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Guy Black

Senior Staff Scientist
Program of Policy Studies in Science and Technology
and
Professor of Business Economics
School of Government and Business Administration
The George Washington University
Washington, D. C.

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ABSTRACT

This paper examines R&D management as it might be performed under an output-oriented approach in which the company's needs for innovations in various product and production areas were identified, information collected on various ways of satisfying these needs, including R&D. A company's R&D program would be the aggregate of its needs in various areas of its business. The spirit behind the approach is that of applying the PPB (planning, programming and budgeting) approach to R&D. The paper summarizes the state of theory on R&D decision making in economics.

Approaches to Research and Development Management

The purpose of this paper is to review some implications of certain trends in industrial research and development management policies. The focal point is the long-standing conflict between self direction by scientific or engineering professionals in the corporate setting, and the effects on it of the escalating tendency for non R&D management to bring all operations, including R&D, under control. The history of industrial research and development has been partly one of reconciliation of the traditions of scholarship and professionalism with the management practices of industry.

With the passage of time, management control practices have generally become more regularized and complete. The desire to include R&D within the general system of control is long-standing, as Anthony's description of 1952 indicated,[1] but current discussions over the manner in which corporate control over R&D operations should be exercised is on a quite different footing than it was a generation ago.

Among widely espoused philosophies of management are those tagged by the phrase "management by objectives." This paper seeks to consider the implications of extending such philosophies to R&D as an instrument of general management. The R&D man's long-standing argument is that close control is

actually destructive of R&D effectiveness, and the nature of R&D has enabled him to put his argument on a unique footing. The objectives in the minds of advocates of "management by objectives" are not those of R&D itself but of the business organization as a whole, and there is inherent in their thinking that R&D would be treated as one tool that might then be examined in the light of the total business's objectives. It is notorious that distinct functional groups in larger organizations have objectives of their own, apart from those of the organization as a whole. The dual role of the scientific and engineering professional as a member of a profession and of an organization have made both the business and scholarly community aware of peculiarly acute problems of reconciliation. One consequence of management by objectives is that the objectives of functional groups become even more vigorously subordinated to the objectives of top management. While in general, this may contribute to organizational effectiveness, it may not do so uniformly or for such functions as R&D.

Perhaps the most explicit and publicized, though not the first, system of management by objectives has been the programming, planning and budgeting system (PPB) which first became popular in the Federal government, spreading later to state and local government and then to industry. The essential idea is structuring the entire spectrum of activities according to output categories, and analyzing, managing and budgeting all efforts directed toward any specific goal as an entity. In the Federal government where half a dozen departments and agencies might have overlapping responsibilities, this approach was conceived initially as a remedy for the consequences of fragmented responsibility. It was proposed that bringing together activities related by objective as was largely done in the creation of a new Department of Transportation,

would create a high-level management better able to perceive needed balances, as between types of transportation, and modes of satisfying transportation needs. Applied in the context of industry, PPB might be called output, or needs-orientation.

Needs orientation does not, in the first instance, refer to needs for R&D, finance, production, marketing; these are functions, all of which are elements in meeting any number of differing needs, such as may revolve around a customer type, a product category or a market group.

With a needs-oriented approach, the purpose of each functional group in the company, including R&D, is to play the role that emerges from an integrated, system-approach type of analysis which seeks to identify the most efficient way in which various needs can be met. A company would identify a spectrum of needs--not, of course, unrelated to each other--and each would be served by a program implemented jointly by a number of functional groups; thus, each functional group would participate in several different programs, and would construct for itself an efficient overall program composed of its efforts in all combined. None of the requisite program development could be implemented without taking account of complex interactions among the activities of a functional group and between functional groups. Further, needs themselves would be met less than completely as pushing too hard to satisfy one would--beyond a certain point--mean giving up too much of another. Rationality in a needs-oriented approach means in the first instance identifying alternatives to needs satisfaction, and then objectively evaluating and selecting the best alternatives, given the context of the organization as a whole. Trade-offs between various types of needs satisfaction would be identified by scrutinizing the implications within various functional elements of the company and summing up the totals.

Were this approach to be followed, the implications for R&D would be an R&D program whose content and composition were derived ultimately from company needs as these had been determined and analysed by management-wide analysis of the means by which they could best be met. Thus, when a needs oriented approach is substituted for the better known approach in which R&D proposes a program which is reviewed and approved by top management, there are substantial new constraints on the ability of R&D management to articulate its own R&D program.

The common approach by R&D organization and management can be called R&D oriented, although the term is somewhat of an overstatement. It tends to put emphasis on a high quality, viable R&D community in the corporate setting, with skills distributed among relevant disciplines, by intellectual level, and by experience level. Maintenance of an efficient and relevant scientific community, with considerable autonomy and independence, and exercising considerable initiative in laying out its own program of work is a paramount consideration in the R&D programs proposed by such organizations. The ground rules under which such organizations operate embody what has become the classic reconciliation of the conflicting needs of scientific professionalism with the needs of the supporting company. It would appear that to some extent this reconciliation is threatened by new emphasis on needs orientation.

The heart of the R&D program under the classic approach consists of projects with rather specific schedules, end points and budgets, and generally specific results sought. R&D programs are put together by R&D management with the assistance of other R&D personnel and with general guidance from company management as to the scale of the program, but very little as to its actual content. A balance is sought along the spectrum of basic research,

applied research and development, and a balance among efforts on product improvement, new products, manufacturing and other processes (e.g., packaging and distribution), and materials. There may be some advance indication from management as to the directions in which it wishes to go, and in which R&D support would be appropriate. Typically R&D management makes a presentation of an R&D program of its own creation to top management as part of the annual budgeting cycle.

This, then, is the R&D oriented program approach, and it will be recognized as the most common R&D practice among American companies with significant R&D programs. The focus of top management review is on whether R&D management has put together a well-conceived and balanced package which takes adequate account of the broad range of company needs for technological innovation, as well as it can be understood by non technical management. If it has, from the standpoint of top company management, R&D management has performed well. If it is necessary to trim budgets, R&D management is expected in the first instance to determine where within the R&D program any budget cutting allocated to R&D will fall. If the proposed R&D program is poorly received by top management and is cut punitively, R&D management is likely to make an initial proposal of how cuts should be distributed among elements of the R&D program.

The procedure has, indeed, some powerful advantages, among which are that it allows R&D management to organize and maintain a high-quality R&D organization, with high-calibre personnel who have developed areas of expertise in depth upon which they can draw as particular circumstances require. Stability, personal growth and institutionalization of R&D are accompaniments of the process. It is perhaps the operating mode in which R&D in industry most resembles academic R&D and lends itself to the college-

like R&D park sometimes supported by large companies. It is a means for minimizing the strains and conflicts confronting the scientist in industry as described by Kornhauser.[2] There is ample evidence that the competence and quality of the R&D organization are, for the R&D group, ends in themselves, though certainly not exclusive ones. Closely related are the goals of making contributions to general scientific knowledge, and it would be wrong to ignore the strong desire of R&D personnel to contribute to their companies as well.

With a needs oriented approach is meant a situation in which the initiative for R&D effort has been shifted significantly out of the hands of R&D management. Marketing, production, etc. may undertake analyses of corporate problems perceived from their point of view, and define those changes which they feel will resolve them. For example, a competing manufacturer may have added a feature to his product and the task levied on "R&D" may be to duplicate it in the company's products. Needs oriented approaches need not consist entirely of such fire-drill requests. Following is one possible long range needs oriented approach to R&D program definition.

Company management may have concluded that over the years its competitors as well as itself will produce new models of certain products with superior features, style changes, using new materials and production techniques. The company's market share as a function of time will depend on the characteristics of its products, its prices, its marketing and merchandising generally. The planning problem is to sequence a mix of activities that will enhance or maintain the company's position--and profitably. Advertising, merchandising, pricing, and product improvement through R&D are among the mix of techniques for achieving a target market share--perceiving these alternatives as continuing

efforts. Market potential, competition, production costs, as they are at present and as they may be in the future can be analyzed. Given profitability as an objective, company strategy is developed from information on these points. In short, through long-range planning a requirement for a continuing flow of technical results can be identified. This, then, becomes the basis for creation of a stable and technologically growing R&D organization.

The crucial point with such approach is that the underlying question being asked is, what mix of activities will best achieve company goals in the area in question. An element of an R&D program comes into being only when it has withstood the comparison with seeking new outlets, advertising, cost cutting, price changes, and the like.

On the other hand, when an R&D program is initiated by the R&D organization the starting question is quite different: what are the best things which the R&D program can do for the company. It seems intuitively clear that the technical content of R&D programs created under these differing approaches will be somewhat different--as will be the manner in which the R&D program is presented for top management approval--although certainly there would be many common elements.

Further, the identification of needs for new or improved products does not automatically translate into a program for its R&D laboratory. The company that truly explores all alternatives will seek out <u>all</u> means by which it might meet new product needs. Among them may well be acquisition of other companies, licensing products developed by others, contracting with outside R&D organizations. A needs oriented company is one that has no predisposition to favor one route over the other except as cost, results, and other considerations indicates one approach to be superior to the others. No such open

minded exploration of alternatives is likely where an R&D program initiates with an R&D organization. It is likely to see its program proposal as its bid for support for the coming year, and to assiduously ignore alternative approaches to technological innovation, not to mention such alternatives to R&D as advertising, and so on.

Implications for Special Tasks for R&D in the Needs Oriented Company

In a needs-oriented company, the requirements laid on its R&D group are for those things for which performance by an internal company R&D group has been identified as the best source.

Needs orientation is indeed likely to have some impact on the internal structure of an R&D group. First, the impact on the initiative of the R&D personnel in project selection has been noted. Under needs orientation, non R&D functional groups will be much more deeply involved in specific R&D project review, and their function will be evaluative of approaches developed by all possible efforts contributory to needs satisfaction of which company R&D will be one. Second, there will be a need for substantially more interaction between R&D personnel and the rest of the company in development of project proposals. R&D should, in the process, get a much clearer idea of what the company really needs, and it should, with adequate feedback, learn to make explicitly responsive proposals for R&D reflecting an understanding of company needs. These proposals would be reviewed by the management in competition with non R&D alternatives. R&D would tend to have a great advantage over non-internal R&D sources from a superior information flow. There is no reason why such alternatives as licensing and acquisitions should be given preferential treatment, though they should be guaranteed their full due by having advocates who are not over-committed to the R&D organization.

There are some interesting management problems with R&D in such a role. Preparing proposals takes resources. It is inherent in an internalized competitive process that R&D should not expect to win all competitions. On the other hand, if not enough proposals were prepared, general management would fail to obtain information on the full spectrum of opportunities. Clearly it will be in the company interest, as well as of the R&D group, that R&D take the initiative of volunteering unrequested proposals as well as responding to requests. Perhaps some target ratio of proposal acceptance is appropriate, the exact number depending on how elaborate the proposals are, and the fallout benefits (which may be considerable) from unsuccessful proposal efforts. From the R&D standpoint, proposal preparation is an expensive marketing proposition--ostensibly part of overhead--and accounting procedures might lead R&D to adopt a policy toward internal proposal effort which was too conservative. One remedy would be to share costs with other functions.

Thus, the work of the R&D group, under a needs oriented approach includes not only the explicit carrying out of approved R&D projects with specific goals, but considerable speculative exploration supportive of determining what <u>might</u> be carried out. Laboratory work as well as proposal writing might both be undertaken. Thus, the work of the R&D organization would fall into two categories: the identification and conceptualization of projects, and the implementation of approved projects. This dichotomy exists today, but it would likely become much more explicit in a needs oriented approach and the "proposal effort" more extensive than is now common for non-contractual R&D.

<u>Is Needs Orientation A Better Approach?</u>

At this point, the crucial question must be faced, are there indeed net benefits in a needs oriented approach? Stated otherwise, is it not possible

that needs can actually be better satisfied by the better established R&D oriented approach? It might even be reasonably asked, whether at the bottom there are any differences in the two approaches, in the sense that they would materialize as different technological mixes, different projects and different management practices.

It is nowadays sometimes forgotten that the project system for R&D management was once under sharp attack. Mees saw it as an approach which "regards research as a business which can be organized and, while recognizing that some of the projects will fail, proposes that the successful ones should carry the failures."[3] Today most management would agree that that is how they wish to deal with R&D. Mees favored an earlier model, "in which the management, having hired an expert in the field (of R&D) leaves it to him and to his men to spend the funds in the hope that the company will get an adequate return." He calculated that the costs of additional administration and diversion of scientists' time into the meetings and reports required is such that the project system could not be superior unless at least 40 percent of scientists time with the less structured system had been misdirected, which he doubted. Mees attributed the growing prevalence of the project system to the anxiety of management to supervise the work of the research department, and further suggested that while it may greatly reduce "errors of commission" it greatly increases "errors of omission."

The Mees strategy for R&D was to obtain the best possible personnel, give them the facilities and support they ask for, make them aware of the company's operations and needs, and leave them to their own discretion as to how they will make their contribution. They may be able to identify tasks, from their technical knowledge, that non R&D personnel could never conceive of.

Especially where the gap in knowledge between the layman and scientist is great, the tasks proposed by non scientists are likely to fall far short of the potential and it is precisely because of their interest in working full potential that good scientists will depart from organizations which set them to work on pedestrian tasks. The past record of industrial R&D certainly suggests that close direction of R&D by non technical management particularly in project selection, results in low grade R&D. Along with spectacular examples of creative industrial R&D laboratories staffed with top-flight personnel and producing impressive technical results, hundreds of technical groups in companies which have rejected the idea of supporting a self-directed R&D establishment, but have maintained technical groups to respond to technique production and product problems which come to the attention of non technical management, and which are responded to in their terms. It is not possible to be definitive as to the contribution of such technical groups, since they have rarely been thought interesting enough to be studied in detail. Undoubtedly most have earned their keep. Not uncommonly, however, companies and industries which have carried their support of R&D no further have lost out to more technologically oriented firms or industries. There is reasonable grounds for believing that the technical or R&D groups which are strongly dominated by non R&D management have failed to make the technological contributions which might have been made, and that their companies have suffered in consequence.

A Reconciliation

If, then, the present trends toward needs orientation in R&D are not to have adverse effects on the productivity of industrial R&D they must clearly

take forms and have consequences quite different from that of the traditional low-technology industry; indeed, the R&D practices of low-technology industry can be taken as examples to be avoided.

It seems entirely possible that output orientation supported by thorough-going systems analysis in which R&D personnel fully participate may indeed reconcile industry's desire for R&D control with the desire of R&D personnel for self direction in ways which are compatible with high quality R&D performance in industry.

There can be a project system allowing initiative to R&D coupled with needs orientation if R&D management is given primary responsibility for articulating the R&D response to needs, doing so in intra grouping competition with other groups--independent from R&D and hence not overly committed to the R&D organization in its present form. Since the success of an innovation is never dependent exclusively on the efforts of R&D, a complete proposal under the initiative of R&D requires inputs from other functional parts of the organization. For the approach prepared here to work, R&D must have access to such resources on its own terms. The sociological study of R&D has come up with some findings that suggest that it should indeed be possible to reconcile periodic internal proposal efforts, as it is translated into demands upon R&D, with the type of work environment in which professional attitudes flourish. For example, Pelz and Andrews find that a moderate multiplicity of tasks raises productivity, although carried too far it is destructive.[4] Occasional participation by R&D personnel in internal proposals may well be intellectually stimulating. Some isolation is essential if continuing efforts are not to be disrupted excessively by fire drills--the frequency of high-priority emergency technical problems is sometimes cited as the reason production-oriented technology is generally

removed from R&D laboratories and put directly under production management. But isolation can be stultifying as well. Many companies have been diligent to keep R&D personnel aware of company needs without levying explicit required tasks, and have been rewarded with a flow of creative proposals.

One of the attractive possibilities in needs oriented approaches is that it may lead to more effective interaction between R&D and other groups of the company. This would be most expected where analytical capabilities within the various functions not immersed in day-to-day problems, if it can be assumed that the most effective interaction will be on the analytical level. With a needs oriented approach it is feasible to lay out the general aspects of a program for an internal R&D group well in advance.

Conclusion

In the context of present R&D management practices, Mees' argument for something less structured than a project approach to R&D management is a relic of the past. What Mees called the project system has emerged as an approach under which the initiative for R&D program content lay primarily with R&D management. Increasingly this initiative has been threatened by procedures under which the initiative of non R&D management would be strengthened, placing R&D management and personnel in the position of being more constrained in the articulation of the total corporate R&D program.

The content of an R&D program proposed initially by R&D management is, of course, relevant to company needs. It differs from the output oriented approach in that it has not been so rigorously screened by a comparison with non-R&D alternatives. Mees' objections to the project system, although perhaps overstated, were real enough and the problems he cited could be worsened under a needs-oriented approach. To compare the cost and effectiveness of the needs

oriented R&D program with his Steinmetzian concept is pointless: the viable comparison today is between the presently dominant project system in which the initiative lies with R&D management and a needs oriented system. Undoubtedly needs orientation would mean a further reduction in time of engineers and scientists at the bench, and it is by no means clear that improvement in results would be sufficient compensation for the lost time. Casual distractions and elaborate reporting requirements can be far more destructive of R&D effectiveness than the mere time involved would indicate, and many companies have failed to obtain or keep high quality R&D through such practices. Any gains in needs oriented management must be weighed against such losses especially if R&D management style affects the quality of engineers and scientists a company can hire. That is, a disorderly collection of geniuses may very well outperform a well managed collection of dullards.

Clearly there are instances in which a high quality R&D group, with considerable self-initiative, even though made aware of the company and its problems, has spent part of its time on topics of scientific interest but no direct company relevance: on the other hand, how is anyone to know they are not relevant without exploring them first? R&D may misconstrue the company's needs and interests and work out unuseable new product and process ideas: some of these might have been abandoned at the onset given a little inquiry from operating management, but perhaps operating management often is overly quick to reject as unwanted or impracticable what it later finds indispensable.

While perhaps the occasional Steinmetz's of industrial research may combine genius with a deep perception of what is good for the company and ability to work self-directed toward that end, the majority of industrial researchers are made of a more common clay. The R&D oriented approach looks like

a judicious compromise between giving the scientific personnel their heads subject to careful indoctrination into the company and its problems, and a stultifyingly rigid control. It should not be discarded lightly.

The alternative, implied by the needs oriented approach carried to an unreasonable extreme, is an R&D group that never seeks to give the company anything beyond general management's conceptual capability, narrowed as it is by ignorance of emerging technology and by concentration on day-to-day tasks. Especially in low technology industries, R&D personnel are likely to be among the most creative-minded people in a company and may be the principal professional-level resource available to management able to combine creative impulses with the technical knowledge which makes creativity productive. There is clearly implicit in the needs orientation approach the possibility that R&D personnel will become more narrowly focused. There is also the possibility that management control rigidly implemented by "bean counters" will close off opportunities for exploratory thinking and the under-the-table activity that is so uniformly credited with many of the technological achievements of R&D laboratories.

The dichotomy between need orientation and balanced program bears some resemblance to that of the project group versus functional group approaches to organization familiar in the R&D management literature. At the heart of that controversy was the argument that giving priority to the individual project, with personnel from all technological skills and all management functions pooled under project management was an effective approach to R&D. This approach turned out to be expensive and to use people inefficiently as a given project moves from one phase to another, requiring differing skill mixes, but it often succeeded in accelerating R&D when cost considerations could be

set aside. To organize personnel by functional groups, each concerned with a mix of projects, makes more efficient use of the personnel, but tends to make project goals subservient to those of the functional group and to use people more effectively. Very much the same points are involved in the R&D oriented versus needs oriented policies outlined above.

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APPENDIX

Reports on the 1971-72 Study of Research and Development in Industry

Dialogues with Management on Research and Development

This report presents edited extracts of tape recordings made of interviews with management respecting their R & D activity as of late 1971. The material is organized topically, so as to present a number of points of view in the same general area. (MON 21)

Output Orientation in R & D--A Better Approach?

This paper examines R & D management as it might be performed under an output-oriented approach in which the company's needs for innovations in various product and production areas were identified, information collected on various ways of satisfying these needs, including R & D. A company's R & D program would be the aggregate of its needs in various areas of its business. The spirit behind the approach is that of applying the PPB (planning, programming and budgeting) approach to R & D. The paper summarizes the state of theory on R & D decision making in economics. (MON 22)

Research, Development and Financial Performance

This study is a cross-sectional analysis of the relationship between financial performance and R & D funding, using first-differences 1970-71 normalized by company size for financial variables and reported percentage change in R & D funding for total and government-funded R & D for the R & D variables. Changes in company net worth were best explained by financial performance; company R & D funding was not significant; however government R & D funding was marginally significant. Among financial variables, sales and working capital were the most significant determinants of R & D funding. The conclusion is drawn that as of 1970-71 the financial community discounted R & D as a factor in company performance. (MON 23)

Research, Development and Business Conditions, 1960-71

This study reports econometric analyses of data supplied by 28 companies for various years 1960-71, which have been pooled for all-industries analyses, and for separate analyses by industry groups of firms. Data have been deflated by GNP and normalized for company size. R & D has been examined for statistically significant relationships with financial variables, and government R & D funding. Company R & D funding were not consistently associated at statistically significant levels with any one financial variable. Government R & D funding and "independent R & D" support were generally significant. The strength of the government-private interaction seems to have peaked about 1965. (MON 24)

The Sensitivity of Types of Research and Development to Business Conditions

This report deals with the results of econometric investigations loosely patterned after those of Horowitz, Hamberg and Grabowski dealing with determinants of R & D funding in industry. However, the variables are not actual financial figures but scaled psychometric responses from executives in 54 companies during a spring 1972 survey of R & D in industry, on such topics as the impact of business conditions on sales, profits, cash position. It appears that "general business conditions" is more significant than any one financial variable alone, perhaps because of its more comprehensive nature. Separate analyses are presented for the non-electrical and electrical machinery industries, for government-sensitive firms, and for those companies with only a single R & D laboratory. It is possible to explore the sensitivity of some different types of R & D, and that from most to least sensitive the order is basic research, product improvement R & D, new product R & D, process-oriented R & D. (MON 25)

Patterns of Association in Research and Development

This study focuses on the scaled responses of executives in 54 firms interviewed in spring 1972 to a series of questions on company performance, financial conditions, current R & D performance and R & D planning, as it was affected by recent

business conditions. R & D ranked after general belt tightening, capital expenditures, and overhead activities as an area of sensitivity to adversity. The "R & D program as a whole" was most sensitive, followed by new product R & D, basic research and R & D program balance. Process-oriented R & D was least sensitive. Simple non-parametric tests were applied to responses sorted by strength of response on 20 questions, and results are reported. A factor analysis confirmed that firms tend to treat their R & D programs as an entity rather than tieing the new product component of R & D to strength of new-product needs, process oriented R & D to process-improvement needs, etc. The government dependent firms were especially hard hit, and were especially likely to tie their R & D funding to the level of sales. Effects of R & D were often strong with firms experiencing a severely weakened cash position. (MON 26)

Patterns of Impact and Response in Research and Development in Industry: Summary of a Study

This report is an "executive" summary of a series of analyses of R & D in industry based on econometric analysis of data on R & D funding, financial variables, and government R & D funding. Taking the economists' model of rational profit-oriented decision-making, it examines the effect of R & D on market valuation of the stock of companies, of financial conditions on R & D funding on both stock valuation and R & D funding. It explores patterns of association in R & D performance. The conclusions are that R & D has no favorable current effect on stock valuation, that R & D funding suffers when financial performance is poor, and becomes somewhat more short-range in its focus, and that product and process oriented portions of R & D programs tend to increase or decrease together. (MON 27)

Description of Methodology in 1971-72 Study of Research and Development in Industry

This report supplies details of the samples obtained in the various phases of this study, some statistical summaries, examples of questionnaires and various form letters used. It is not a treatment of study methodology in general, and is intended only to supplement the various reports in the series on the 1971-72 study.