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ABSTRACT

A STUDY WHICH WAS CONCERNED WITH ESTABLISHING DATA AND A CRITERIA BASIS FOR EVALUATING AND DESIGNING RESEARCH AND SCIENCE FACILITIES IS OVERVIEWED WITH SUGGESTIONS FOR FACILITY DESIGN. THE SURVEYING METHOD, ORGANIZATION, AND RESULTS ARE ALL INCLUDED, REVEALING STATISTICAL INFORMATION FOR SCIENCE FACILITY PLANNERS. PROBLEMS AND MISCONCEPTIONS OF TODAY'S FACILITY PLANNING AND DESIGN ARE REVEALED ALSO. A BIBLIOGRAPHY IS INCLUDED. (TG)

DEVELOPING DESIGN CRITERIA FOR RESEARCH FACILITIES
(A Report on a Brief Exploratory Study of
Approaches to Establishing an
Objective, Quantitative Data Base)

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Introduction

It is estimated that more than $750 million are spent annually in the United States for building new or remodeling old research facilities. Though the exact amount of such investment by industry, government, educational and other institutions is unknown, it is substantial and can be expected to continue to grow with the growth of science and technology in our society.

A study of the design characteristics of laboratories erected in the last few decades reveals widely varying judgments on broad principles of planning.[1] Only a few laboratories are reported to have been designed from criteria that incorporated the results of serious study of the current and probable future working needs of the researchers. Even in the comparatively limited area of basic environmental factors--lighting, heating, ventilation and acoustics--the approach frequently taken has been one of piecemeal incorporation of current practice rather than an ordered assembly and application of existing knowledge in relation to the total building design.[2]

An approach to building design that attempts to think outward from the activities of the researcher to his total work place is seldom found. Too often the size, configuration, location and characteristics of the various types of working space provided both the laboratory and non-laboratory researchers are determined by competing demands and subjective judgements based on past experience or practice rather than on the actual space use and needs of the persons for whom the facility is being constructed. Discussions with research managers, facilities construction planners and architects indicate, in fact, that decisions on research facilities design are too frequently made on the basis of "common practice" or on the basis of design criteria developed for industrial plants.

It was within this context that we in the Technology Management Programs group[3] at Stanford Research Institute (SRI) undertook a limited study on research facility design criteria early this year. The specific occasion that provided the opportunity for our study was our management's decision to construct a new building on a new site for the purpose of rehousing an entire existing multidisciplinary research unit known as SRI's Southern California Laboratories (SCL). It was our management's desire to provide this research unit with the amount and kind of space that would most appropriately accommodate its research interests in both laboratory and non-laboratory sciences--based upon the best available information and judgment from past experience plus whatever design criteria could be developed from a brief special study.

At the time of our study, the general size and research structure of the Institute in total and of our Southern California Laboratories in particular were as follows:

1. The total SRI staff was just over 3,000 including 1,603 research professionals and research area and program directors. The Institute was organized into eight major hard and soft science research areas which contained some 200 active research programs. Approximately 1,000 research projects were being performed each year.
2. Our Southern California Laboratories were working in 2 of our 8 research areas and in 15 of our research programs. They had a total staff of over 100, one-half of whom were research professionals. These Laboratories are located in the Los Angeles area some 400 miles south of our principal research facilities in the San Francisco Bay Area.

Study Approach Taken and Examples of Findings

At the inception of the study we had to decide whether we should spread our limited time over the whole range of laboratory and non-laboratory space use problems or concentrate our efforts in selected areas. We chose to concentrate where the least quantitative data were available[4)] and where space use was most man-oriented: the non-laboratory areas of research facilities. Our approach essentially consisted of eleven steps--some taken concurrently:

1. Literature survey.
2. Selection of study sample.
3. Random survey of space use.
4. Physical measurements of workspace.

5. Survey of researcher's manipulation of local environment.
6. Survey of conference room use records and furniture move records.
7. Survey of critical problems (critical incident questionnaire).
8. Data analysis.
9. Discussion of preliminary findings with portion of sample group.
10. Development of design criteria.
11. Discussion of design criteria with facilities construction management and master planner/architect.

This paper will directly cover only the first seven steps, though the thinking and experience gained in the other four will be reflected in various statements made. I will give some examples of our findings as I briefly describe each step.

Literature Survey

We found the literature reporting on objective, quantitative studies of researchers' use of space and the impact of building design on research activities to be very thin. While some very good work has been done, substantial voids exist in the body of knowledge needed to assist rational management decisions on the design of research facilities.

Most of the existing literature is based on the subjective, intuitive judgment of research managers or architects and on certain analytical, a priori viewpoints such as saving of steps, saving of time, and ease of access (i.e., the quantitative data used in plant layout to achieve the efficiencies and the integration of related work units demanded for low cost mass production). Some of these industrial engineering concepts are still definitely useful in certain limited aspects of research facility design. However, our own and other groups' recent research on problems of organizing and managing technical intellectual resources indicates that it is not such things as the saving of motion and the integration of work flow that become critical in research facilities design--but rather, it is the man-centered, project-changing, idea, information, and special equipment oriented nature of research that is vital to facilities design.

There are several areas of thought suggested, though not directly discussed, in the literature that we believe could be usefully applied to research facility design. Examples of these are the work of Hall,[5)]

Hediger,[6] and Horowitz.[7] They all have to do with spatial relationships and boundaries and the apparent meanings man or animals attach to them. This special area of thought and study is now called "proxemics" when it concerns man and "territoriality" when it concerns animals or man.

Dr. Hall's work on the differing spatial needs of different cultures suggests that it ought to be fruitful to look into what could be called the sub-cultures of research: the culture of the chemist surely differs from that of the communication researcher. Our own brief study suggested this, and a research group with whom we work in Heidelberg is currently doing studies related to such a hypothesis.[8]

Selection of Study Sample

The study sample finally selected consisted of 239 researchers from 27 program groups, working in 11 research facilities contained in 5 different types of buildings at our Bay Area headquarters and our Southern California Laboratories. As noted in following comments on various aspects of the study, the maximum number of sample group participants that could be handled in any of the study steps was 220.

The approach used in sample selection was not a totally random one due to time constraints. The study results indicate to us, however, that the sample selected was well balanced; we probably could not have greatly increased the utility of our data by use of a completely random approach--and we would undoubtedly have had to greatly increase the time necessary to handle the study due to the substantial distances between and within the buildings containing the program groups selected for study.

Random Survey of Space Use

The random survey of space use is really a form of time and motion study, sometimes called work sampling or ratio-delay study here in the United States and the "pop-round" technique in England. Whatever the title, it can be a very productive tool. We developed a random observation approach and an observer checklist tailored to our particular interests with observation points and items to be observed emphasizing non-laboratory space use.

The observer team made 6,815 random observations of the space use practices of 220 SRI researchers within the base sample group over a 2-week period. An effort was made to record 16 items regarding each researcher's use of space at the moment of observation.

We found for example that:

1. The data did not support the long-held beliefs of many researchers and research managers that the manner of operations and space use of our Economics group at the Southern California Laboratories were substantially different from those of their counterparts 400 miles away in our headquarters. Contrary to these beliefs, for instance, the extent of office use (i.e., percent of time in and out of office) of the two Economics groups were within 3% of one another--each being in their research offices just over one-half of the time.

   On the use made of the office for reading, the use time was identical--27%.

   On the use made of the office for communication (verbally) we found that for

   - Talking on telephone, the use time was identical--9%.
   - Talking face-to-face, the use time varied by only 2%--each being about 25%.

   On the use made of the office for writing, the use time again varied by only 2%--each being just under 40%.

2. In keeping with the long held beliefs that differences existed in the two widely separated group's manner of operations and space use we did find some very minor dissimilarities. One group made more use of their desks while in their offices, the other group made more use of tables. Also, the use made of such things as office machines and blackboards differed. In short, dissimilarities in space use existed, but they were not significant.

Our findings concerning the non-laboratory space uses of laboratory researchers turned out quite differently. The Southern California Laboratories Science group had less similarity of space usage with their headquarter's counterparts. Further, for the various portions of space use, the patterns would shift, sometimes being closest to the Life Sciences group, sometimes to the Industrial Chemistry group, and sometimes to the Physics group in the headquarters side of the sample. The reasons for these variations are not totally apparent to us.

Some other findings also emerged that might be interesting to you. For instance, when in their office, most lab-using researchers use the office one-fourth or more of the time as a place for communicating verbally. When not talking, these researchers use office space more for writing than for reading. Typewriters, dictating machines, and stenos are seldom used. Calculating machines and space for them are either quite important or seldom needed--this being apparently related to both research needs and researcher work habits.

Physical Measurements of Research Office Space Usage

After first establishing a number of necessary guidelines, measurements were taken of the horizontal and vertical use of space in 178 research offices. Various rooms were also photographed to quickly record special characteristics. Measurements of space use included:

- Gross usable floor and wall space.
- Space occupied by furnishings and equipment.
- Free floor and wall space.
- Total available in-office storage space.
- Total surface working space available.
- Total surface working space in use.
- Miscellaneous measurements and notations, such as offices' location in relation to laboratory or supporting services, and type and quantity of utility services supplied to the offices.

From our physical measurements, we found, for example, that 92% of the sample had at least 9 linear feet of bookshelves; 65% had 18 linear feet or more; and 31% had between 36 and 109 linear feet. Whatever the available bookshelf space, over two-thirds had shelves 90% occupied. In addition to the reaction that the printed word frequently expands to occupy the space available, such figures suggest that research offices should be designed with some quantity of built-in bookshelves as a standard item.

We also found from our physical measurements and from the literature that each researcher's office should probably have approximately 25 sq. ft. of free floor space for the researcher himself plus identical allowances for each additional person expected to confer with or work with the researcher long enough to require a chair. In comparing this estimate to actual conditions we found that:

1. 30% of the offices had less than 25 sq. ft. of free floor space (i.e., by our estimate inadequate space for the occupant and none for visitors).
2. 40% had sufficient free floor space for only one visitor.
3. 22% could accomodate only two visitors.

These findings, however, do not warrant the conclusion that bigger offices per se are needed or desired. Our data convinced us that while a researcher's work output is affected (although we do not know how much) by the availability and use of space and of working surfaces in his office, it is also substantially affected by such factors as the size, location, numbers, and characteristics of conference rooms, work layout rooms and special storage rooms. The majority of researchers are much more concerned about these factors than they are about the size of their personal office.

Investigation of Local Environmental Manipulation by Individual Researchers

Attempts to personalize local environment were observed in 178 of the same offices included in the previous study step. These observations covered such items as thermostat settings, window adjustments, special heating or cooling apparatuses, and wall, table and floor decorations.

An example of our findings is that while thermostat settings revealed an average difference of only 4 degrees between offices, in 25% of the cases, settings in adjacent rooms on the same side of the building varied from 6 to 14 degrees.

Survey of Conference Room Use and Furniture Move Records

During our study we collected available records on the daily use, during the preceding 12 months, of 15 conference rooms. We also gathered and tabulated records for a 12-month period on those furniture and equipment moves between research offices which were large enough to require central services or outside contractor support.

While these records were incomplete, as could be expected, it appeared that conference rooms were used most frequently during certain hours of the day. This suggests the possibility of more dual use design of conference rooms.

With regard to the furniture and equipment moves, we were able to establish that, during the preceding 12-month period, there were a minimum of 859 such moves requiring a minimum of 4,469 hours of maintenance personnel labor. The records on the type of furniture and equipment moved suggest that there is a good probability that some, and perhaps a substantial amount, of this handling of research office items could be dispensed with through better facility design.

Survey of Critical Incidents (identification of critical problems directly related to current SRI facilities designs)

The lack of hard information about what people needed and the wide variations in judgments on space planning principles led us to believe that the best way to get at the individual researcher's needs was to use a critical incident technique which would show where they were hurting, not just what they would like to have. We felt that a critical incident survey would result in a harder set of data because it would give us more than just a "wish list."

The questionnaire survey we developed was aimed at determining: whether there was substantial agreement among SRI researchers regarding the existence or non-existence of critical problems; if there were critical problems, what was the primary nature of the problems; what were some of the characteristics of researchers who agreed that critical problems existed; and, what specific examples could be obtained on building designs that the researchers considered to be detrimental to the effectiveness or efficiency of their work?

The questionnaire we developed probed for the existence or absence of critical problems in relation to the researcher's use of facilities during periods of acquiring research projects, performing research, report writing, and handling administrative detail. We covered the same 220 researchers previously sampled and received 209 responses.

From this survey we found, among other things, that

- The information obtained was surprisingly closely related to the other data gathered.
- 73% of respondents felt critical problems existed; this group backed their viewpoint with a total of some 600 specific examples.
- The specific examples of problems related to space utilization could be placed into the following 6 basic categories, the first 4 of which were given most frequent mention:

    1. Communications (formal and informal)--one-third of the examples given us identified building-related communications problems to have been severe enough to hurt their work.
    2. Storage and retrieval--of both data and equipment.
    3. Equipment--design, location and availability were all identified as critical problems.
    4. Work layout space--additional vertical and horizontal work layout space needed both in offices and in special rooms.
    5. Disassociation--the need to withdraw into uninterruptable work privacy on occasion.
    6. Environment--particularly as it relates to physical comfort, mental stimulation and buildings that encourage their own use.

The background information we requested from each respondent permitted us to analyze the "No Critical Problems" and the "Some Critical Problems" groups from the following standpoints:

1. Length of time in SRI (by total count and by research area).
2. Previous jobs held (by total count and by research area).
3. Age (by total count and by research area).
4. Major or specialty (by total count and by research area).

Among many other important items, this data told us that:

- Of the 47% of the respondents who had been in SRI from one to three years, 70% identified one or more critical problems.
- Of the 21% of the respondents who had been in SRI 10 years or more, 86% identified one or more critical problems.
- A minimum of 70% of the respondents from all age groups between 25 and 50 identified one or more critical problems; and for the 36 to 40 year age group it ran nearly 80%.
- Those who had entered SRI from self employment or from partnership in a firm were least concerned with critical problems (only 50%) and those who had entered SRI directly from student status in a university were most concerned (85%).

- Of the 23 different education majors or research specialty categories contained in the sample group, the four largest categories by rank order were: Chemists or Chemical Engineers; Business Administration; Economics; and Physics. Of these, the least concerned with critical problems were those in Physics (67%); while those most concerned with critical problems were the Chemists or Chemical Engineers (79%).

Concluding Remarks

Although the objective of our study was to develop quantitative data and certain design criteria that would be helpful to our management's decisions on a new SRI research facility, the data we gathered have suggested a number of things to us that we feel may be of more general interest.

1. First, as is common to all researchers, our limited effort suggested a number of questions we would like to have been able to include in our study. We are convinced, in fact, that some of those questions we were not able to include are vital to improvement of research facility design. An example of such questions would be: What are the communication patterns (who talks to whom) and what are the work relationship patterns (who works with whom) between the various disciplines and research specialties?
2. The many facilities problems that our study identified in a portion of SRI's total facilities are not unique to that portion--nor are they unique to SRI. Regardless of the vast sums spent on research facility construction over the last two decades, little about the design of research facilities from the standpoint of the researchers themselves is yet known with assurance by any organization.
3. The actual use of space within multidisciplinary research facilities is usually different from what it is believed to be by either the research staff or the managers of the research organization.
4. Objective, quantitative data is obtainable on the ways in which researchers use space and the importance to a researcher's work of certain types, configurations, and locations of space; and, when such data is obtained, patterns can be identified.
5. While each research organization will probably have some space usage characteristics that are unique there are apparently intra-disciplinary/intra-specialty consistencies in space usage as well as inter-disciplinary/inter-specialty differences.
6. Design criteria, based upon patterns of space usage by researchers, can be developed that would considerably improve current practices.

Even though the study was a limited one, we see a number of implications to our own and perhaps other organizations.

1. It seems to us that research buildings should be designed to encourage both informal and formal communications; building configuration and the location of primary and secondary rooms should encourage happenstance meetings of staff members as well as to provide many convenient spaces for planned meetings of small groups i.e., 3 to 7 people.

2. We think there is a need to design new pull-down and pull-out space in offices and small conference/work rooms; to find new ways to obtain multiple use of surfaces--both horizontal and vertical; and to provide walls which permit many types of usage consciously without concern for marring appearances or requiring repair; and to consciously use whatever goes on the walls for additional acoustical control.

3. We see in the data ideas for new approaches to the individual researcher's storage and retrieval problem. Most of what one hears on the subject of storage emphasizes closed storage. We think that there is a new need for open, visual storage. It also appears that special rooms could be designed to attract as much as possible of the researcher's files out of his own office--such rooms providing something like a set of personal lockers, floor to ceiling, with appropriate access but with the addition of attachments or shelving on which to lay material for examination, sorting and the like; and with such rooms additionally equipped with copying machines, collating tables and general supplies. The same rooms might also be used for equipment storage or coffee rooms, in short, whatever it is found will attract the researcher to use them as a personal file storage room. In no circumstance, however, should such rooms be thought of by the researcher as distant "attic storage;" any approach that gives that impression will certainly fail.

4. Thought on how to temporarily and efficiently "turn off" offices would also be profitable. Though previously mentioned only briefly in regard to the researcher's desire for disassociation, on occasion the need for privacy is as great as the need to communicate--and there are times when the best work requires uninterrupted privacy. Currently most researchers have no way of achieving this: the phone, the door, and the walls are all channels of interruption.

5. There is a need for a feedback mechanism in which facilities, or even man-machine systems are studied at some point after they go into service to determine how people actually modify and adjust to make them operate. It is only through such studies of how people use buildings and use equipment that we will be able to develop design criteria that reflect the key component in all research facilities, the researcher himself.

NOTES

1. The Nuffield Foundation, The Design of Research Laboratories, Division for Architectural Studies. London, England: Oxford University Press, 1961. 211 pp.

2. Manning, Peter, ed., Office Design: A Study of Environment, Pilkington Research Unit, Dept. of Building Science, University of Liverpool. Liverpool, England: Rockliff Brothers, Limited, May 1965. 160 pp.

3. The Technology Management Programs group at SRI is concerned with the development of a body of knowledge relevant to the management of technological change. The following titles of several reports recently published by the group indicate the nature of its research interests and some of its exposure to research facility problems:

"Work Activities and Attitudes of Scientists and Research Managers: A National Survey"

"Application of the Behavioral Sciences to Research Management"

"Adaptations of Scientists in Five Organizations: A Comparative Analysis"

"Study of the Mobility of Scientists and Engineers between Scientific and Technical Specialties and the Factors Affecting the Type of Mobility"

"The Role of the University in the Formation, Growth, and Effectiveness of the Local Defense R&D Industry"

"The Development of a Potential Defense R&D Complex--A Study of Minneapolis-St. Paul"

"The Structure and Dynamics of the R&D Industry: The Los Angeles and Boston Complexes"

"The Structure and Dynamics of the Research and Exploratory Development Sector of the Defense R&D Industry"

"An Exploratory Study of the Structure and Dynamics of the R&D Industry in the United States"

"Comparison of R&D Practices in Other Countries and the United States"

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6. Hediger, Heini, Study of the Psychology and Behaviour of Captive Animals in Zoos and Circuses. New York: Criterion Books, 1955.

7. Horowitz, Mardi J., M.D., "Human Spatial Behavior," American Journal of Psychotherapy, XIX, 1 (January 1965), 20-8. Study was aided by Office of Naval Research contract to University of California School of Medicine.

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8. Krauch, Helmut, Studiengruppe Für Systemforschung, Heidelberg, Germany.