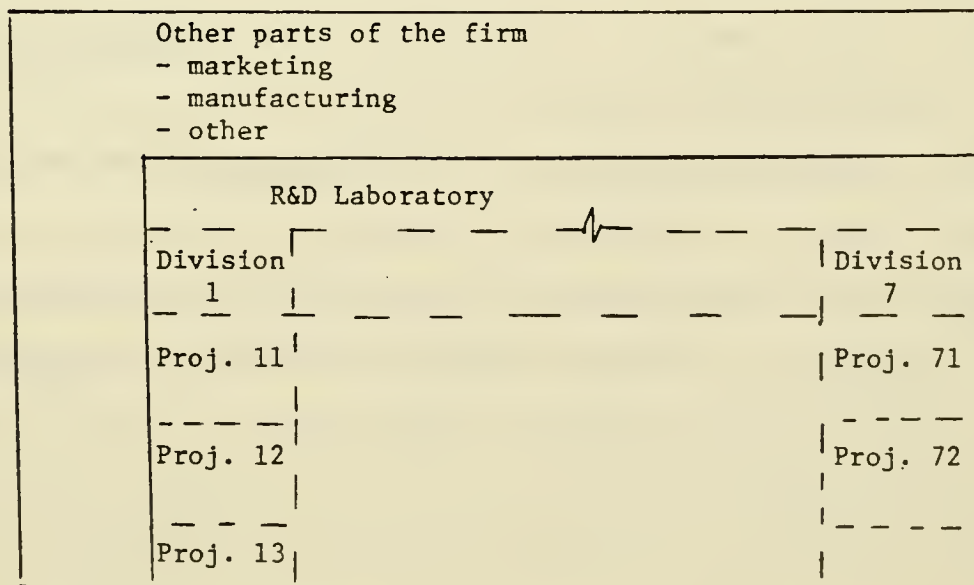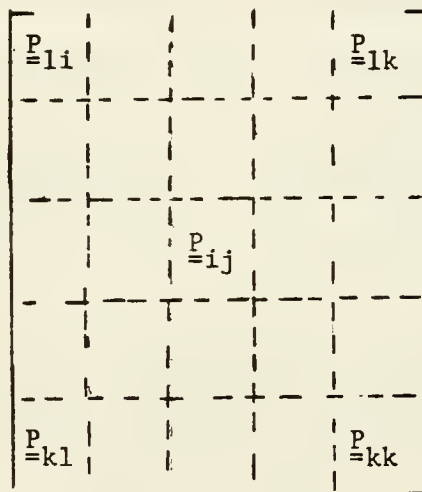

Fig. 1 <u>Schematic View of Organization</u>

Definition.

i)   Project communication: Communication within project

ii)   Laboratory Communication: Communication outside of the project but within lab.
        − Intra-Division Comm: Communication outside of project but within division
        − Inter-Division Comm: Communication outside of division but within div.

iii)   Communication with other parts of the firm: Communication outside of labora-
                                                    tory but within corporation
        − Marketing comm.: Communication to marketing groups
        − Manufacturing comm.: Communication to manufacturing groups
        − Other: Communication to other organizational areas

i.e. $\underline{\underline{D}} =$

$$\underline{\underline{D}} = \begin{bmatrix} \underline{\underline{P}}_{1i} & & & \underline{\underline{P}}_{1k} \\ & & & \\ & & \underline{\underline{P}}_{ij} & \\ & & & \\ \underline{\underline{P}}_{k1} & & & \underline{\underline{P}}_{kk} \end{bmatrix}$$

Similarly, the Laboratory Communication Matrix, $\underline{L}$, representing

the communication flows within the entire laboratory, consists

of submatrices $\underline{\underline{D}}_{ij}$, i, j = 1, ...m

where $\underline{\underline{D}}_{ii}$ represents the division communication matrix for

        division i, i = 1,....m

        $\underline{\underline{D}}_{ij}$ represents the inter-division communication matrix

        (for data as reported by people in division i)

        i, j = 1,...m   i ≠ j

In aggregating individual communication contacts with a particular organizational area, we might consider the row or column data of the corresponding communication matrix. However, it should be noted that these two sets of data contain different biases. The row data represents the communication contacts reported by that (particular) respondent, whereas the column data represents the communication contacts reported by all others with that particular respondent. The row data is thus susceptible to individual biases in data reporting; i.e. the respondent is more likely to report communication that he considers to be more important (since these are the contacts that can be recalled easily), and the data is more sensitive to individual non-returns. The column data, on the other hand, comes from a variety of different respondents. It is thus more susceptible to group biases; e.g. it has been found that people tend to over-report communications with persons of higher status (e.g. Allen and Cohen 1969). In this study, an average of row and column data will be used in measuring communication contacts.

Lastly, communication networks may also be decomposed according to the content of the discussions. Since the major focus in this study is on the flow of technical information, discussions dealing with administrative or organizational matters will be excluded.

Task Type and Task Variability

To measure task type along the spectrum of R&D activities, respondents were asked to rate both the objectives as well as percentage time spent of their work efforts. The categorization of task types was defined as in Table I. Task objectives were measured on a 12 point scale, i.e. 3 degrees of refinement within each task categorization). The lowest point scale (pure basic research) was assigned a value of 10 while the highest point scale (most applied technical service) was assigned a value of 47. Similarly, the task work effort scale was measured by using an average of task characteristics (13 for basic research to 43

TABLE I*

Task Characteristic Categories

I

Basic Research

Work of a general nature intended
to apply to a broad range of appli-
cations or to the development of
new knowledge about an area.

II

Applied Research ·

Work involving basic knowledge
for the solution of a particular
problem. The creation and eval-
uation of new concepts or compo-
nents but not development for
operational use.

III

Development

The combination of existing or
feasible concepts, perhaps with
new knowledge, to provide a
distinctly new product or process.
The application of known facts and
theory to solve a particular problem
through exploratory study, design and
testing of new components or systems.

IV

Technical Services

Cost/performance improvement to
existing products, processes or
systems. Recombination, modifica-
tion and testing of systems using
existing knowledge. Opening new
markets for existing products.

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*From Tushman 1976, p. 66

for technical service) weighted with the percentage time effort spent in each category or activities. The two scales were found to be very highly correlated ($r = 0.91$, $p \leq .001$). Task type was thus measured by simply averaging these two scales. The individual task type scores range from 11.4 to 47.0 with an average of 33.7 ($n = 233$).

Similarly, to measure task variability, the respondents were asked to rate, on a 5 point scale, the rapidity with which the demands of their jobs were changing (i.e. techniques, skills, information needs, etc.). The responses ranged from 1 to 5 with an average of 3.56 ($n = 239$).

Project Characteristics

To measure project work characteristics (i.e. task type and task variability), individual responses were pooled by projects. Bartlett's M test and a one way analysis of variance were used to check the appropriateness of pooling. If the variance within a project was significantly greater than the pooled variance ($p \leq .01$), then the project was not included in the analysis. Based on this method, project characteristics were obtained for 58 projects. The distribution of the task type characteristics fell into three distinguishable categories; i.e. research (14 projects), development (23 projects), and technical service (14 projects). Also, task variability was split along the median into high and low values.

Project Performance

Data on project performance was obtained by interviewing the division managers ($n = 8$) and laboratory directors ($n = 2$). They were asked to evaluate all the projects with which they were technically familiar. Each project was thus independently rated by several managers on a seven point scale. A comparison of the rater means and intercorrelations indicated that one of the respondents biased his evaluations, and his responses were excluded. The scores of the remaining nine judges were then pooled to get project performance Each project was rated by at least two judges with an average of 4.7 judges per project. The mean and median of the performance scores was 4.6, with a range of 3.0 to 6.4.

RESULTS

Performance will be related to internal communication at three levels in the following analysis. First there is communication within the project itself, among those individuals who are directly assigned to the project. Then there is communication between project members and the remaining technical staff of the laboratory. Finally, there is communication between project members and employees of the parent organization outside of the R&D laboratory.

Differences in the Amount of Internal Communication

Intra-Project Communication: There is very little difference in the extent to which an individual project member communicates with fellow project members, in the three task areas (Figure 2). While there is slightly more internal communication for development projects this difference is far from significant statistically. The average project member had roughly 24 communications with other project members during the 15 sampling days or about 1.6 communications per day. The extent to which individuals differ in their intra-project communication does vary significantly, however (Table II). In research and technical service, project members do not differ quite as much in the extent to which they communicate among themselves, as do participants in development projects.

Communication With the Rest of the Laboratory. Again, the three areas do not differ significantly in the extent of project members' communication (Figure 3). There is some apparent tendency for technical service people to communicate more with other laboratory staff. This difference is not significant, but whatever tendency there is, may be due to technical service projects drawing somewhat more heavily on the laboratory staff for technical support. In
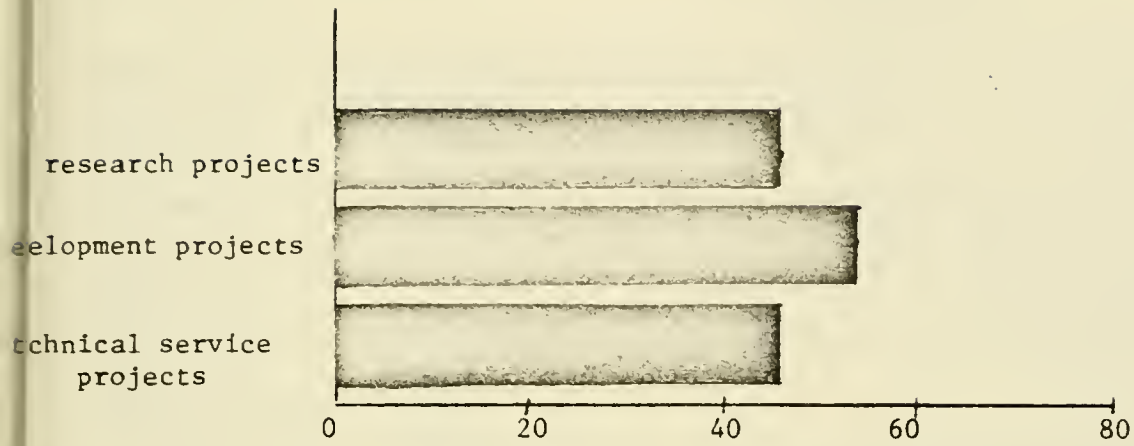
Figure 2. Mean Level of Technical Communication
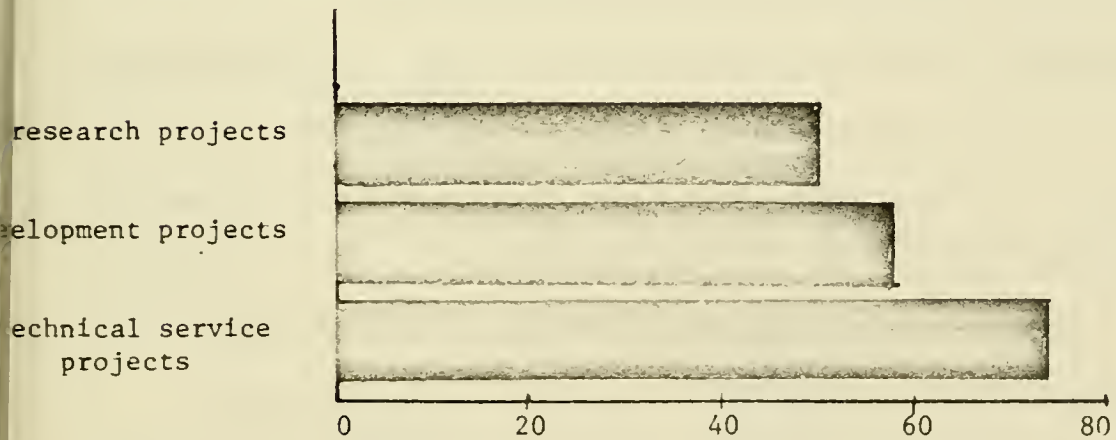· Within the Project

Figure 3. Mean Level of Technical Communication
Within the Laboratory

TABLE II

Variation Across Project Members in Technical Communication
Within the Project

Type of Project	N	Coefficient of Variation $(\frac{\sigma}{u})$
research	13	0.45
development	21	0.58
technical service	15	0.42

F = 3.34, p = 0.04

TABLE III

Variation Across Project Members in Technical Communication
With Other Members of the Laboratory Staff

Type of Project	N	Coefficient of Variation $(\frac{\sigma}{u})$
research	13	0.66
development	21	0.63
technical service	15	0.56

F = 0.51, p = 0.99

In contrast with within project communication, the three areas do not differ much in the way that laboratory communication is distributed among project members (Table III).

Communication With Other Parts of the Organization. Here there are very marked differences in the amount of communication (Figure 4). The average member of a research project communicates about once every three days with someone from parts of the firm outside of the R&D laboratory. On technical service projects, the average is about once a day. Development project members fall about midway between these extremes.

This is not a surprising result. It is to be expected that technical service engineers would have the greatest requirement for communication with other parts of the firm, and research staff the least. What is surprising is that the difference is not greater than observed. For members of research projects to communicate outside of their laboratory an average of once every three days is surprisingly high. It should bode well for the performance of those projects. Whether, in fact, it does contribute to performance will become clear as the analysis progresses.

The variation across project members also differs among the three areas. Now the trend is in the opposite direction (Table IV). Research projects show the greatest variation and technical service projects the least. Apparently, the responsibility for communication with other parts of the firm is assumed by specific personnel on research projects, while project members share the the responsibility more equally in technical service projects.

A major part of the variance in organizational communication by research projects is directly attributable to the fact the project managers of research projects assume more responsibility for organizational communication (Table V). This is not true for communication within the laboratory, where the number of communications per week by the project manager is nearly the same as the number

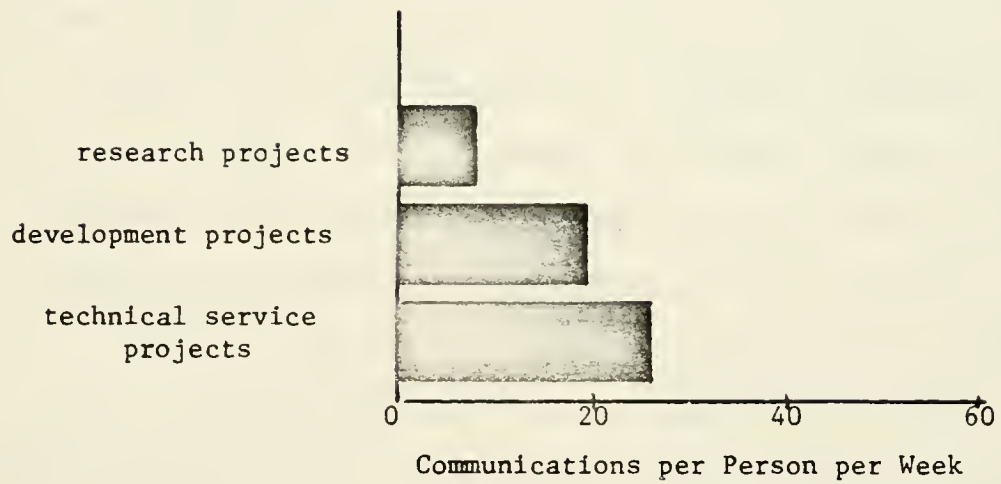Communications per Person per Week

Figure 4. Mean Level of Technical Communication
with Other Parts of the Firm

TABLE IV

Variation Across Project Members in Technical Communication With
Parts of the Organization Outside of the R&D Laboratory

Type of Project	N	Coefficient of Variation $(\frac{\sigma}{u})$
research	13	0.64
development	21	0.65
technical service	15	0.25

F = 4.71, p = 0.01

TABLE V

Comparison of Project Managers and Others in Communication With
Parts of the Organization Outside of the R&D Laboratory

Type of Project	Ratio of Mean Level of Communication by Project by Project Managers to Means for all Project Members
research	1.73
development	1.09
technical service	1.45

reported by the average project member (ration = 1.04). Managers of research
projects may assume the role of protector for their project members and take on
more responsibility for organizational relations to allow their subordinate
more time for research. Whether this is an effective strategy or not remains
to be seen.

Relationship With Performance

Communication Within the Project

In all three cases there is no significant relationship between project per-
formance and the degree to which project members communicate among themselves
(Table VI). All three correlations are quite weak and fail to even approach

TABLE VI

Relation Between Technical Communication Among Project Team Members
and Performance

Type of project	N	r	p
research	14	0.05	N.S.
development	23	0.14	N.S.
technical service	21	0.17	N.S.

statistical significance. Surprising as this may appear, it is not the first time
that research has failed to uncover any relation between internal project communi-
cation and project performance. In a study of matched identical twin projects,

Allen et.al. (1968) found that while members of higher performing project teams communicated more with other members of their laboratory, they did not communicate any more with fellow project members than did members of lower performing teams.

It was observed earlier that research, development and technical service projects differ significantly in the way in which communication is distributed among project members. Development projects showed the widest variance in internal communication. For development projects this turns out to be neither beneficial nor harmful (Table VII). For research projects, however, the greater the variance, the poorer the performance of the project. Apparently, when one or a few project members dominate internal communication project performance suffers. For technical service projects when a single member (usually the project manager) dominates

TABLE VII

Relation Between Performance and the Variation $(\frac{\sigma}{u})$ Across Project
Members' Communication Within the Project

Type of project	N	r	p
research	13	-0.50	0.03
development	21	-0.01	N.S.
technical service	15	0.28	0.11

internal technical communication project performance tends to be higher.

Communication Within the Division

Projects were always a sub-entity within a technical division, which was organized around broad product technology areas. Looking at the importance of

communication between project members and their colleagues within this division, we find it to be important only in the case of development projects (Table VIII).

TABLE VIII

Relation Between Communication with Members of the Technical Division Outside the Project and Performance

type of project	N	r	p
research	14	-0.17	N.S.
development	23	0.31	0.08
technical service	21	0.18	N.S.

Most of the research projects were contained within one of the divisions. The disciplines that they drew upon were varied, each project roughly describing a discipline area. As a result, there was somewhat less communication among projects in a division and no effect on performance. Research projects had to obtain their technical support from outside of the organization (Allen, et.al. 1977). Technical service projects, on the other hand, had a very high level of intra-divisional communication, but again no effect on performance. Technical Service projects were organized in product area, rather than technology, divisions. They therefore would find their technological support diffused through other groups as much as within their own. Only development projects were organized within technological/disciplinary divisions. The development project therefore obtained its technological support from within its own division, to a greater degree than either research or technical service projects.

Turning to the variation across project members in terms of their communication within the division, we find that only in the case of development projects is there anything approaching a significant result (Table IX). Perhaps in the case

TABLE IX

Relation Between Performance and the Variation σ_u Across Project Members
Communication with Division Members Outside the Project

type of project	r	p
research	-0.25	0.19
development	-0.27	0.11
technical service	0.03	0.44

of product and process development engineers it could be argued that no one should specialize in intra-divisional contact, but even here the argument is only very weakly supported. It just doesn't seem to make much difference for performance, whether or not this occurs. Certainly there is no "gatekeeper" effect for projects communicating within their own division.

Communication With Other Divisions

It is surprising to see an inverse relation between performance of research projects and communication with other divisions in the laboratory (Table X).
This may be due to members of technical service projects seeking help from research, and interfering with the conduct of research projects. If this is true, the technical service projects aren't receiving much benefit either, since for them the relation between performance and inter-divisional communication is also inverse, and ever stronger. Only development projects fail to exhibit the inverse

TABLE X

Relation Between Communication with Other Divisions in
the Laboratory and Performance

type of project	N	r	p
research	14	-0.34	0.12
development	23	0.09	N.S.
technical service	21	-0.47	0.02

pattern. For them, it apparently makes no difference. There is no relation
between performance and inter-divisional technical communication.

In surprising contrast with this finding is the discovery that it does
make considerable difference, just how these communications are structured
(Table XI). If there is a person, or subset of people who are primarily respon-
sible for inter-divisional communication, the performance of research projects
and product development projects will be impaired.

TABLE XI

Relation Between Performance and the Variation in Project Members'
Communication σ_u with Other Divisions

type of project	r	p
research	-0.35	0.11
development	-0.46	0.01
technical service	0.08	0.36

Communication With Other Parts of the Firm

As would be expected, development projects are strongly benefited by communication with other parts of the firm (Table XII). It is surprising to see that technical service projects are not similarly helped. One would expect technical service to be strongly connected to marketing, and to produce better performance, the more closely they coordinated their activities with marketing. In fact, that does appear to be modestly true in the present case (Table XVI). It is less important for technical service projects to communicate with manufacturing. In

TABLE XII

Relation Between Communication with Other Parts of the Firm
and Performance

type of project	N	r	p
research	14	-0.11	N.S.
development	23	0.46	0.01
technical service	21	0.06	N.S.

In the case of development projects, it is important to communicate with both marketing and production (Table XIII). This is a result that cannot be over-emphasized. There is a vast abundance (Myers & Marquis, 1969; Achilladelis, et.al., 1971; Meadows & Marquis, 1968; Prakke, 1975) of evidence on this point. Product and process development projects must maintain a strong and constant awareness of market needs. This is much less important for research projects, which show no benefit from interaction with other parts of the firm. It is interesting to note that while it is important for development projects to interact with other parts of the firm.

TABLE XIII

Relation Between Performance and Functional Areas Outside
of the R&D Laboratory

type of project	marketing		production		other	
	r	p	r	p	r	p
research	0.12	N.S.	0.20	N.S.	0.21	N.S.
development	0.44	0.02	0.36	0.05	0.01	N.S.
technical service	0.20	N.S.	0.02	N.S.	0.21	N.S.

Not only is it important for members of development projects to communicate with other functions, but it is necessary for all members of these projects to maintain contact. No individual or subset of individuals should dominate this

TABLE XIV

Relation Between Performance and the Variation $(\frac{\sigma}{u})$ in Project Members' Communication with Other Parts of the Firm

type of project	r	p
research	-0.05	0.43
development	-0.36	0.05
technical service	0.04	0.43

relationship (Table XIV). The greater the variation across project members in contact with other functions, the poorer the performance of the project. This would argue against such specialization in this communication as reported by Rhoades (1977). Controlling for the mean level of communication reduces this negative correlation to a non-significant level, however. The data would no longer argue against a specialized role, but they do not lend support to such specialization, either.

TABLE XV

Comparison of the Relation to Performance Between Mean Level of Communication and the Variation in Communication with Other Parts of the Firm (Development Projects)

correlation between project performance and:	r	v partial	variables partialled out
mean level of communication with other parts of the firm	0.46	0.36	variation in communication
variation across project members in communication with other parts of the firm	-0.36	-0.12	mean level of communication

SUMMARY AND CONCLUSIONS

The single most important conclusion to be drawn from the study is that
not all R & D functions are alike in the way they operate, nor should they be
managed in the same way. This is a significant point for those doing research
in the field, since the tendency has been to merely describe an organization,
as an R & D laboratory, or its personnel as engineers and scientists. In fact,
it makes a great deal of difference just what sort of work the organization
and its staff are pursuing. Many have long realized the differences between
university basic research scientists and engineers in industrial laboratories.
Now it appears that the distinctions that must be made are even more subtle
than that staff performing more research-oriented tasks in an industrial
laboratory will behave very differently and have quite different needs from
staff concerned with product and process development. These in turn, are quite
different from those concerned with product modification and adaptation.

More specifically, the results indicate that our general concern for
stimulating technical communication within the laboratory (Allen, 1970;
Allen & Fusfeld, 1976) may be misplaced in the case of research and technical
service staff. Only the product and process development engineers seem to
really benefit from this form of interaction. Previous studies were primarily
of engineers responsible for product development, and they concluded correctly
that internal communication was strongly related to performance. Generalizing
these results to the entire laboratory was, however, a mistake. We now know
that the nature of the work makes a great deal of difference to the extent
to which such results can be generalized. In a similar manner, we have long
been aware of the importance of good communication between R & D and marketing
(Cf. Prakke, 1975). The present study reinforces and reminds us of the obvious

fact that such contact is really only important for product development staff. The performance of research projects is less affected by the research staff's relations with marketing.

Finally, we have the beginnings of some indications that very different supervisory styles are needed, depending upon the nature of the work. Research projects show the best performances when they are not dominated by any single individual, including the project manager. Technical service projects, on the other hand, perform better when the manager is more controlling and structures internal technical communication to a greater degree.

Much more will, of course, need to be done to investigate all of these areas. The present study is but a beginning and we must be careful in generalizing from it. Nevertheless, it is an interesting beginning and should open fruitful new areas for research.

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