Reprinted by permission of Elsevier Science. *Evaluation and Program Planning* (http://www.elsevier.nl/locate/evalprogplan) Vol. 14, pp. 391-396, 1991 0149-7189/91 $3.00 + .00 Printed in the USA.

MODERNIZING INFORMATION SYSTEMS: A COMPARISON OF SCIENTIFIC AND TECHNOLOGICAL RESEARCH PERSPECTIVES

JONATHAN A. MORELL
Industrial Technology Institute

ABSTRACT

As part of a series which compares different methodological paradigms, this article highlights technological and scientific themes in an information systems research study. While scientific endeavor is primarily oriented toward overcoming difficulties that stand in the way of seeking truth, technological efforts are devoted to finding practical solutions to real-world problems. The implications of this difference are applied to a telephone survey of high ranking information system executives in a variety of organizations. Topics in the survey included.- coordination of information resources,- improving data quality; evaluation of information system change,- software productivity,- information technology's role in pursuing strategic goals; information technology's impact on white collar work, and information resource management. Although both scientific and technological objectives are attained, a variety of factors led to a much heavier technological emphasis.

INTRODUCTION

This article presents a case study of how scientific and technological perspectives co-mingle, interact and coexist in information systems (IS) research. It is one example of many that are presented in this series. The intent is twofold. The first is to add to the cumulative wisdom that evaluators and applied researchers might glean from reading comparisons of different research paradigms applied to real-life cases. The second purpose is to show information system researchers why they might wish to conduct their work differently, depending on whether their intent is primarily technological or scientific. For both audiences, the message is that scientific and technological thinking leads to different choices at all stages of the research process - design, implementation, data analysis and dissemination of findings.

BACKGROUND AND RESEARCH CONTEXT

The Client

The study was sponsored by the Naval Military Personnel Command (NMPC), in support of work going on within the Manpower, Personnel and Training (MPT) community of the United States Navy. Essentially, MPT is the Navy's "Human Resource Development" department.

MPT's work is formidable. The Navy has approximately 550,000 members, most of whom change jobs every two or three years. There is uncertainty concerning the success of recruitment and retention efforts. Training must be linked to fluctuating schedules for the acquisition and retirement of weapons systems. Budgets may change. Against this backdrop there must be continual short- and long-term integration of information, planning, and action.

To fulfill its mission, MPT relies heavily on information technology. As an example of this reliance, we recently catalogued 44 different automated information systems in only *one* section of NMPC's multifaceted data processing group.

The Need to Improve Information Technology

The ideal information system is easy to maintain, secure, user-friendly, integrated with related systems, easily upgraded, and able to generate a wide variety of fixed and ad hoc analyses. The current state of MPT's systems are far from this ideal. The need for modernization derives from both a general movement in the world of information systems (IS), and from special circumstances in the U.S. Navy. The general context has four dimensions. The "information resources management" movement in the federal government is promoting expectations that information technology will be used wisely and well (Caudle, 1987; Newcomer & Caudle, 1986). Technological developments in networking, office automation and software make it possible for - non-computer experts to access and manipulate complex data bases. Computer aided software engineering and developments in programming languages make it possible to coordinate diverse system development efforts. The ubiquity of the personal computer has given many people a taste for computers, and a desire to use them.

Over and above these general trends, the Navy has a special need for a modern information infrastructure. Federal budget pressures are straining resources at the same time that the "600 ship navy" is drawing personnel from shore duty to sea duty. Thus efficient shore based operations will depend increasingly on Information Technology (IT).

Arrayed against these forces for modernization are contravening pressures. There is an installed base of hardware, code, expertise, and supporting organizational structures. Change is difficult from a human and organizational point of view. Financial resources though available - are limited. There are risks - failures **in** information system development are notorious.

The Role of the Oak Ridge National Laboratory

At the time of this work we were engaged in a wide variety of activities to assist NMPC in modernizing its use of IT. Included were efforts to develop strategic plans for change, the development and analysis of data architectures, and work on data dictionaries and information resource encyclopedias. The majority of our activities were carried out through subcontractors, thus adding the element of contract management to our role.

An important theme running through all our specific projects was an effort to provide intellectual leadership Lo NMPC in developing strategies for change. In this regard our role was one of an organizational development consultant -pointing out options, bringing about awareness of possibilities and difficulties, and helping the client implement the decisions.

There was also the need to fulfill our mission to do research. The Oak Ridge National Laboratory (ORNL) is primarily a research institution. Thus both the reputation of the institution and of its research staff is largely founded on traditional indicators of academic success publications in refereed journals, presentations at prestigious conferences, seats on advisory committees, and research money. This study was a deliberate effort to balance the need to assist our client and the need to produce research.

DESCRIPTION OF THE RESEARCH

The essence of this study was an effort to discover how diverse private sector organizations contend with a range of information management issues that were relevant to NMPC. The study's content and methodology emerged from a literature review, from discussions with information system researchers, and from conversations with information system executives in the public and private sectors. These activities led to an interview protocol which focused on the following issues: coordination of diverse information resources; improving the data quality of information generated by computers; methods of evaluating efforts to change IS; software productivity; use of IT to pursue strategic organizational objectives; interaction between IT and white collar work; and implementation of formal "information resource management" programs.

The sample consisted of 31 firms spread across manufacturing (6), retailing (I 1), transportation (8), and financial services (6). Each was among the top 20 companies in its category, as determined by Fortune 500 ranking data. Of the companies, 19 (61 %) agreed to participate. These organizations certainly represent the complex information system environments we sought. A common description of IS activity in these companies would number database size in hundreds of gigabytes, and speak of between 500 and 1000 information system professionals operating on budgets of hundreds of millions of dollars.

Data collection was by means of an hour long, semi-structured telephone interview, either with the company's highest ranking IS executive, or his/her designee. Recruiting began by means of a "cold call" to the main corporate phone number, which eventually led to an office which could supply the potential respondent's name, official title, and precise mailing address. A letter of invitation was then sent, and followed up by a telephone call for the purpose of scheduling the interview. (Repeat calls and letters were employed as necessary.) Prior to the interview, each respondent was sent an overview of the issues to be covered.

THE DIFFERING PARADIGMS OF SCIENCE AND TECHNOLOGY

In an effort to understand how program evaluators might produce more practically useful results, Morell (1979) reviewed differences between scientific and technological values concerning: theory, the choice of topics for investigation, levels of accuracy, and the nature of acceptable evidence. An aggregate sense of these differences emerges from the views of several different authors.

Skolimowski's (1966) belief is that the goals of science are to investigate reality, enlarge knowledge, acquire truth, and study "what is." In contrast, the goals of technology are to increase the efficiency of given techniques, and to create a reality of our own design. In general, technology is far more concerned with what 4i ought to be," rather than with "what is." Agassi (1966) cites the minimum elements of technology as including aspects of applied science, implementation of research findings, and the maintenance of existing systems. Sporn's (1964) view of engineering argues that engineering empiricism can guide action even in the absence of a theoretical base. To do so, engineering must include elements of science, tools, methods, systems, and social organization. Jarvie (1972) believes that technology attempts to be effective rather than true. Walentynowicz (1968) argues that scientific success lies in establishing
truth, while engineering success is the effective solution of a given problem. Further, engineering solutions *must* be acceptable in terms of a fixed set of resources. All of these views are summed up succinctly by the following quote:

> Technologists apply science when they can, and in fact achieve their most elegant solutions when an adequate theoretical basis exists for their work, but normally are not halted by the lack of a theoretical base. They fill in gaps by drawing on experience, intuition, judgment and experimentally obtained information. (Wiesner, 1970, p. 85)

The above are extreme formulations which do not take into account the imprecise boundaries that exist among fields. They also overlook many scientists' efforts to do work that is of practical value, and technologists' efforts to make general contributions. Still, these writings highlight the crucial fact that the scientific enterprise is essentially oriented toward overcoming practical problems in order to further the search for truth. The raison d'etre of technology, on the other hand, is to help maximize solutions which must be effective within practical, uncontrolled, real-world limitations. The remainder of this paper will highlight the consequences of these differences by applying them to the research described in the previous section.

TECHNOLOGICAL AND SCIENTIFIC ANALYSIS OF THE RESEARCH EFFORT

The series editor specified 10 "areas of impact" which may be affected by the investigatory paradigm chosen by a researcher. Conceptually, these may be grouped into three categories: *Methodologicall/epistemological concerns* which cover theories and conceptual models; research design; data collection methodology; data analysis system/MIS; and generalization of findings. *Relationship of investigator to users of information* covering relationships with funders and stakeholders; linkage to local program decision making; and communication, documentation, and publication of results; and the *third category* which has only one element: our own view of the study's contributions.

Methodological/Epistemological Concerns

Theory and conceptual models. From the scientific point of view, this study contains little in the way of theory or model building. Had circumstances been slightly different, however, both scientific and technological objectives could have been realized simultaneously. This point is best illustrated by an example which compares what might have been, to what actually happened. Consider the question of how IT affects an organization's needs for employees.

Because of the aforementioned pressures on available shore duty personnel, three related questions might have been of practical interest to the sponsor: What is the relation between the use of IT and employment levels? How might IT affect span of control? In the interest of managerial efficiency, how might IT help centralize or decentralize various aspects of organizational functioning?

In terms of more general theory and model building, these questions could fill a gap in our knowledge of organizational behavior. There is quite a bit of research on the impact of IT on employment, either for the nation as a whole, or for particular sectors of the economy (Burke & Rumberger, 1987; Osterman, 1986). Only a small amount of this research, however, specifically focuses on the need for managerial personnel, and almost none of it addresses the intra-organizational dynamics by which IT affects the deployment of managers (Morell & Sutherland, 1990). This theoretical issue might be resolved by research which dealt with the three practical questions described above.

This overlap of scientific and technological interests was prevented because other concerns were much closer to the sponsor's needs. Although some of those needsdid have connections with the wider realm of organizational behavior, many did not. Thus the study's only contribution to theory or model building

was its enlightenment value about how future research should be conducted. To illustrate this statement, consider some of the actual findings.

The data reveal two mechanisms by which IT affects workforce levels. Either employment needs were reduced because of automating the functions of data input, report generation and data analysis; or networking technology allowed managers to increase their span of control. Whenever such cases occurred, they did so within the context of greater organizational change, at a time when the organization as a whole was attempting to adapt to changes in its environment. The changes do not occur simply because the technology made the change possible.

In terms of quantitative social science, the above findings are unsatisfying because variable specification is imprecise; because the Ns are small; and because generalizability is limited by sampling difficulties. In terms of qualitative social science, the findings are not satisfying because the interviews did not provide the rich, multifaceted and in-depth information that gives qualitative study its greatest power. But despite these shortcomings, the data suggest dynamics by which IT may affect employment, and the context needed for such change to come about.

The technological value of this study is considerably greater, as the data contain powerful suggestions that may guide practical action. This point is best illustrated by an example derived from questions concerning "mechanisms of coordination."

> Our data make it clear that effective mechanisms of coordination should consist of some combination of two elements - regular meetings, and specific efforts to integrate diverse activities. An example of "plan integration" can be found in a corporate requirement that: (a) all business units are required to have an annual plan which includes a section on IS; *and* (b) that the vice president for IS review those sections.
>
> One example of the effective use of meetings was the establishment of a short, open, company wide, daily teleconference to disseminate system status information, to describe problems and their solutions, and to communicate concerns. A second example came from a corporate head of IS who meets on alternating weeks with his top staff, and with representatives of groups within the company who had major IS responsibilities. The intent was to form a "human network" to make sure that activities and projects are coordinated. This system insured, for instance, that new applications would not generate forms which appeared similar to existing forms, or that a new system would be implemented without adequate plans for user training.

These findings are neither systematic nor rigorous. Other methods of coordination may also exist. We do not know much about the variety of ways in which each model is manifest in different organizations. There is no reliable estimate of the relative frequency of each model. Little can be inferred about the circumstances under which any given strategy would be effective. Still, this information represents an extremely powerful guide to practical action because it is instructive of workable methods of coordinating complex IS activity.

Research Design, Data Collection Methodology and the Data Analysis System

Because design, data collection and data analysis are so intimately tied, they will be dealt with together. Open-ended questioning was required because of the difficulty of specifying in advance, precisely what categories of responses would be obtained. Written questionnaires were ruled out because of the difficulty of obtaining questionnaire responses from elite populations. Telephone interviews offered an opportunity for in-depth discussion, while saving considerably on the travel costs of face-to-face interviewing. A desire to tap the diversity of activities going on across many organizations made it

necessary to work at increasing the number of organizations sampled, to the detriment of obtaining several respondents within each organization. Interview content was determined by our judgment as to what information would be most immediately useful for our client.

These compromises generated the limitations on scientific value that were set out in the previous section. Samples were too limited for accurate parameter estimation. Variable specification was imprecise. Limitations on respondents' time constrained the depth of the information that could be collected. Because it was practical to interview only one respondent at each site, validity checks on the responses of participants could not be conducted. Because of the number of topics that had to be covered, time spent exploring any given issue was limited. In general, the problem was that practical constraints limited the type of data that could be collected, thus preventing the use of powerful qualitative or quantitative analysis tools.

Generalization of Substantive Findings

The choice of using large private sector (as opposed to government) respondents was driven by the assumption that the greatest diversity in information management activities lay in the private sector. The consensus was that federal information management officials must use most of their time contending with the information resource management regulations that stem from the Paperwork Reduction Act, and which are operationalized by the dictates of the General Services Administration and the Office of Management of the Budget. It was hoped that by discovering the solutions and difficulties of others, practical strategies could be developed that would be relevant to the Navy's situation.

This choice of respondents immediately raises the question of generalizability, a major issue in scientific research. One problem is the difference between government and the private sector. For instance, Tornatzky et al. (1983, pp. 97-99) point out four differences between the public and private sectors that are likely to be "consistent and operationally significant" for the purposes of promoting innovation: norms of responsiveness, locus of responsibility for consequences, concentration on "public goods," and perhaps, planning horizons. A second problem is not knowing how far results can be generalized to other companies in the private sector.

None of the obvious solutions to these limitations could be incorporated into this research. Including government settings would have reduced the number of private sector respondents. The sample could not be stratified on factors likely to influence the IS structure because the requisite knowledge about respondents was unavailable prior to conducting the interviews. Thus practical constraints allowed only a minimal generalizability dimension -the restriction of the sample to very large, complex organizations. This, at least, provided some sense of the boundaries within which the study's findings may be applicable. The generalizability problem diminishes, however, when we view these findings in terms of the entire scope of technological activity. Consider the data presented above on "mechanisms of coordination." These findings will enlighten planners, help avert disasters, promote workable solutions, and provide a more secure base for decision making. These are highly desirable objectives of technological research.

Relationship of Investigator to Users of Information

Our mandate here was to address four issues: relationships with funders; linkage to local program decision makers; response of peers; and the communication, documentation and publication of results. Because the funders and the primary decision makers are one and the same, these two issues will be addressed together. Similarly, the response of peers is tied to the dissemination of findings, so these issues are also best treated together.

Relationships with Funders and Decision Makers

The impact of this research on decision makers is both direct and indirect. The direct route is communication between the researchers (us) and the sponsor. These communications may take any of a number of forms formal reports, briefings, or informal conversations. The sum total of these efforts, however, is bound to have a relatively small impact on decision making. The reason is that this research constitutes a small part of a very large and complex set of efforts. In terms of money, manpower and the immediate importance of work, this study pales in comparison to those other activities.

A more promising avenue of impact is indirect - from the research to the entire ORNL team, and from there to the Navy. Recall that the team had a responsibility to provide many services to NMPC, including traditional systems analysis, subcontractor management, and intellectual support for policy making. Thus by influencing the entire ORNL team, the overall impact of the research might be amplified.

Response of Peers and Dissemination of Findings

The critical issue here is the generalizability of findings. Once a sense of that generalizability is obtained, it becomes possible to determine the publications and meetings where results of the study would be welcome. The roots of the problem go back to study design -how can questions be formulated, and interviews conducted, in such a way as to produce information specific enough to help the sponsor, and generalizable enough to interest diverse audiences? This is not an easy balancing act. How many of us have produced reports of such restricted interest that we could not get them published? Similarly, many of us have produced research that was recognized as a contribution to the literature, but which had no practical impact whatsoever. The solution in this research lay in its choice of topics. Despite the considerable practical and theoretical importance of those topics, the open literature contains very little relevant empirical data. Thus, the value of the study for a variety of audiences is assured.

Researcher's Personal View of the Study's Contributions

My view of the study's contributions is based on two themes discussed above-methodological limitations and the importance of the topic. The study had neither the qualitative nor the quantitative power that I would have liked. This could not be avoided, due to constraints on resources and the sponsor's needs for information on a wide variety of topics.

On the other hand, there is no doubt that the research is perceived as useful and interesting by a wide variety of people. The near unanimous reaction of those who are familiar with this work is that they would like to know more as results become available. There is a sense that computer expenditures are large; that outlays will grow; and that IT will have an increasingly large impact on organizations' efficiency, effectiveness, productivity, and viability. Though limited in scope and budget, this study provided much enlightenment for those concerned with how information resources should be managed.

REFERENCES

AGASSI, J. (1966). The confusion between science and technology. *Technology and Culture* 7, 348-366.

BURKE, G. & RUMBERGER (1982). *The future impact of technology on work and education.* London, N.Y.: Falmer Press (Taylor and Francis Group).

CAUDLE, S. (1987). High tech to better effect. *The Bureaucrat 16(l),* 47-52.

JARVIE. (1972). Technology and the structure of knowledge. In C. Mitchum & R. Mackey (Eds.), *Philosophy and technology (pp.* 5561). New York: Free Press.

MORELL, J.A. (1979). Evaluation as social technology. In J.A. Morell (Ed.), *Program evaluation in social research.* Elmsford, NY: Pergamon Press.

MORELL, J.A., & SUTHERLAND, D. (1990). Managerial employment and information technology-an exploration of organizational dynamics. *Office Systems Research Journal 15-25*.

NEWCOMER, K., & CAUDLE, S. (1986). Federal information resource management: Embracing the concept. *Information Management Review, 2(l),* 29-36.

OSTERMAN, P. (1986). The impact of computers on the employment of clerks and managers. *Industrial and Labor Relations Review, 39(2),* 175-188.

SKOLIMOWSKI, H. (1966). The structure of thinking in technology. *Technology and Culture, 7,* 371-383.

SPORN, P. (1964). *Foundations of engineering.* Elmsford, NY: Pergamon Press.

TORNATZKY, L.G., EVELAND, J.D., BOYPAN, M.J., HETZNER, W.A., JOHNSON, E.C., ROITMAN, D. & SCHNEIDER, J. (I 983). *The process of technological innovation: Reviewing the literature.* Washington, DC: National Science Foundation.

WALENTYNOWICZ, B. (1968, September). On methodology of engineering design. *Proceedings of the XIV International Congress of Philosophy* (pp. 586-590). Vienna.

WIESNER, J. (1970). The need for social engineering. In F. Korten, S. Cook & J. Lacy (Eds.), *Psychology and the problems of society.* Washington, DC: American Psychological Association.