Statistical Consulting in Industry

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The statistics community is showing increasing interest in consulting in industry. This interest has stimulated questions concerning recognition and job satisfaction, job opportunities, and educational and training needs. These questions are considered in this article. A central theme is that effective statistical consulting requires total involvement in the consulting situation and that good recognition flows naturally from such an approach. This concept is defined in operational terms.

KEY WORDS: Statistical consulting; Recognition for consultants; Training for consulting; Job Opportunities for consulting.

1. INTRODUCTION

Current trends suggest that in coming years a larger proportion of statisticians will be employed as practitioners, including consultants, while a smaller proportion will be university teachers and researchers. Many of these consultants-to-be will seek employment in industry. Students, teachers, and others are asking questions in several areas:

- Can the recognition and job satisfaction available to the statistical consultant in industry match the familiar forms of recognition available within the university framework?
- What are the prospects for job opportunities as statistical consultants in industry?
- What educational and training patterns are appropriate for these industrial jobs?

These questions collectively were the subjects of two recent national symposia in Chicago and at Clemson University (see author footnote). The points of view expressed in this article are an operational philosophy. Although the discussion refers specifically to statistical consulting in industry, much of the commentary applies equally to consulting in other mathematical sciences or to statistical consulting in other environments.

2. CONSULTING AND RECOGNITION

2.1 Why Is Recognition a Problem?

Recognition may be obtained only by supplying the necessary ingredients and energy, just as high yield from a chemical process can be obtained only by supplying the proper mix of ingredients in the proper steps. Accordingly, we should focus our considerations on the ingredients and the process that lead to high consulting impact and high recognition.

It is important to understand that the statistical consultant is never working on his or her own problems, but always on other people's problems. This situation has profound implications for the training and the recognition that are appropriate to the statistical consultant. Other professionals may design a bridge, cure a patient, or run a plant, but the consultant statistician is always in the role of helping others to do their jobs better.

Statistical consulting is unique in that, together with computers, statistics is used and is useful in far more fields of application than any other technical discipline. The figure is a page from a brochure we use internally in Du Pont to describe our Applied Statistics Group's business. Clearly, the work of a statistical consultant applies to almost all functions of an industrial enterprise: manufacturing, marketing, product safety, research and development, biological, environmental, and personnel. Business data analysis is not shown only because it is done by other groups in Du Pont. With such widespread need and use of statistics, why should the question of recognition of the statistical consultant ever become a problem?

I believe that whenever recognition is lacking the fault is the statistician's. The usual failure is that the statistician has too narrow a view of his or her proper role, having focused attention on only a small part of the proper function.

2.2 Recognition Is a By-Product of Total Involvement

It is the responsibility of the statistician to achieve what I shall call *total involvement* in the consulting situation. What does this mean?

Total involvement means many things. Suppose you are the consultant. Some of the key things you must do are

1. Meet the clients regularly on their home ground. In fact, most projects involve more than one client or client group. If you ignore any one client, you do so at the peril of the project. Moreover, you must take the initiative to meet and communicate with all parties. This often means travel, but that is the nature of your profession.

In some situations the statistician is assigned as a member of a multidiscipline project team. When that happens, every other member of the team automatically becomes one of the statistician's clients.

2. Learn the client's subject matter and lingo. This has two benefits; it helps you to be sure you understand the real problem, and it helps you to communi-

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cate with your clients. For example, it is important to visit the place where the data will be taken. Observe critically the operation of the equipment and the procedures actually being used. Talk to the operators and technicians as well as the professional staff. You should also read selected reports, journals, or books in the clients' subject field.

3. Understand the problem from the clients' viewpoints, including the viewpoint of their boss. This means you must talk to the clients' boss, too, and you will have to take the initiative—ask questions and listen carefully.

4. Devise a statistically sound plan of action. The plan should provide data that will permit analyses to resolve the key questions of all parties. Your plan should be the simplest, most practical, least expensive one that will do the job. Note that the consulting process may be well along by this time, but this may be the first place you need to use a lot of formal statistical methodology.

5. Consider it one of your responsibilities to be sure that all the client parties get together to agree on a plan of action (i.e., *your* plan, for the statistical aspects). Insofar as the clients may not all have identical goals, you may need to help them resolve their differences in developing the plan of action.

6. Monitor progress and refine the plan, if necessary, as the work proceeds. It will often be necessary for you to do some low-key expediting to keep the whole project moving.

7. Analyze the data. Use as much, but only as much, statistical complication as the circumstances warrant.

8. Get your report and recommendations promptly to all parties verbally. Obtain their feedback; then submit your report to them in writing. Get it to them in time to meet their deadline.

Write your report so that it can be understood by everybody who should read it, not just your immediate client. For example, copies should go to the client's boss, and to your boss, at least. Your report should state succintly on the first page not only your conclusions but also any action you want the client to take.

You may need to help the client write his or her report. Often it is desirable for you to write a report jointly with the client. This may result in a jointly written publication, which in itself can be an important form of recognition.

9. Follow up repeatedly until the needed changes are implemented.

10. Go back to square one to tackle the next round of problems.

Clearly, the consultant must play many roles: problem identifier, idea generator, model builder, collaborator, expeditor, peacemaker, author, politician, and, above all, results getter.

I believe that total involvement, as I have described it, goes well beyond what many statisticians actually do. Nevertheless, total involvement is standard practice for many other consultant statisticians. In my experience, recognition is never a problem for the statistician who competently practices total involvement. Invariably, whenever recognition is poor, at least one of these key steps has been neglected.

Previous writers on statistical consulting have discussed various aspects of total involvement, but only a few have suggested that the statistician's responsibilities are so comprehensive as here depicted. Among the references appended to this article is the bibliography assembled by Woodward and Schucany (1977). Readers seeking a broad perspective on consulting will find worthwhile a review of all items in that bibliography. In the present article, only a few specific references are made to articles that have special relevance.

The classic article, "Errors of the Third Kind in Statistical Consulting" by A. W. Kimball (1957), recounts a series of actual examples in which total involvement was not achieved because several key steps were neglected.

This brings us to a consideration of what total involvement is *not*.

- The statistical consultant must not try to *do* the engineering, physics, medicine, or other subject matter of the study.
- The statistical consultant must not try to *be* the executive running the show.

To try either of these is to guarantee failure.

Frequently, the end product of the statistician's effort on a problem is a procedure, often embodied in a computer program, that the client can use to handle future instances of the same problem. The procedure or computer program may be very general, such as a regression package, or it may be specially devised to solve a specific problem. Either way, the statistician provides a continuing service without having to be personally on the scene for each new instance of the problem. There is a big danger in such situations, of which the statistician who practices total involvement must be keenly aware. The unsupervised situation will gradually change in many ways, for example, problem content and personnel assigned to the work. Any change carries with it the danger that the procedure may be misapplied. We have seen this happen any number of times. Total involvement means monitoring such situations for months or years after installation to assure that the procedures are kept up-to-date and correct for the problem and to assure that assigned personnel are properly trained. This problem was recognized by Deming in his 1965 article on statistical practice; since then, both the opportunities and the dangers have multiplied, especially with the increasing use of computer procedures.

2.3 What Do We Mean by Recognition?

- It is reasonable to expect to achieve major impact on what happens in the client's organization. This

impact should be comparable to the impact of a middle-to-upper-line manager in the organization.

- It is reasonable to expect a high reputation inside and outside the client organization.
- It is reasonable to expect comparable pay and organizational level in your part of the organization.
- It is unreasonable to expect publicity as the achiever of the good results. The problem belongs to the clients, and they solved it. You only helped, even if 99 percent of the ideas and initiative were yours.
- In the same way, the statistician's support personnel (programmers, clerks, et al.) cannot expect direct publicity as achievers of the good results, but part of the statistician's responsibility is to see that due recognition is provided for all who contribute.

2.4 Achieving Total Involvement for a Group of Statistical Consultants

So far, this discussion has focused on the statistical consultant functioning as an individual providing services to a client group. When more than one statistician is involved, there is a burden on them to coordinate their recommendations and their services. If these statisticians are members of a group of statistical consultants, then there is an opportunity, in fact a burden, on their own supervision to provide guidance and support in achieving total involvement.

This concept raises issues of how best to organize for statistical consulting in industry. A full discussion will not be attempted in this article, but the interested reader would do well to read the article by Minton and Freund (1977), who discuss organization for the conduct of statistical activities in colleges and universities. There is a direct parallel between a multidepartment university setting and a multidepartment diversified industrial enterprise. Minton and Freund claim that their "Mode IV," a central statistics center, department, or institute, has the highest potential of overcoming the weaknesses and exhibiting all the strengths of other modes. I believe this conclusion is equally valid for industrial consulting. Here the important concept is the central administration of broad work assignments, career development, technical support, organizational development, and the like. While central administration is being maintained it often is necessary to have some forms of geographic decentralization to bring consultants closer to their clients. As a practical matter, the central group in a large, decentralized organization may not have administrative responsibility for every statistics practitioner at every site. Even so, the central group can provide technical resources and in-depth backup for the independent statistics practitioners.

Every consultant learns that some clients are "good" and other clients are "not so good." A good client seeks help on good problems and interacts with the consultant in fruitful ways, so that the outcome invariably is favorable. Daniel (1969), Sprent (1970), and Hyams (1971) discuss many of the factors and stereotypes that make for good or bad clients with good or bad problems. The internal consultant group (cf. Cameron 1969), however, has a long-term responsibility that must transcend any difficulties created by the not-so-good clients that may from time to time be primary contacts for important problem areas. Here again, the concept of total involvement must be invoked. If the primary contact is resistant to vitally needed statistical assistance, the consultant group, including its supervision, must devise a strategy to sell the client organization as a whole, in which case the resistant primary contact will normally accede to the proposed plan of action. Admittedly, it may sometimes take months or years to accomplish this end, and sometimes it happens only after pressures from the marketplace become severe.

Manufacturing
—Product Quality
—Process Modeling and Calibration
—Interlaboratory Studies
—Defect Detection
—Cost Reduction Studies

Marketing
—Sales Technical Service
—Customer Problems
—New Product Development
—Product Brochure Data Development
—Consumer Tests for Preference, Similarity, Wear, Comfort, Taste, Odor
—Proof of Product Claims

Product Safety
—Consumer Testing
—Flammability, Explosibility
—Toxicology

R&D
—Theoretical Models — including Chemical Reactions, Analysis of Spectra
—Screening and Optimization Experiments
—Development of Patent Claim Specifications
—Simulation Studies
—Probability Models

Biological
—Toxicology
—Pharmaceuticals — including clinical trials
—Clinical Instrumentation

Environmental
—Air and Water Quality, Noise

Personnel
—Performance Evaluation
—Salary and Wage Administration Analysis
—Safety Data, EEO Data

Areas of Application

2.5 Managing the Work Program

When an individual consultant or a consultant group does good work, it is pretty certain that before long the consultant will discover that there is too little time to deal with each project in the full depth of "total involvement." In this situation, value judgments must be made and priorities established. Fortunately, by the time this begins to happen, the consultant often has already-existing periodic contacts with many individual clients and managers in the client organization. Thus, a specific new project may not require much incremental effort to achieve total involvement. Also, in such situations the consultant has the background on which to make personal judgments about the best way to allocate his or her limited time resource. A group of consultants facing this situation has additional options; the group can reallocate work or add new consultants.

Total involvement at its fullest requires a range of consulting and technical skills that can only be learned over a period of years. A new consultant should begin immediately to develop these skills and to learn from colleagues who already possess this important know-how.

3. JOB OPPORTUNITIES FOR CONSULTING IN INDUSTRY

With this background we can consider the job opportunities for statisticians for consulting in industry. First, let's deal with formal education needs. Our own group has about 18 statisticians supplemented by programmers and others, making a total of about 30. Nearly half the statisticians have PhD degrees; most of the rest have MS degrees.

This distribution is just about right for us now. Ten years ago, the proportion of PhD's was lower, but almost all our recently hired statisticians are PhD's. This emphasis has been heavily influenced by the fact that Du Pont is a large, high-technology company, so that many problems are large and conceptually complex. I believe that this is typical of a portion of the job market and that there will be a continuing and growing need for a substantial proportion of PhD-level consultants in high-technology industry. It is important to recognize that many MS and a few BS consultants acquire by experience all the skills necessary to function at a level equivalent to those with PhD training.

In my judgment, there is also potential for a much larger number of MS-level consultants in a much broader cross-section of industry (together with a smaller proportion of PhD-level consultants). Not much of this job-opportunity potential has been tapped as yet. This large number of jobs will never materialize for statisticians unless the precepts of total involvement become widely adopted by statisticians and widely acknowledged by employers as a typical characteristic of consulting statisticians. Thus, the opening questions about "recognition" and "job opportunities" are seen to be closely interrelated in the sense that when statisticians do the things that lead to high individual recognition, they create the conditions for additional job opportunities for all statisticians.

It is important to acknowledge that employers always have more than one option to pursue a desired result. For example, there are other specialties whose practitioners would be, and have been, more than willing to attempt to fill a vacuum left by statisticians. Included among these competitors are operations research, MBA, and computer-science specialists, depending in part on the field of application.

4. TRAINING FOR CONSULTING

Next, let's look at the content of PhD and MS programs. Some assets for consulting are listed here.

1. The graduate must be knowledgeable in all basics of statistics. This could mean many things to many people, but at the least a consulting PhD must be skilled in

Multiple regression,
Analysis of variance,
Design of experiments,
Nonlinear estimation,
Time series analysis,
Contingency tables,
Methods for subjective data,
Quality control, and
Sample design.

Quite a few PhD's seeking employment in industry have not had meaningful contact with many of these subjects.

2. Other assets are collateral or prior training in

Physical and biological sciences,
Mathematics,
Computer science,
Numerical analysis,
Economics, and
Liberal arts.

An undergraduate degree in a physical or biological science or a field of engineering often is an ideal background for a graduate program focused toward statistical consulting. Some of the background that figures importantly is familiarity with the concepts and language of science, a lot of applied mathematics used in model building, and some contact with "live" data. A PhD candidate who intends to seek employment in industry should consider a dissertation topic in an area of direct consulting usefulness.

In any profession, the benefits of being "broadly educated" rather than "specifically trained" are pervasive and real. Liberal arts, economics, and the like

contribute to the perspective with which total involvement is understood and practiced.

Many schools are providing experience in real consulting situations, through "consulting intern" programs, statistical consulting labs, consulting projects, and the like. This is a very healthy trend and should be expanded.

We in industry do observe some clearly counterproductive practices in many schools. I refer, for example, to the persistent attitude that consulting or working on practical problems is degrading per se. A related counterproductive practice is the tendency toward excessive course work in abstract mathematics and mathematical statistics. The point here is *not* that theory is bad. Rather the point is that theory and practice must each be heavily influenced by the other on a regular, continuing basis. The problem is that much current teaching and research are highly ingrown theory that has not been influenced by, nor had influence on, consulting practice in a long time. A graduate student would do much better to spend some time learning concepts and skills of consulting practice. Exclusive theory emphasis may seem to be tolerable in cases in which the PhD will do only university research and teaching throughout a career, but in the long run denigration of consulting is bad strategy for all concerned. The statistics of population demography and student enrollments alone argue forcefully against such an attitude.

Training does not stop when the consultant leaves his or her graduate program. There is a continuing burden on the consultant and on the employer to expand the consultant's skills. Some of the initiatives that employers should take are

- Assignments, even early in the career, that carry broad responsibility;
- Encouragement to do research and publication;
- Special assignments;
- Career counseling and planning;
- In-house seminars; and
- Attendance at courses and meetings.

To be effective, these all require a strong effort from the consultant as well as the employer.

5. THE STATISTICAL CONSULTANT AS ENTREPRENEUR

I could summarize by saying that the statistical consultant is an entrepreneur. In our group we service about 110 plants, laboratories, and other sites in the United States and Europe. Each statistician is assigned as a long-term consultant to a number of sites. Typically, a consultant will cover several plants or laboratories for a given product line, which gives him or her a perspective not available to many of those in the line organization. We expect the consultant to come to know the products, the business and technical problems, the people (at all levels in the organization), and the technology on which the product line is based.

We hold the consultant responsible for

- Identifying where statistical services are needed;
- Convincing clients to tackle problems;
- Developing proposed solutions;
- Convincing clients to implement results;
- Long-term monitoring; and
- Total cost control of services.

One might ask the consultant-entrepreneur to list what's great about consulting in industry. The list could include the following:

- Important problems abound, with major impact on corporate business, on product quality, and on environmental and health questions.
- Objective and prompt feedback is obtained.

Through cost-of-service charging, client management has a direct mechanism to provide feedback to consultants. Good results will be followed by a willingness to support still more work; the opposite, however, is also true. This feedback is important to the consultant; hence it is a mistake for consultants to seek to have their entire cost borne on overhead.

- Effective research is stimulated.

A steady input of good research problems, including real data sets, is thrust on the consultant. This is extremely helpful in directing research to fruitful ends. Many industrial consultants produce a steady flow of research publications and find that the industrial environment is stimulating for their research, even though it occupies only a modest portion of their on-the-job time. It is beneficial to support this modest research time with overhead funds.

- Good backup services are available, including programmers, computers, and office services.
- There always is lots of contact with other people.
- The available range of problem content is extremely wide.
- High recognition in terms of approbation, pay, and organizational rank is available for good performance.
- Professional society activity is feasible.

Some industrial statisticians, like some university statisticians, become involved in administrative or editorial aspects of technical society activity.

Together these features can provide a high degree of job satisfaction. Some elements are similar to a university environment, while other elements can only be found in industrial consulting. Like any other entrepreneur, the success of the consultant's business will depend on his or her having an effective marketing strategy, having the right ingredients, and putting them together in a complete process to create a top-notch product.

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