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ABSTRACT

This review of literature concerned with technological innovation and innovation process research is divided into five general parts. Part I defines basic concepts and terms and outlines major analytical themes. Part II develops the individual and organizational dimensions within which innovative activities take place. In Part III, the sequence of events from technology generation to implementation and dissemination is described, and strategic options available to organizations in the management of innovation are discussed. An assessment of the role of government in affecting organizational technology is provided in Part IV and Part V presents a list of conclusions drawn from the review. These conclusions focus on the stages of innovation, the social units involved in the innovation process, perceptions of innovation by technology producers and users, indices of innovation, uncertainty about new technologies, the relationship between innovation and organizational size and structure, innovation in public and private sector organizations, characteristics of innovative individuals, the relationship of the research and development (R&D) function to innovation, the implementation of innovation, technology transfer, university/industry research interactions, the innovativeness of small high-technology based firms, and the effects of regulation and other government policies on innovation. An extensive list of references concludes the publication. (ESR)

# THE PROCESS OF TECHNOLOGICAL INNOVATION: REVIEWING THE LITERATURE

Productivity Improvement Research Section
Division of Industrial Science and Technological Innovation

National Science Foundation

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# PREFACE

This review of literature in the fields and subfields generically known as "innovation process research" has been four years in preparation. It represents the product of several different disciplines and research traditions and, as such, it is likely to be frustrating to some of its readers. Different concepts can go by similar names, and the same concepts may likewise be found under different guises and in different places. No single organizing framework is adequate for integrating all the diverse themes to be found in this literature.

The integrating approach which we have chosen to employ starts with the idea that technological innovation must be considered in an *organizational* context. This focus is relevant for two related reasons. First, most significant innovations require the mobilization of organizational resources to be effectively utilized, and thus are inherently bound up with the dynamics of organizational behavior. Second, many previous reviews of innovation research have focused either on macro variables such as tax or social policies or on micro variables such as characteristics of innovation adopters, to the frequent exclusion of the organizational contexts in which the effects of these variables are played out.

While we try to consider the full array of variables employed in previous innovation research, the complexity of the field makes it inevitable that we will have, either by design or inadvertance, excluded certain references deemed by any particular reader to be of importance. Despite these limitations, we believe that this review is worth presenting to the field. First, there is nothing like it currently available. While there are many excellent reviews of discipline-focused or technology-focused subsets of the literature -- some more detailed than ours -- there does not appear to be any comparable reference volume drawing on the wide range of sources brought together here.

Second, we have seen a need in our extramural research program for a mechanism to brief potential researchers on perspectives other than their own, as a way to enrich each individual approach. Innovation processes research is a phenomenon capable of being described from many different points of view, and these differences can be illuminating rather than simply frustrating in the right sort of comparative circumstances. In addition, we have attempted to make this review of interest to managers of technological innovation as well as literature analysts -- to provide managers with some tangible help in addressing the day-to-day decisions involved in innovation processes.

This review is divided into five general parts; Figure 1 presents is a schematic diagram of its structure. The first two chapters (Part I) define basic concepts and terms, and sketch some analytical themes which run through the rest of the discussion. Part II (Chapters III-V) develops the individual and organizational dimensions within which innovation activities are carried out, represented in the figure as a series of boxes surrounding the central arrow. Part III (Chapters VI-VIII) describes the "arrow" itself, the sequence of events from technology generation to implementation and dissemination, and discusses strategic options available to organizations in the management of innovation. Part IV (Chapter IX) concludes with an assessment of the role of government in affecting organizational technology, emphasizing the macro-environmental surroundings (shown on the

# THE INNOVATION PROCESS:

## CONCEPTUAL OVERVIEW

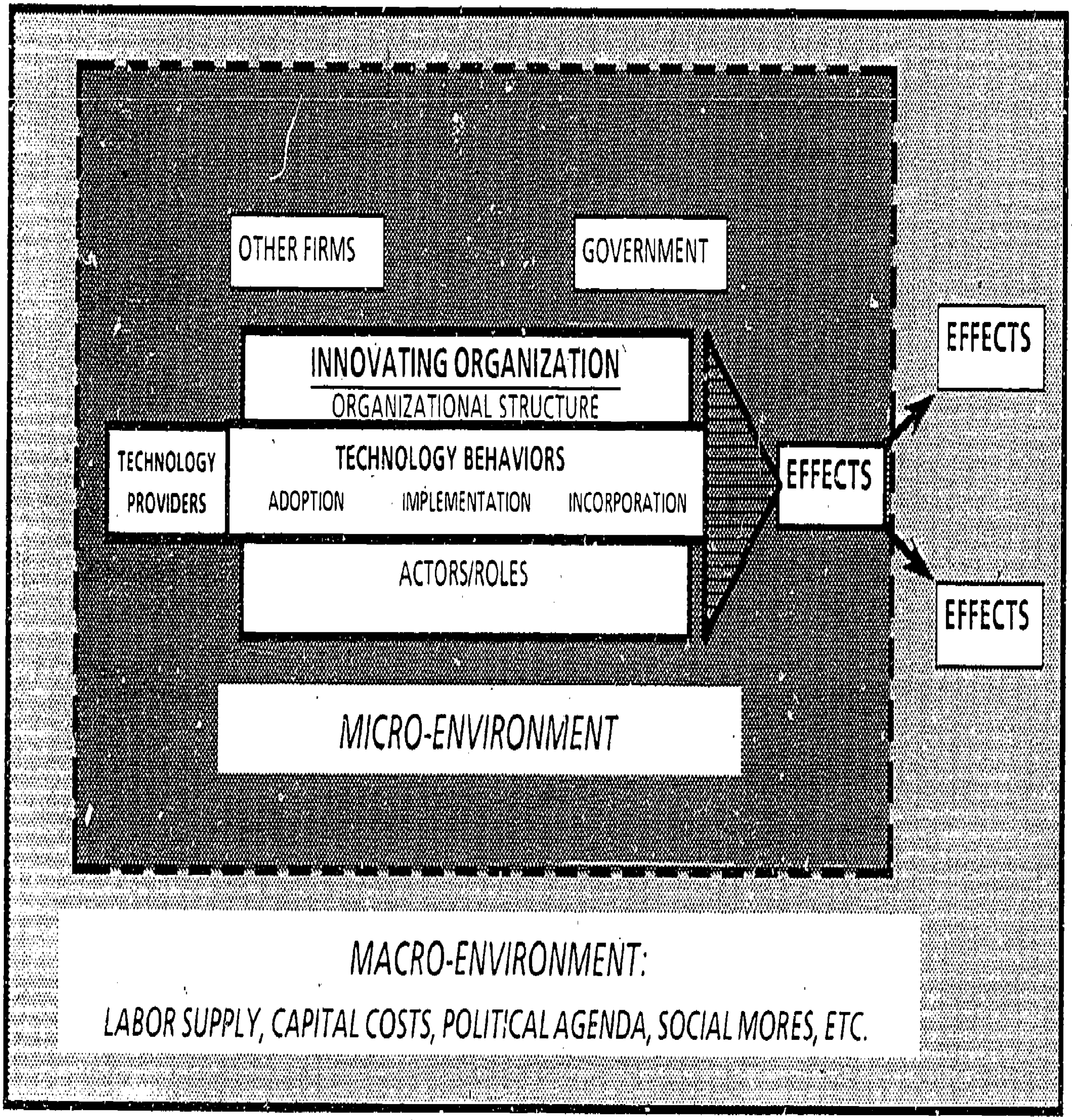


FIGURE 1

diagram, appropriately enough, as a large gray area). Part V, a brief summary of "lessons learned and unlearned", defines what appear to us to be the most salient conclusions emerging from the review. Readers are advised to refer to the diagram as an aid in remembering where any part of this large and diverse presentation links to other parts which may interest them.

Like the field itself, this review should ideally never stop growing or changing its perspectives. The major differences evident between this edition and our preliminary version of two years ago testify to the rapid evolution both of the body of knowledge and of our understanding and synthesis of it. Future reviews should profit from the experience of this volume.

Clearly, there can never be an "Authorized Version" of innovation literature. The field is too complex and too full of value and perspective differences to make such an exercise practical even if it were desirable. It remains our firm belief, however, that any individual research effort in the innovation field will be enriched by at least a passing glance at the range of methodological and conceptual concerns we have outlined here. The more you know, the more you realize that there is to know. In this spirit, we offer this review and eagerly invite feedback on both its substance and style from all interested researchers.

# PART I

# DEFINITIONS AND APPROACHES TO INNOVATION

CHAPTER I

# TECHNOLOGICAL INNOVATION: DEFINITIONS AND CHARACTERISTICS

This review is dedicated to the understanding of innovation. The focus, however, is not necessarily upon everything that is "new", nor upon innovations that consist purely of abstract ideas. Rather, its emphasis is placed on those changes which involve human activities and artifacts -- that is, *technological* innovation. It is appropriate, then, to begin with basic definitions of the key terms "innovation" and "technology".

For the purposes of this review, *technology* is considered to be "any tool or technique, any physical equipment or method of doing or making, by which human capability is extended" (Schon, 1967), or even more simply, "work done in organizations" (Perrow, 1967). This definition encompasses the combination of material artifacts and social systems used to make things (process technologies) as well as those things that are made for consumption by users (product technologies). Every product implies a process by which it is made, and integral to any process is its resulting product.

Implicit in this definition is the consistency and/or replicability of processes or practices, and their deployment is a dynamic activity involving multiple stages. Physical tools or machines, used in a finite number of ways that are largely replicable by different operators, constitute the usual referents for the term; specifying a tool is usually assumed to specify its use. A wrench, for example, is excellent for loosening and tightening nuts, but it makes a poor toothbrush. To the extent that a social behavior is operationally replicable and less than infinitely modifiable, it can usefully be treated as a technology for many purposes. The set of combinations of physical and social elements in technology will be a consistent theme in this discussion.

*Innovation* is defined as "a technology new to a given organization".*
By this definition, not all technologies are innovations; only those recently introduced into a setting are. After a new technology becomes established or "routinized" in an organization (see Chapter VII) it is no longer an innovation. Thus, the distinction between the terms *technology* and *innovation* is largely perceptual, a function of what phase in the process of innovating is being observed.

Paralleling this distinction, this chapter has been organized into two parts. One is concerned with already-established technology -- its functions in the organization, and the relationships it has with other parts of the setting. These are in effect "macro-organizational" aspects of technology. The second part of the chapter concerns some more detailed aspects of technology which affect its change or replacement -- that is, characteristics of new technologies or innovations as perceived by actors involved in that process.

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* We exclude from our domain of discussion the scope of purely "policy innovations", or changes in organizational policies and goals which do not affect tools or procedures used to do work. Clearly, some policies *do* affect tools, and are thus appropriately considered herein.

## Technology: Macro-Organizational Perspectives

For this analysis, the term *technology* is given a wider interpretation than it has frequently received in the past. Technology concerns more than just hardware inputs and outputs of productive operations; it includes also the *functions* that tools serve to improve organizational performance, and the *interactions* that tools have with their social setting.

One major theme of technology-organization interaction is the amount of *uncertainty* in the relationship between tools and the ways in which they are and can be used. Many discussions of technology have ignored this issue.* The now rather outdated concept of "technological determinism" suggested that there was one and only one way to operate a technology efficiently and effectively, and that this typically involved one basic form of organization -- the structured, hierarchical, bureaucratic model (Taylor, 1947; Koontz and O'Donnell, 1955). It was usually assumed that tools were designed to serve a single "best" purpose, rather than several purposes at the same time. As an organizational corollary, technology was presumed to require a "Weberian" hierarchical and structured bureacratic organization (Mooney and Reilley, 1939).

This view was initially amended by organizational contingency theorists, who argued that each different type of technology (or, more specifically, organizational task) has a unique organizational structure most appropriately adapted to its use, and that use of any other structure will attenuate the effective deployment of that technology (Woodward, 1965; Burns and Stalker, 1961). Depending upon the amount of uncertainty or

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* Chapter III develops some of these themes in more detail, particularly the definitions of the different "schools" of analysis.

"nonuniformity" (Litwak, 1961) inherent in a given technology, some particular organizational form will be most efficient. Nonuniform tasks seem to attach to nonbureaucratic organizations; uniform tasks seem to be associated with bureaucratic structures.

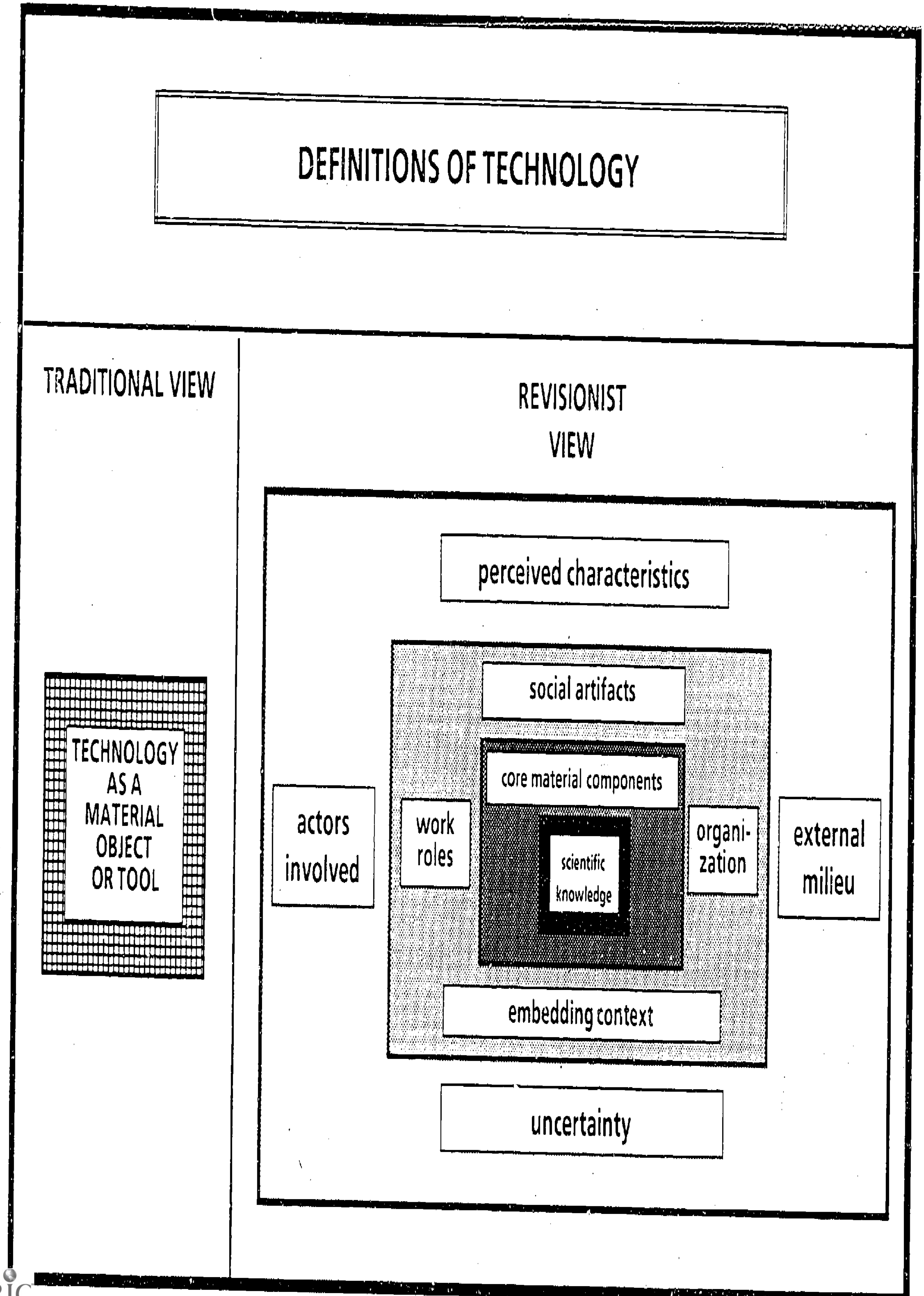
Thompson (1967) has differentiated technologies on their "technical rationality", or the degree to which activities produced desired outputs with certainty. Similarly, Scott (1972) notes the crucial role of "efficacy", the relative certainty of the cause/effect relationships underlying an activity. Some activities are more certain, or efficacious, than others. Metal cutting and forming, for example, is a relatively straightforward set of tasks in which the application of known replicable procedures results in a successful outcome. Teaching children to read or predicting the economic future, on the other hand, are usually more uncertain tasks, at least within present capabilities.

Yet even contingency theory approaches to technology are incomplete, in that they tend to assume that the amount of uncertainty associated with a technology or task is unambiguous. Not only may technologies have different uncertainty-producing characteristics depending on the operator and the situation; technology and associated work roles may also be altered so as to result in different uncertainty levels depending on the circumstances and processes of their deployment. For example, even assuming that there is a "core" of hardware and machines that is held constant (such as the ls needed to assemble an engine), these may almost always be deployed in alternative ways.

hese deployments of hardware in turn involve varying degrees of task uncertainty, and correspondingly different types of appropriate organization structures. For example, rigid hierarchical production lines and unstructured autonomous work groups have both been used effectively in automobile assembly. Sociotechnical systems theorists such as Trist and Bamforth (1951) and Rice (1958) have shown that there is usually more than one way to operate any given machine technology effectively, depending on the manipulation of work roles and social structure (see Chapter VI). Davis and Taylor (1972) indicate that this possible range of social and technological forms is often forgotten by system designers, managers, and even researchers. At the very least we need to recognize that even largely hardware technologies have a great deal of potential for variation in their implementation (see Chapter VII).

A comprehensive view of technology and innovation must embrace *both* tools and the different ways in which they are used by organizations, and the corresponding degree of ambiguity about how both tools and uses should be defined. In focusing on the interaction between a tool and its setting, it is important that these two aspects remain conceptually distinct. In many cases the operational definitions used for technology and structure become hopelessly confounded with each other (Mohr, 1971; Cooke and Rousseau, 1981). The amount and nature of the *social* component in a technology and the amount and nature of the *material* component (machines) are not end points of a single continuum. Rather, they should be considered as two separate aspects (Brooks, 1982). Technology must be defined at least in terms of an interplay of products, processes, and related human behavior (Rousseau, 1979; Bigoness and Perreault, 1981). Figure 2 summarizes this extended definition.

Pelz and Munson (1980) provide a useful schema for clarifying this interplay of tool and use in their distinction between the *technological content* and the *embedding content* of an innovation. The technological



DEFINITIONS OF TECHNOLOGY
TRADITIONAL VIEW
TECHNOLOGY AS A MATERIAL OBJECT OR TOOL
REVISIONIST VIEW
perceived characteristics
social artifacts
core material components
actors involved
work roles
scientific knowledge
organi- zation
external milieu
embedding context
uncertainty


FIGURE 2

content is its "knowledge base" derived from either science or practical wisdom. The knowledge base is embodied in particular tools or artifacts, in behavioral practices, or in some combination of the two. Embedding content is the set of organizational behaviors or processes which enable the knowledge to be applied in that particular setting.

A simple example may serve to illustrate the point. Consider a garment firm in the process of converting from hand to machine sewing. The technical function is sewing, and the new technology used to perform this function is the sewing machine. Certain changes in operator behavior are necessary in order to use this machine. The embedding content consists at least of the sewers' learning how to thread the machines, feed the material, etc. -- all of the behaviors necessary in order to operate the new machines. The technology is thus represented by *both* the machine and the behaviors necessary to operate the machinery. The embedding content is probably not all known in advance, and there may be more uncertainty than is recognized by the designers of the machines. In fact, much of the embedding content will only become "revealed" during the process of implementation (for example, what to do with the production line when the machines break down).

Some varieties of technology not tied to particular hardware or artifacts may not be easy to recognize as such, despite the fact that they do define the systematic production work of organizations. The constant core of these technologies is that they have an R&D base and a history of increasingly specific application. They are "tools" in the sense of involving manipulation of concepts, formulae, and procedures rather than the manipulation of steel or electronic circuitry. Pelz and Munson (1980) refer to such practices as "knowledge based innovations", in the sense that they are validated by replicable procedures rather than embodied in invariant material hardware. The terms *social technologies* or *managerial technologies* seem appropriately descriptive.

Illustrations of social or managerial technologies which meet these criteria are many and varied. One example from psychiatric treatment is the Fairweather Lodge (Fairweather *et al.*, 1969), a treatment innovation for chronic schizophrenics. An example from education is the Student Team Learning method (Slavin, 1977). The term may also embrace evaluation research techniques, management by objectives, cost analysis, personnel selection procedures, psychological screening (Moore, 1920), human factors engineering (Morgan *et al.*, 1963; Perrow, 1982) and economic forecasting (Fitts and Jones, 1947). Of current particular interest is the quality circle movement (Cole, 1979), which has found significant application in Japanese management. The concept of social technology is elaborated in a recent review of social science contributions to national productivity (Tornatzky, Solomon *et al.*, 1982).

The interaction of technology and social structure may also require analysts to consider secondary effects of technological change. Secondary effects include those technological and organizational responses to the adoption of technology which are incidental to the technology per se. Pelz and Munson (1980) term these secondary effects *technological accommodation* and *organizational adjustment*. They are distinguished from technological and embedding content in that while they may flow from the adoption of a technology or add to its efficient operation, they are not essential to its use nor even necessarily similar across organizations.

Secondary effects of the technology adoption may result in widespread organization changes which are more important to the organization than the initial adoption effort, and which are not necessarily understood by the organization at the time of initial commitment to the innovation. The more fundamental the technology involved, the wider the organizational ramifications are likely to be. The effects of computers on organizations, for example, are extremely significant and largely unpredictable prior to implementation of new systems (Kraemer and King, 1979; Bikson, Gutek and Mankin, 1983; Johnson *et al.*, 1983). In summary, the application of technology is intimately bound up with social and organizational variables.

Perhaps obscured in this preliminary working definition of technology, one that captures both operational and contextual aspects of the term, has been the fact that "tools" are used by individual human operators whose views on what makes up technology are quite important to *how* they are used. In the next few pages the unit of analysis and working definition of technological innovation will be extended to cover perceptual as well as concrete aspects of the concept.

## Innovation Characteristics: Technology as it is Perceived

Since an *innovation* is only that technology (material or social) new to a given setting or organization, it is inseparable from the *process* of innovating -- that is, adopting and implementing new processes, products, or practices. One of the main approaches taken in past discussions of the innovation process has been a concern with innovation *characteristics*, or those perceived attributes of technology that seem to be related to its adoption or implementation. This analytic tradition has attempted to derive predictive models of innovation using characteristics of the technology as predictors (Fliegel and Kivlin, 1966; Mohr, 1969; Bingham, 1976).

In a sense, the innovation characteristics approach parallels organizational contingency theory's preoccupation with task attributes. The latter, with its emphasis on understanding characteristics such as task uncertainty and uniformity, is quite similar to the disaggregation of innovation into components such as complexity, cost, and compatibility. It is useful at this point to examine some of the advantages and limitations of this line of analysis.

One of the issues of contention in this literature is the extent to which these innovation attributes reflect objective, invariant aspects of a tool or technique, or are primarily a function of idiosyncratic perceptions that vary from person to person and setting to setting. Downs and Mohr (1976) have most clearly articulated the relativist position. As stated by Downs (1978):

> The concept of "an innovation" is a very dangerous reification. Few properties of a given innovation are immutable and it rarely represents the same thing for two organizations. The risk, relative advantage, compatability, and so forth are different for prospective adopters and the impacts of different organizational determinants change as these characteristics of the interface between organization and innovation change.

A recent meta-analytic literature review by Tornatzky and Klein (1982) indicates that the empirical literature is not necessarily as situation-specific and inconsistent as Downs and Mohr suggest. In fact, there appears to be some constancy to perceived aspects of technology that may have descriptive and predictive value. For example, perceived characteristics such as "complexity" and "compatability with existing practice" were consistently (if moderately) related to adoption across a variety of technologies and settings.* Some primary characteristics (i.e., "core

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* The concept of "relative advantage", while likewise related significantly to innovation across cases, is usually defined in so tautological a fashion as to be almost uninterpretable.

attributes") can be operationalized with acceptable rigor (Calsyn, Tornatzky, and Dittmar, 1977; Hall and Loucks, 1978) even when the technology is social rather than material. On the other hand, evidence indicates that differences in perceptions may in fact have consequences for innovation behavior (Bingham, Freeman, and Felbinger, 1982); the debate remains open.

The critiques of the innovation characteristics literature have also produced a number of useful suggestions for innovation research procedures, beginning with Downs and Mohr's (1976) suggestion to use the "decision to innovate" as the preferred unit of analysis rather than the "innovation" itself. The focus is thus transferred from the tool itself to the social acts by which the tool becomes part of the system. If one attempts to integrate perceptual aspects of technology into a working definition, it is important to gather data from those most directly involved in using or deciding about the tool. Characteristics such as relative advantage, compatability, risk, communicability, divisibility, etc., which previously were considered to be inherent in the technology, can be reconceptualized as "characterizing the relationship between the innovations and the innovating organization" (Downs and Mohr, 1976: 706). Similarly, Feller (1978) proposes studying the "decision to adopt", which involves relating adopter needs, communication channels, decision making processes, and adopter roles to innovation characteristics.

Another related issue of stable versus variable characteristics of innovations concerns the *longitudinal* nature of the innovation process. Since innovation characteristics have been defined as perceptual judgments by actors involved in adopting and implementing technology, and since that process of adoption and implementation is usually a longitudinal one, then it is a reasonable hypothesis that those perceived characteristics change over the course of the process. The significance of innovation characteristics to the innovation process probably depends on which stage is the focus of study.*

## Causal Links Between Technology and Innovation

Thus far, two approaches to defining technology and innovation have been distinguished: analysis of innovation as an *organizational task*, and analysis of innovation as reflected in *perceived characteristics*. Evolving work in both bodies of literature is leading to a more developed understanding of the concepts of technology and innovation. The organizational literature has moved from a simple view of technology as machine and organization as hierarchy to a conceptualization of enormous possible variety in technology/organization systems. Likewise, the understanding of innovation characteristics has evolved from a concept of invariant attributes to that of perceptual gradients affected by setting, participants, location, and stage.

There has also been a parallel evolution in understanding the causal ordering among these phenomena. Namely, innovation is a *learning process*. On the individual level, there is a recognition that characteristics, as perceptions, develop and change as a result of experience and thus can also be conceptualized as indicators or *results* of innovation rather than just as *causes* of it. On the organizational level, causality has come to be considered as reciprocal rather than linear. Technology and organization evolve simultaneously, and changes and developments in either area have

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* Chapter II develops these concepts of innovation stages in considerably greater detail.

direct repercussions for the other. This evolution of causal inference requires more sophisticated analytical strategies than have characterized much previous work -- a point discussed in more detail later.

At bottom, the debate about definitions and characteristics of technology involve empirical questions about how to account for variance in the real world. For example, if the question is what is the best or most efficient way to organize the deployment of technologies A and B, the answer might be conceived as two overlapping distributions of response. On balance, technology A might usually be best implemented in a bureaucratic setting and technology B in a non-bureaucratic setting. But there will always be exceptions depending on context, participants, and intentional redesign of the technology. Similarly, technology A might usually be seen as simpler than technology B. But again, there will always be exceptions. The task confronting researchers in this field is to define with data the actual shapes of these hypothetical distributions.

There are perceptual and conceptual barriers in the research process itself. As should be clear from the preceeding discussion, the field of innovation research is inherently a multidisciplinary (and occasionally interdisciplinary) body of inquiry. Not only does it encompass foci of analysis which cut across the traditional concerns of the social and occasionally engineering sciences, but it also carries the methodological baggage of all these disciplines as well (Kuhn, 1962). In fact, one of the problems which has most bedeviled the growth of cumulative knowledge in the innovation process field is the different terms of analysis and methods.

The most prominent disciplinary foci have been economics, political science, sociology, psychology, and industrial engineering, although other disciplines have also been involved in parts of the field (geography and anthropology, for example, have both contributed heavily to diffusion research).* Each field has its own major area of concentration, its own special language, its own preferred modes of inquiry, and its own ways of defining key questions of interest. Moreover, even when research is structured to contain elements from several disciplines, research questions tend to cluster around one approach without achieving much integration. Thus, it is helpful to have some idea as to what the disciplinary focus of particular questions might be, in order to understand the uneven progress of the field. This review will draw liberally on all these disciplines, and readers are cautioned to remain alert to changes of perspective involved in this eclecticism.

## Summary

The main purpose of this chapter has been to reanalyze an all too common view of technology as disembodied machine or tool. Properly understood, technology (and innovation) encompasses the organizational setting in which tools are deployed, the work roles of people involved in their use, and the perceptions of actors involved in adoption and implementation. These reciprocal relations between technology and its social surroundings are not static but are likely to change as the process of innovating unfolds over time. One of the greatest problems faced by those who would understand technological innovation is the fact that people in organizations often do not think of themselves as intimately involved with technology. The concept of human beings as alienated from their machines

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* Chapter II presents a discussion of some of the advantages and limitations of each mode of analysis.

(Vonnegut, 1966), or the vision of Charlie Chaplin being devoured by the machine, should be replaced by the more comfortable perception that our tools can be manageable extensions of ourselves -- *if* we know enough to make them so. Metaphysical concerns aside, the ensuing chapters will continue to emphasize both the social and organizational, as well as technical, aspects of innovation.

# CHAPTER II

## STAGE-PROCESS MODELS OF INNOVATION

Studying the process of innovation is a complex research task. The purpose of such research is to make generalizations and defensible inferences about the behavior of organizations, groups, and individuals involved in technological systems over time. But the available methods of analysis rarely allow the dynamics of such processes to be observed directly. The conceptual models used to describe innovation behavior are often tested with data derived from observing only some parts of the total system, parts limited significantly in time and space.

Before continuing the discussion of what is known about innovation, it is necessary to describe some of the analytical problems which complicate research in the field. The most pervasive organizing schemes in the innovation field have rested on two main premises:

1) Innovation is a *process* of many discrete decisions and behaviors that unfold slowly over time;

2) Innovation involves *social* units at many different levels of aggregation, including individuals, groups, organizations, singly and in combination.

This chapter will first outline some commonly employed innovation process models and then describe some of the complications introduced by different research strategies and by different levels of the systems being observed. Some observations will be made on the problems with identifying appropriate dependent variables in innovation research, and on the advantages and limitations of different disciplinary foci.

## Stages and Processes in Innovation

The process of innovation is, like other organizational processes, a sequence of explicit or implicit decisions (Janis and Mann, 1977). As the process unfolds, people and groups are forced to select among alternative courses of possible actions based on value preferences or utility functions, and on their ideas about the purposes which the technology serves.

Despite past emphasis in the literature on simple, frequently dichotomous (adopt/nonadopt) measures of innovation, few analysts would claim seriously that the process is really the result of any single organizational decision, or that all decisions are overt or explicit. In fact, a typical innovation process is likely to have many of the aspects of "garbage-can" decision sequences (Cohen, March and Olsen, 1972), featuring more or less serendipitous combinations of problems and solution opportunities. Often decisions can only be inferred from subsequent behavior. While some decisions are probably more crucial than others in shaping eventual outcomes, it is difficult to claim that any one decision is really critical.

Not only is it difficult to identify discrete pivotal decisions; it is also difficult in most cases to identify all "decision makers". It is rare that a single decision by a single decision maker can explain technological change in an organization.* Innovation in organizations often involves

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* It can, however, frequently explain a *lack* of change -- most organizations have many individual points at which "no" can be said, while saying "yes" requires a great deal of interpersonal cooperation.

many individuals, inside or outside the referent organization (Shull, Delbecq and Cummings, 1970). Where many people participate in the production of decisions -- some in selection of actions, some in the provision of information -- many utility functions or sets of value priorities will be found (Mohr, 1976).

The concept of *stages* in innovation represents a way of organizing the many continuous decisions to be found in innovation processes. It is probably a distortion of reality, but a conceptually useful one. A stage is defined by one or more decisions and related behaviors which are connected in some logical fashion and which move the process toward subsequent decisions. The utility and validity of stage concepts resides with the analyst. There is nothing inherent in a stage conception of innovation which implies that individuals actually involved must agree on or even realize just what stage they are going through. Several studies (Lambright, 1980; Eveland, Rogers and Klepper, 1977) have indicated that innovation often occurs without much awareness on the part of most participants of what is going on outside their own limited spheres of activity.

It should also be apparent that there are multiple units or levels of analysis embedded within the concept of stages. Stages are really only an intellectual tool to simplify a complex process. At any given time, as the process of innovation unfolds, decisions are continually being made by individuals at all levels of aggregation, acting either alone or within the constraints of a group or organization. This means that in practice it may be extremely difficult to identify how decisions feed each other in a linear or logical sequence (Witte, 1972; Pelz, 1982).

There are two major points of view from which stages are commonly described -- the point of view of the *producer* of new technology, or that of the *user* of the technology. These viewpoints lead to rather different research emphases, since they refer to dissimilar sets of decisions and actions.* The stages of the innovation process in either case center around the evolution of the technology from general idea to specific product or practice. For each stage of these two models, there is a body of research explicating the processes operating at that stage. In aggregation, this encompasses the "innovation processes literature" described in this review. Figure 3 compares the two types of models described below.

Technology *Source*-centered Models

From the point of view of the source of technology, stages of the production of technology are generally defined as some variant on the pattern:

1) Basic research
2) Applied research
3) Development
4) Testing or Evaluating
5) Manufacturing or Packaging
6) Marketing or Dissemination

As these stages proceed, the innovation becomes defined with greater specificity, both for what it is and for what it is not. At the conclusion, one has a definite item in hand, although, as Chapter I noted, this definiteness may be more apparent than real. Within organizations whose primary

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* Clearly producers of technology can also innovate in their own processes or procedures, functioning as users rather than sources of technology, in the fashion described below. This may entail interaction either between organizations or (frequently) between groups within the same organization.

# STAGES AND PROCESSES IN TECHNOLOGICAL INNOVATION

## PRODUCER AND USER STAGES

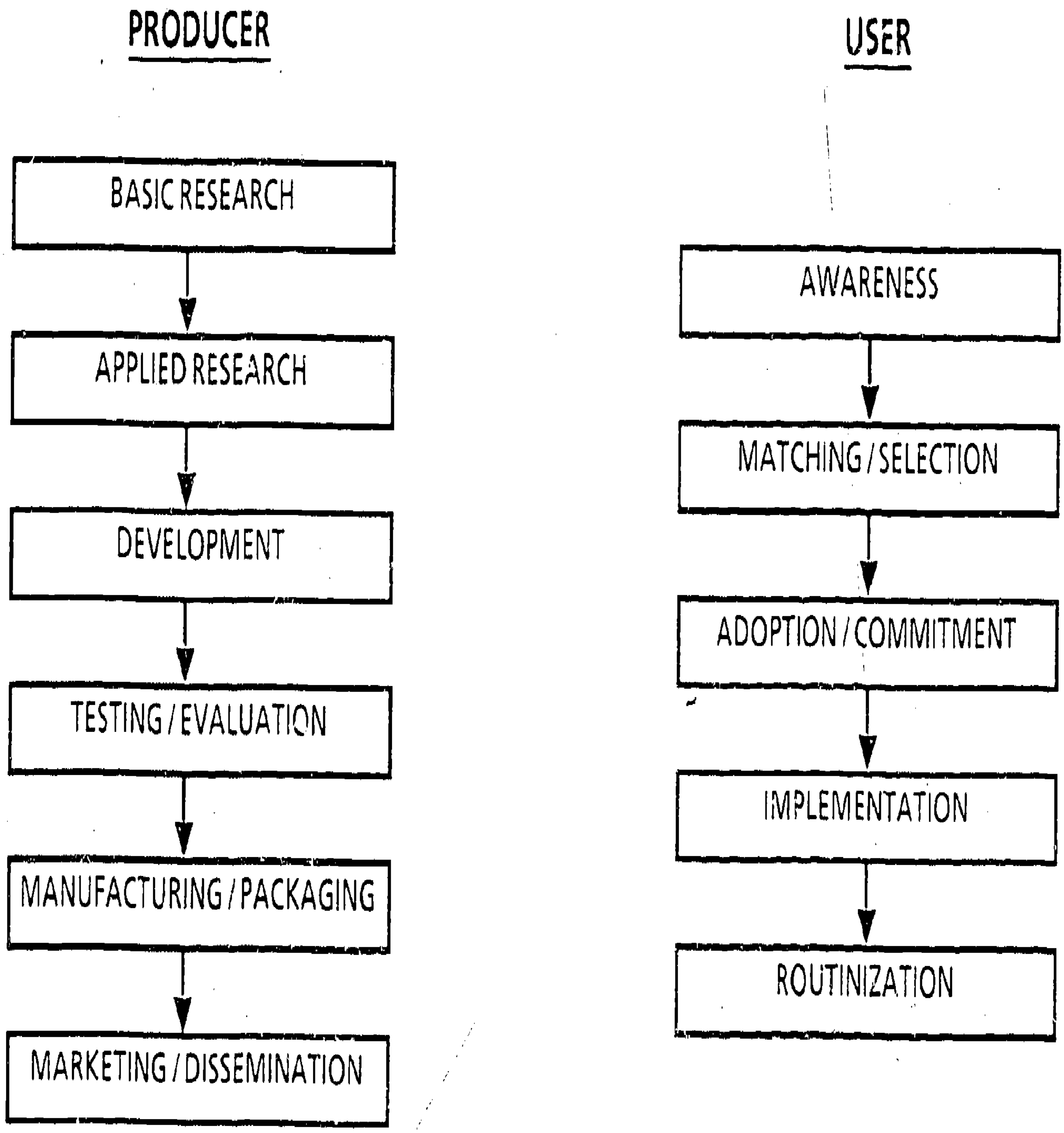


FIGURE 3

purpose is production, these functional stages are frequently embodied in the organizational structure as distinct organizational entities.*

## Technology *User*-centered Models

The endpoints of the source-centered model (marketing/dissemination) mark the beginning of the stages applicable to users of the technology. Stages from the perspective of the user of technology generally highlight decisions related less to outputs and more to procedures. Moreover, there may be many users of a technology, and the adoption/implementation process may play itself out differently in various sites. Stages from this perspective are generally variants on the pattern:

1) Awareness
2) Matching/Selection
3) Adoption/Commitment
4) Implementation
5) Routinization

As with source-centered models, user-centered models may highlight or downplay different aspects of the decision process depending on the purposes and interests of the researcher. No single terminology is universally accepted or even appropriate. Some analysts concentrate more heavily on the earlier, information-centered parts of the process (e.g., Walker, 1974; Allen, 1977); some, more heavily on the later, action-centered portions (e.g., Yin, 1980a).

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* Moreover, there are opportunity costs to be allowed for; each specification of the innovation of necessity precludes its taking some other potentially rewarding shape (Comfort, 1981).

It is difficult to combine these two perspectives into a single sequence. In general, the source stages probably occur before the user stages, but not inevitably; many studies (e.g., von Hippel, 1979) have noted crucial interactions between sources and users which guide the development of particular technologies. Moreover, many users are their own sources, and the user/source interactions take place within the same organizational structure. Even when nominal source and user are supposedly distinct, much "source type" behavior occurs in the user organization. Further development of technology almost always takes place within the user, particularly the crucial processes of custom-fitting the technology to the organization (Pelz and Munson, 1980). Thus, the two approaches can be considered as intertwined throughout the society, although they can be distinguished for different types of analyses of innovation (Havelock and Havelock, 1973). In this review, the focus is primarily on the users of technology; issues of the production of technology are addressed primarily in terms of how they affect use and users.

## Problems with Stage Models

While stage models of innovation probably capture the reality of innovation decision making more effectively than static or dichotomous models, and hence have more to offer policy makers and managers alike, their application is conceptually and methodologically thorny. This section outlines several areas in which the analyst must take particular care in structuring and conducting stage-oriented innovation process research.

Difficulties in Defining "Adoption" of Innovations

The central event in the analysis of innovation from the user's perspective is usually considered to be "adoption", the point which divides the organization's not having the technology from its having it. Unfortunately, this term has meant different things to different researchers. Some analysts have used the term synonymously with the entire innovation process, particularly in diffusion-of-innovation studies where a dichotomous (adopt/nonadopt) dependent variable is employed. Other researchers who have viewed innovation as an unfolding longitudinal process have referred to "authoritative commitment" (Lambright, 1980) or to the making of some decisive adoption decision (Fairweather, Sanders and Tornatzky, 1974). Others have questioned the value of the concept of adoption at all. For example, Eveland (1979:6) notes that:

> ...if the innovation process is, as these studies suggest, a series of complex and contingent decisions, then the logical question is just which one of these decisions is in fact crucial -- the one naming the point in time at which the organization moved from not having the innovation to having it...In research practice, 'adoption' is usually assessed largely in retrospect, by the 'weight of the evidence'...

The value of the concept of adoption to any given stage model ultimately depends on the purposes of the research.* If one is doing market research and trying to determine whether or not a purchase has taken place, it is appropriate to identify a single decision as "adoption". In situations where a presumably irreversible act is involved, such as acquisition

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* The concepts introduced in Chapter I concerning the degree of specification of organizational tasks and innovation characteristics are relevant here. In addition, Chapter VII discusses further the question of "fidelity" in implementation, another way of looking at this problem.

of equipment, the adoption construct may also be defensible. It is less useful in situations where adopters may "un-adopt" at little or no cost to themselves, which is often the case where technologies may be acquired but never really deployed. For some purposes, the point of adoption may be used to distinguish where the process changes from a primarily symbolic activity ("deciding") to a behavioral ("implementing") one. At the least, however, it is worth while to distinguish conceptually and methodologically between "adoption" as a single event and "adoption" as a surrogate term for innovation processes generally. In general, stage models are most useful for organizing a body of empirical information about a *sequence* of decisions rather than for defining adoption.

## Defining Levels and Units of Analysis

Some problems are posed for the use of stage models by inappropriately defining the level of analysis. Researchers have tended to categorize entire organizations as being in one or another stage of the process at a particular point. But this approach is called into question by the many studies which have found that only rarely is an entire organization involved; innovation is usually carried out by small groups or individuals (Pressman and Wildavsky, 1973). Moreover, different components are likely to be involved at different times. At any given point, some parts are likely to be in early stages, other parts are in later stages, and some parts may not be involved at all. In fact, after implementation is complete many if not most parts of the organization may remain essentially untouched by the change. It is not surprising, therefore, that researchers have found it difficult to predict what stage of the process a given organization is in on the basis of some independent variables, particularly variables defined at relatively high levels of aggregation.

It is also important to remember that stage models of innovation are at this point in their evolution essentially descriptive and diagnostic tools for looking at interconnected decisions, not predictive tools in any real sense. To generate a full model, one would have to be able to specify which variables predominate at which stages, and what forces govern movements between stages (Mohr, 1982). While this may be the goal of innovation process research, it is a goal not yet achieved. One of the main reasons for this state of affairs is the disaggregated nature of innovation process research itself. While the terms of the conceptual debates are relatively clear to all participants, the manner in which empirical and/or conceptual differences may be resolved remains somewhat obscure.

It is a basic premise of models of social systems that behavior can be studied at various levels of aggregation. Each level of aggregation has certain properties which are not possessed by the components of the level acting independently. Aggregation is not, however, simply a process of pooling lower levels. Simon's (1973) analysis of the "decomposability" of systems and Weick's (1976) discussion of "loose coupling" within systems both emphasize that behavior at any one level is a complex, not a simple linear, function of the ways in which sub-units come together to form larger units. This may sound like a truism -- however, it is one of the most commonly neglected "truisms" in organizational analysis. Two aspects are relevant to the problem: (1) how to conceptualize the relationships between levels, and (2) how to analyze data representing different aggregations of human units.

<u>Conceptual and Research Design Issues:</u> It can be argued that many analytical problems in multiple units of analysis stem from more basic conceptual failings. These are primarily of three types: (1) failures to acknowledge different levels and units of analysis; (2) problems with research design and measurement; and (3) confusion in relating data derived from different methods.

The first error is often a function of basic disciplinary chauvinism. Some examples include macroeconomists' failure to acknowledge the existence or analyzability of organizational behavior, psychologists' dismissal of organizational norms and procedures as they affect individual behavior, and policy makers' lack of understanding that all policy stands or fails at the level of the organization or work group. There seem to be only two ways in which this problem can be addressed, both of which are premised on the notion that conceptualization, theory, and problem definition concerning innovation are inherently multidisciplinary exercises. One solution would be for researchers to become conceptually proficient in several fields -- a worthy goal, but difficult to fulfill given current academic mores. A second solution is to use a research team approach involving pooling of different specialties.

Difficuties in dealing with multiple levels of analysis may also be the result of an inadequate research design and inappropriate research methods. Research on organizational phenomena typically requires the use of statistical inference: formal and standardized ways of drawing conclusions about a set theoretically or empirically derived hypotheses on the basis of relatively small number of observations. How much information one can isolate about the relationships of interest from noise or error produced by uncontrolled effects of other influences depends to a gr[illegible] extent upon the design of the research. Elements of the research design include: operationalization of the variables, development of a sampling plan, determination of sample size, selection of research instruments and instrument items, development of the data collection plan, and selection of analytical techniques.

The rules of statistics are ruthless and unyielding, and in studies of organizations, especially difficult to uphold. As Festinger and Katz (1966: 173) note about sampling considerations:

> Many investigators protest that they do not make these decisions -- these decisions are made for them. One does research in industries into which he can get entree...But such situations frequent though they may be do not obviate the necessity of the nature of a sample and its characteristics.

Like entree, multiple levels of analysis pose problems which must be recognized and dealt with in the design of studies of organizational processes. The design of research begins with the development of research hypotheses -- clear concise statements about what is known and not known about the phenomena under study. From such statements it is possible to determine the magnitude of permissable error and the elements of the research design. Since the state of understanding of relationships at different levels most likely varies, so will the sample size, sampling plan, instrument items, data collection methods, etc. Basing the design on one level or another would make the results at other levels of analysis uninterpretable.

In addition, variables may change meaning between levels. Simple aggregation of individual measures to form group descriptors may produce invalid composites. For example, the socioeconomic status (SES) of a school child measures family resources and environment; the average SES of a school may be a better indicator of peer norms and community support. The R&D spending of a firm measures its ability to generate new products to compete with its competitors; in contrast, average R&D spending in an industry measures mainly the dependence of that industry on new technology. Burstein (1978) and Roberts, Hulin and Rousseau (1978) both comment on this problem at length. In addition to aggregation problems there are also disaggregation problems. There are certain "global" features of larger units (Burstein, 1978) which are incorrectly attributed to component units -- for example, the tendency to assume that the productivity of a nation such as Japan is an index of the values of the individual people involved. Much of this problem could be alleviated if the conceptual understanding of different social units, from different levels of social aggregation, matched the precision of the data themselves.

The third problem, closely related to the above, is particularly difficult to resolve. Although the aim of all varieties of research is to describe the same set of organizational actions, there are serious epistemological questions regarding the techniques best adapted to identifying the critical features of that behavior. How to balance off a finding derived from experimental methods (Weiss and Rein, 1970; Riecken and Boruch, 1974) against one derived from a case study analysis (Yin, 1981; Greene and David, 1981), or a highly quantitative finding (Boruch, McSweeney and Soderstrom, 1977) against a more qualitative one (Miles, 1977; Van Maanen, 1982), is not intuitively apparent except to some ideological partisans of a particular point of view. In general, using all types of research strategies and data sources, with due attention to the limitations of each (Campbell and Stanley, 1966; Garfinkel, 1967; Glaser and Strauss, 1967; Patton, 1980) is to be encouraged.

Analytical Issues: The drawing of inferences about behavior at one level from data measured at another level is not automatically an error, but frequently is. Unfortunately, we often *want* to draw inferences about the behavior of organizations from data gathered from individuals, or about industry behavior from firms. At other times we may face the inverse problem, as when we try to draw inferences about the productive behavior of individuals from data about work groups' overall productivity. Thus, technique and purpose are quite possibly at odds.

Various fields have noticed problems of cross-level inference at different times. One major impetus for systematic attention was Robinson's (1950) formulation of the "ecological fallacy" in social research; however, statisticians had been aware of the problem as far back as Pearson (1896). The problem is, simply, that at different levels of aggregation the same data can yield widely varying statistics. Robinson (1950) and Hannan (1971) both have good discussions of the mathematics underlying this problem.

Aggregation problems exist not only across structure or space but also across time (Kimberly, 1976a). Pooling data describing events which occur at different times is a common technique; it is seldom done with explicit attention to the inferential consequences of this assumption. At its extreme, this pooling results in removing time from analyses entirely, and can lead to anachronisms such as "correlating yesterday's innovativeness with today's independent variables" (Rogers and Eveland, 1978) in a reversal of the plausible causal ordering. Similarly, the aggregation of observations from different time points is frequently done simply in order to increase sample sizes.

Since Robinson, a number of analysts have developed approaches for dealing with multi-level inference problems (Borgatta and Jackson, 1980). Most of these methods are varieties of structural-equation manipulation techniques (Goldberger and Duncan, 1973); such structural modelling is a convenient way to represent cross-level influences, and forces an explicit analysis of the nature and level of the variables involved (Hannan, 1971).

A common procedure is to decompose a multi-level relationship into individual effects, context or aggregate effects, and comparison or "frog-pond" effects. There are a number of approaches to estimating such models. Firebaugh (1978) discusses the "cross-level bias" introduced by using variables at different levels of aggregation in the same structural model. Brown and Saks (1975) outline an approach using a decomposition of cross-level effects; Burstein, Linn and Cappell (1978) extend this analysis to consider within-group variations. Erbring and Young (1979) outline an estimatable "endogenous feedback" model which conceptually overcomes many of the difficulties noted earlier.

Much attention has been given to the question of what is the "real" level of analysis for particular issues, given the difficulty of multi-level inference. However, restricting analyses to one level does not seem to be either helpful or necessary. Phenomena do not belong neatly to one level alone of a hierarchical system, and analyses which attempt to restrict their inferences to one level will miss many of the most interesting interactions which affect their data. Thus, instead of spending time attempting to find the "proper" level of analysis, suitable attention to multilevel analytical techniques should be encouraged.

## Dependent Variables: A Cautionary Note

The bulk of this review concentrates on describing the course of innovative behavior and the external and internal factors which affect such behavior. Like most innovation researchers, it devotes relatively little time to analyzing the dimensions of *dependent* variables. Most of the existing literature has focused on innovation narrowly conceived, and the conceptualization and measurement of dependent variables has reflected this approach. However, some comments about the "criterion problem" in innovation research should be offered.

Ultimately, the dependent variable or criterion used in innovation process research is the success or failure of an innovation to achieve certain purposes in practice. For many years, the explicit or implicit reason for studying innovation was based on the equation of *innovativeness* with productivity or *effectiveness* -- that is, innovative organizations were presumably better organizations. Making statements about how to increase organizational innovativeness was seen as implicitly equivalent to making statements about how to increase their productivity. This equation of the concepts of innovativeness and productivity has been termed the "pro-innovation bias" (Rogers, 1975; Kimberly, 1981), and has undoubtedly contributed to both the interest in innovation research and to overexpectations about its short-range payoffs.

But organizational theory and research challenges this equation; neither empirical nor theoretical evidence sustains such a direct relationship between organizational innovativeness and organizational health. Organizational effectiveness is a complex concept subject to evaluation from many different perspectives (Goodman and Pennings, 1977; Cameron, 1981), and research suggests that being innovative is only one of the many ways to achieve it (Georgopoulos, 1972; Van de Ven and Ferry, 1980; Cooke and Rousseau, 1981). Success or failure in innovation is valuable, but it is usually a necessary but not sufficient cause of organizational growth and survival.

Within the traditional innovation research framework, innovativeness has usually been treated as a dependent variable to be predicted by environmental, organizational, and technological characteristics. But if one rejects the view that innovation is ipso facto a good thing, new models tying innovativeness in turn to more fundamental criteria are required. In addition, if as has been suggested innovation is not one decision but a whole sequence of related decisions, there is no single dimension of "innovation" to interact with productivity. Finding a single set of stimulus/innovation/productivity links is likely to be difficult.

If the study of innovation processes is to become integrated into the large field of organizational behavior and management, it must be recognized that the usual indices of innovation -- adoption or even implementation -- are only part of a multivariate profile of organizational outcomes. The proper dependent variable must include effectiveness measures of some sort. That is, it should be a measure of some other feature of the organizational system whose occurrence is valued either because it is *intrinsically* valuable, or because it is *instrumentally* valuable in achieving the occurrence of something which *is* intrinsically valuable. Thus, the choice of dependent variables is of necessity a value-decision. Interpreting any research study involves understanding what choices about valued outcomes were made by the researchers, the focal organization(s), and/or the research sponsors (Prien, 1966).

The conceptualization and measurement of innovation effectiveness can be done in several ways. One approach is to focus on the content of effect criteria, emphasizing the aspects of activity involved. Cameron (1981) distinguishes four general classes of effectiveness models (sets of criteria); his breakdown is similar to that found in several other syntheses:

1) *Goal models:* Criteria relate to system outputs (effects on clients or other organizations) or transformation characteristics (production, efficiency, etc.);

2) *System-resource models:* Criteria relate to system inputs (command of scarce resources): staff, maintenence, efficiency, etc.;

3) *Participant-satisfaction models:* Criteria relate to the "satisfaction" (on various dimensions) or those who participate inside the system;

4) *Ecological models:* Criteria relate to the "satisfaction" of various clienteles and sponsors of the system.

Essentially, the choice of a "model" for choosing among potential effectiveness variables is a choice of a *referent group* for the criteria -- that is, a determination of whose values will be used as a standard to assess "effective" behavior (Bass, 1952; Pickle and Friedlander, 1967; Strasser *et al.*, 1981). Some of these effectiveness criteria might be *negatively* related to innovation. For example, to the extent that participant satisfaction is a valued goal and the introduction of a particular technology is disruptive to participants, then innovation will produce negative results.

Another approach to classifying criteria is based on identifying the level of applicability of the criterion in a hierarchical system of multiple roles (Eveland and Strasser, 1979):

1) *Societal criteria:* purposes relevant to the social group generally;

2) *Organizational criteria:* purposes relevant to the maintenance of the organization;

3) *Professional criteria:* purposes relevant to the norms and expectations of professional groups, transmitted during the training process;

4) *Individual criteria:* purposes relevant to the satisfaction of individuals within the organization or outside it.

Success in achieving one set of these criteria does not preclude success in terms of achieving another, but neither does it guarantee such accomplishment. The purposes may be the same or may differ. The criteria cross with Cameron's (1981) classification. That is, individual, organizations, and societies may each be concerned with outputs, resources, or satisfactions at various points and in various ways (Hannan, Freeman and Meyer, 1976).

The use of multiple criteria becomes important if one aims at explaining decision making at subunit levels -- which is in turn crucial to constructing innovation *process* models. Organizations are inherently home to many different value sets. Unfortunately, some analysts (e.g., Price, 1972) conceive effectiveness criteria only in terms of broad organization-wide "goals". This approach ignores the fact that behavior which is suboptimal from an organization-wide perspective is often rational in terms of more *local* criteria, such as those appropriate to the work group or individual.

Some analysts, rather than select a single criterion, have attempted to group criteria into broad definitions of effectiveness, recognizing that there are explicit tradeoffs to be made among them. A framework suggested by Quinn and Rohrbaugh (1981) defines three dimensions of "competing values" on which criteria may vary:

1) Flexibility *vs.* stability

2) People *vs.* organization

3) Means *vs.* ends

Whatever mode is applied to categorizing criteria, the aim is the same: to be able to separate out the different purposes being served by organizational behavior as a step toward determining how well given actions (such as being innovative) contribute to each of them. Criteria, after all, are interesting only to the degree that actions can be related to them. If the success or failure of innovation is evaluated in terms somewhat distinct from the process per se, it is reasonable to expect both "successful failure" and "failed success". The former are the cases where the failure of innovation led to a better organization; the latter, those where being innovative impeded the achievement of other organizational objectives. Abernathy's (1978) work on innovation in the automobile industry provides many illustrations of both of these outcomes. The degree of success or failure must, in this sense, be assessed according to criteria *beyond* the degree of implementation itself -- short or long range criteria for assessment of productivity which are not confounded with innovativeness per se.

The remainder of this review includes a wide range of dependent variables, ranging from simple innovativeness to complex implementation or productivity outcomes. Usually the organizational effectiveness criteria being employed are limited, often focusing no farther than innovativeness itself. The reader is advised to think carefully about just what domain of criteria is being explicitly or implicitly employed at any given point; findings relevant to the achievement of one criterion are usually only marginally generalizable to the achievement of others.

## Innovation Processes and the Limits of Disciplinary Inquiry

As Chapter I noted, the field of innovation process research has been the property of many different disciplines and points of view. Disparities between disciplines exist in both the *content* of research topics and in the *methods* used to study them. There are, of course, many methodological similarities; all disciplines tend to use statistical analyses, although they may use them for different types of inferences. Many methodological differences can be traced to content differences, although there are some disciplinary traditions which tend to affect choice of methods (for example, the psychological tradition of experimentation and the economic tradition of dynamic modelling). Furthermore, each field is likely to define a different scope of questions as relevant to the formation and execution of public policy, particularly insofar as such policies can affect innovation behavior -- a scope which is a function of other disciplinary concerns.

At this point, some very general statements will be offered about the approaches of the major disciplines to innovation process research, as a guide to other content-specific portions of the review. A focus to this presentation will be a discussion of how each discipline or analytic tradition has approached the issue of "stages" in innovation as a conceptual device. This brief discussion should *not* be interpreted as casting summary judgments on the worth or quality of science in these fields, or as any comment on the vast areas of each field *not* involved with innovation research. Moreover, no particular study undertaken within the orientation of a given discipline will display either all the faults or all the virtues of a given approach. This treatment should, however, provide some road-maps for a subsequent exploration of the contributions of different kinds of empirical research to understanding of innovation processes. Figure 4 provides a summary of the points developed in this discussion.

# DISCIPLINARY APPROACHES TO INNOVATION

| | ECONOMICS | ENGINEERING | POLITICAL SCIENCE | PSYCHOLOGY | SOCIOLOGY |
|---|---|---|---|---|---|
| FOCUS | ORGANIZATIONS AS ADJUNCTS TO MARKETS: EFFECTS OF INNOVATION | ORGANIZATIONS AS TOOLS FOR PERFORMING PREDEFINED TASKS: THE PRODUCTION PROCESS | PURSUIT OF INTERESTS THROUGH FORMATION OF GROUPS; DISTRIBUTION OF INTERESTS AS RESULT | INDIVIDUAL COMPONENT OF HUMAN BEHAVIOR: HOW PEOPLE RELATE IN GROUPS | SOCIAL STRUCTURE OF GROUPS: IMPLICATIONS FOR GROUP AND INDIVIDUAL BEHAVIOR |
| PRIMARY CONCEPTS | MACRO- AND MICRO-SYSTEMS: ASSUMPTION OF RATIONAL ACTION | COMPONENT INTEGRATION: ADJUSTMENTS TO ADDRESS COMPONENT FAILURE | INTERPLAY OF INDIVIDUAL AND GROUP INTERESTS: CONTROL MECHANISMS AND KINDS OF INTERESTS | PERSONNEL SELECTION; EMPLOYEE MOTIVATION; GROUP DYNAMICS | PERMANENT ASPECTS OF ORGANIZATIONAL STRUCTURE: ITS EFFECT ON OUTCOMES |
| POLICY CONSIDERATIONS | EFFECTS OF POLICY ON MACRO INDICATORS SUCH AS G.N.P. | RELATIVE EFFICIENCY OF VARIOUS MEANS FOR ACHIEVING PRODUCTION PURPOSES | IMPACT OF GOVERNMENT DECISIONS; DECISION-MAKING METHODS; HOW DECISIONS IMPLEMENTED | UNDEVELOPED: ISSUES WHERE DEPENDENT VARIABLE IS ASPECT OF INDIVIDUAL BEHAVIOR | GOVERNMENT ACTION AND NONMONETARY REWARDS: POWER, STATUS, ETC. |
| METHODOLOGY AND MODELS | ARCHIVAL SOURCES; CONCEPTUALLY DRIVEN; INFERENCE; REDUCTIVE MODELS | OBSERVATION; REDUCTIVE MODELS | SURVEYS: RELIANCE ON ARCHIVAL SOURCES; PROCESS MODELS; AGGREGATED CONCEPTS | SURVEYS AND OBSERVATION; SOCIAL EXPERIMENTATION; DISAGGREGATED MODELS | ORIGINAL DATA COLLECTION; CAUSAL INFERENCE; STRUCTURAL MODELS |
| MEASUREMENT AND ANALYSIS | RIGOROUS; HIGHLY QUANTITATIVE; EMPHASIS ON TIME-SERIES | CONSUMPTION AND EFFICIENCY; QUANTITY OF OUTPUT | EITHER EXTREMELY QUANTITATIVE OR EXTREMELY IMPRESSIONISTIC | MULTIPLE MEASUREMENT AND SCALING; QUANTITATIVE AND QUALITATIVE | RIGOROUS MEASUREMENT; HIGHLY QUANTITATIVE |

FIGURE 4

Economics

The field of economics focuses on that part of human behavior which involves exchanges of goods and services of value among economic units. The major focus is a transaction mechanism, the *market*, and questions of interest center on how the market works for those participating in it.

For economists, organizations exist primarily as adjuncts to markets or substitutes for them in circumstances where pure market transactions are not possible (Schumpeter, 1942; Schmookler, 1966; Chandler, 1977). When economists use organizations ("firms") as units of analysis, the firms are viewed as rational individual actors. Organizations, like individuals, do not always actually *make* rational decisions, but the analytical assumption is that they try to do so. Economic theory is generally divided into macro and micro components. Macroeconomics deals with the aggregate behavior of whole economies; microeconomics, with the behavior of individual firms within an economy or industry. Microeconomic theory, while concerned with the effects of incentives and goals, has not been much involved with the intricacies of intraorganizational decision making (with some exceptions, such as Williamson, 1981). Such variables are considered largely endogenous.

As noted, only a relatively small fraction of the questions of interest to economists relate to technological innovation. When such issues are addressed, the discussion usually centers around how government and firm policies affect broader outcomes such as inflation, employment and economic growth, which are assumed to be determined by the operations of markets (Kendrick, 1961; Feldstein, 1978). This often involves investigating how departures from pure market behavior change transactions and distributions of values (Niskanen, 1971). Policy instruments commonly considered are subsidy, regulation, and taxation, where the application of the tool is broad (across society or some segments of it) and where it is presumed to be applied reasonably equally. Such policy interventions are assumed to be external to the firm, but to have causal efficacy in determining firms' behavior in the market.

The micro/macro distinction is significant here. Public policy concerning innovation and productivity is typically made on the basis of *macro*economic theory, and effects are generally sought on macroeconomic indicators such as gross national product (Denison, 1962). Yet the interventions themselves are largely *micro*economic in application -- that is, they influence the economy only to the degree that they have effects on individual actors. The mechanisms for this interface of macro and micro effects remain largely unexplored empirically.

Economists have generally not explored the dynamics of stage models such as discussed here, although in many economic history studies (e.g., Rosenberg, 1976) a stage model is implicit. Economic analysis usually assumes that the intervening processes between inputs and outputs are largely unknowable, or at any rate irrelevant as long as the same outputs are reached (Griliches, 1973). Thus, multi-stage models tend to be reduced to a one or two stage concept. Process insight in economics generally focuses on "transaction costs" and their management (e.g., Williamson, 1981).

Economic research tends to be highly quantitative and methodologically sophisticated. Since the field is generally theoretical, its rigor is conceptually driven rather than empirically based. There is a tendency to use simple proxy measurements for complex concepts (e.g., "GNP" for "economic welfare", "wages" for "personal productivity") and to engage in extensive mathematical analysis (Leontief, 1982; Kamien and Schwartz, 1982). Variables tend to be constructs such as costs, prices, profits, returns to investments, physical quantities, market shares and structure, and rates of growth or decline over time, rather than behavioral concepts. Much emphasis is placed on the rationality of economic units and the concept o "optimizing behavior".

Economists have generally had better success in including dynamic change over time in their models than have many other fields, and have developed (under the label of "econometrics") most techniques for analyzing time-series data. Data sources are usually public or semi-public records, and there is relatively little gathering of original data or field research. Data reliability and empirical validity are correspondingly less emphasized. Economic inference is generally applied to societies (or at least firms) generally, and is best interpreted as a prescription for aggregate rather than individual or organizational behavior.

Engineering

Engineering analysis of technology in organizations (the field called "industrial engineering") is a tradition going back at least to the turn of the century, and focuses on organizations as tools for performing predefined tasks (Bartley and Chute, 1947; Perrow, 1982). The overriding concern is the production process, and individuals and groups are seen as components to be integrated along with mechanical ones into that process (Buffa, 1977). Of interest are those problems posed by component failure (in either type of component) and the consequent need to adjust the mechanism to cope with this failure.

The industrial engineer can apply his/her perspective equally well to large or small scale settings, simple or complex tasks. Core purposes are usually taken for granted -- the overall efficiency of the process is the basic justification for the analysis -- but the relations and hierarchy among sub-goals within this overriding framework of efficiency is of considerable analytical interest.

Interest in policy issues tends to center around questions of the relative efficiency of various means for achieving production purposes, and how government decisions affect the choice of means. Traditionally, engineers have been concerned with the implementation of production processes and both the user and producer stage models have been applied at various times. However, the application of these models tends to be rather atomistic and reductionistic in the treatment of human motivations and social relationships.

Research methods make heavy use of observation and relatively little use of introspection. Variables typically include concepts such as time-and-energy-consumption of processes, efficiency, and quantity of output. Generalization is typically in the form of broad principles, with a recognition that particular situations vary widely. In contrast to the more social-science disciplines, engineers have been significantly more involved with the actual development and deployment of production technologies.

## Political Science

Political science focuses on the human behavior involved in the pursuit of interests through the formation of large groups and the distribution of interests throughout society as a result of that behavior. Since the time of Aristotle, the major focus for political science has been the *state* ("polis") as an aggregation of individuals who by their participation in it become something more than simply individuals - that is, they become "citizens" and partake of a collective interest in addition to their own. It is this interplay of individual and group interests which is the primary focus of inquiry. Political scientists tend to see organizations and groups as "little states". Emphasis tends to be on control mechanisms and the kinds of interests that are involved, and emphasizes conflict as a natural state of affairs. As such, it offers a healthy antidote to the tendency of other disciplines to stress coordination and rational interaction.

Public policy questions tend to revolve around the impact of government decisions on the relative standing of various interests or stakeholders. There is also some concern with the mechanisms by which decisions are made (e.g., legislative behavior) and carried out (much of the initial interest in implementation behavior was in the public policy context). Political scientists are generally attuned to the concept of process as a slow unfolding of decisions and events, and their analysis of user behavior in particular generally appreciates the stage distinctions noted earlier. Political analyses of "agenda-setting" (Crenson, 1971; Cobb and Elder, 1972; Walker, 1974), in particular, have applications to technology generation and selection which have not been well developed to date. Unfortunately, their analysis is often at a level of conceptual aggregation (e.g., "decision making") that loses sight of the intricacies of technology deployment at the working level. Many errors involving inappropriately large units of analysis have been made from a political science perspective.

Political research tends to be either extremely quantitative or extremely impressionistic. Variables typically include distribution of political power among groups, defined policy choices, interest preferences, and ideology. Data sources are frequently survey-based, tied into political outcome assessments such as election results. The unit of analysis in political science often parallels that in economics. As noted above, organizations, blocs, and states are usually the focus of analysis with little interest in detailed intraorganizational phenomona. As a methodological corollary, reliance tends to be placed on established archival data bases and a disinclination to gather data inside the systems studied. Inference is seldom extended beyond the particular population in question. There has been attention to dynamic modeling of political phenomena, but static models continue to predominate in the literature, at least in part because of the unavailability of time-series data on many key political behavior variables.

Psychology

Psychology focuses on the individual component of human behavior. Even when the group (or organization) is the ostensible unit of analysis, primary interest lies in how the individuals relate to each other. Cognitive or social psychology is often concerned with understanding thought and decision processes; behaviorist or social-learning approaches concentrate on relating external stimulus and reward contingencies to individual and interpersonal behavior. For both, dimensions of individual behavior make up the major subject matter for this field.

Psychological research in organizations tends to center on issues such as personnel selection, employee motivation, and group dynamics (e.g., Lewin, 1947). There is little theory or research considering the organization beyond the level of small groups or group aggregates. Policy research is not well developed within psychology; it tends to focus on issues where the dependent variable is some aspect of individual behavior. Psychologists have, for example, studied the effects of educational policies on student performance, of mental health policies on personal function, and of organizational reinforcement on individual performance in the work place.

Unfortunately, psychologists tend to commit an "ecological fallacy" that is the inverse of that committed by political scientists. With their preoccupation with the individual as the unit of analysis, variables operating at the level of the organization tend to be ignored. Psychologists are usually comfortable with evolutionary stage models, but tend to miss many of the contextual aggregate-level factors which affect progress through those models.

Psychological research involves both quantitative and qualitative measurement, with use of both survey and observational data common. Experimental methods have been developed in psychology to a much more sophisticated degree than in any of the other social sciences; most of the methods for social experimentation can be traced to psychologists (Fairweather and Tornatzky, 1977). Field collection of original data is common. Inference tends to be sought to the entire population of individuals. Multiple measurement of complex concepts is common; much of the methodological advance in measurement and scaling has come in the psychological context.

## Sociology

Sociologists focus on that part of human behavior which involves interaction among people in groups and organizations. Their focus is at once more limited and more detailed than that of political scientists. Groups are typically (although not exclusively) smaller than "states", and emphasis tends to be on the internal structure of the group rather than on interpersonal influences (a point noted by Collins, 1981). It is this concept of "social structure", its major dimensions such as centralization, complexity, and formalization, and its implications for individual and collective behavior which constitutes the guiding model for sociology.

Sociologists have always had a major part in the study of organizations, and much of the body of current "organization behavior" literature is sociological in origin and focus. That is, it concentrates on the relatively permanent aspects of organizational structure and relates these to organizational and individual outcomes. Rural sociology has been particularly influential in the study of innovation *diffusion*, especially where individuals as adopters are the units of analysis (Rogers, 1983).

Sociological analysis is generally weak on its attention to process dynamics, and its best analyses are generally confined to relationships among variables within a stage rather than across stages. The discipline is also relatively weak on conceptualizing market relationships and integrating economic variables into analyses.

Policy questions which interest sociologists tend to center around how government actions of one form or another affect the distribution of nonmonetary rewards such as status, power, and dependence, among and within social groups. Sociological research tends to be highly quantitative, with considerable emphasis on rigorous measurement of limited and well-defined concepts and a strong tradition of original data collection through field research. Variables typically include structural features of groups such as "centralization" and "formalization", social influence processes, and social status. Analysis tends to be correlational/causal and single-point oriented, and inference is sought broadly -- that is, the aim is to define a conclusion which is generalizable to all or at least most groups.

## Summary

This chapter reviews a number of conceptual and methodological concerns common to most of the specific analyses described in the remainder of this review. We believe that much of the non-cumulativity frequently noted in innovation process research can be traced to failure to take such issues into account. In particular, there have been few attempts at genuinely *inter*disciplinary work in the field, through which conceptual schemata and empirical findings might be integrated. Different disciplinary approaches have seldom been employed by a single researcher within a single research project. Readers should think carefully about these issues in evaluating the substantive contributions of any specific piece of research.

# PART II

# ORGANIZATIONAL AND CONTEXTUAL COMPONENTS OF INNOVATION

# CHAPTER III

## ORGANIZATIONAL APPROACHES TO THE STUDY OF INNOVATION

Organization theory, a set of ideas drawn from many disciplines, is an area of inquiry that underlies much of the study of innovation processes and technological change. It is a bridge between "pure" social and behavioral sciences on the one hand, and management practices at the level of the organization on the other. It is an often baffling mixture of the intellectual and the normative, the data-bound and the ideological, and there are many frustrations inherent in trying to integrate findings within it (Mohr, 1982)

Organization theory is substantially more relevant to the practice of management at the operational level than to Federal policy making at the macro level, where "policy" is normally construed to operate. But organization theory as an applied science, "an approach to the systematic study of organizational behavior" (Rubenstein and Haberstroh, 1966:v), provides useful information for policy makers about what they can and cannot expect the organizations affected by their policies to do, and hence is directly relevant to the efficacy of public policy formulation and management.

As noted earlier, innovation involves intricate longitudinal processes. Since large-scale resources are typically required in the development and implementation of innovations, organizations *qua* organizations are involved with significant portions of these processes. In a modern industrial state it is fruitless to attempt an understanding of innovation outside the organizational context. The popular image of the solo inventor operating in a basement is largely fiction. The development of an innovative idea into a commercial technology requires a concentration of experts, and the implementation of that technology probably requires a centralized means of production, at least in those cases where the technology will have significant societal effects. These considerations even apply when "small" organizations are the foci of innovation. It is necessary, therefore, to understand the structured and repetitive patterns of interaction and behavior which is the essence of "organization" in order to understand innovation processes. This is in part the role of organization theory and research, and, as noted later, of *inter*organization theory as well.

Organizational analysis draws upon general theories as one source of potentially testable propositions. Sources of propositions other than general theories include both specific empirical results not tied to any general theory, and experiential insights and questions. Interest in such propositions within the government is not only based on explaining or predicting organizational behavior itself, but also on identifying factors that can be influenced by Federal policy or by management practice, either obviously and directly or subtly and indirectly. This includes determining the inherent limits beyond which such influences will *not* extend.

## Schools of Analysis

As an introduction to this conceptual literature, we examine four dominant general theories or schools of thought about organizations

(Perrow, 1979): (1) the "classical" perspective; (2) the revisionist or "human relations" approach; and (3) the neoclassical or "contingency" approach; and (4) the general systems approach.

## Classical Organization Theory

The classical view is represented by bureaucratic theory (Weber, 1947), traditional management concepts (Massie, 1965; Koontz and O'Donnell, 1976) classical public administration (Gulick and Urwick, 1937), and various versions of "scientific mana  nt" (Taylor, 1947). The common premises of these approaches are that the goals of organizations are relatively clear and unambiguous (or can be made so) and that the members of organizations can be made to serve these goals efficiently by management's deployment of rewards and motivating mechanisms concerned with members' needs for material concerns and security.

From these premises it follows that complex organizations should be designed to insure the predictable, orderly, and rational flow of work. Specialization is employed to maximize worker competence in subdivided tasks, rules are written and employed to achieve coordination between workers and units, and a hierarchical organizational structure is used to provide for centralization of authority and decision making. Communication is formal, and policy making units separate from the operating hierarchy are employed to set and assess organizational goals (e.g., a board of directors or a legislative body).

As Chapter I noted, this view of organization assumes that people can be combined with machines in linear and rational patterns. It also assumes that all tasks confronting the organization can be rationalized and made predictable, at least in the long run. Innovation, in this framework, is a series of rational decisions leading to a single clearly defined outcome.

## Human Relations

Beginning in the 1930's, this classical view was subject to vigorous questioning. Eventually, what is often called the "human relations school" evolved. Much of the original impetus was provided by the Hawthorne studies at Western Electric (Roethlisberger and Dickson, 1939), and was further developed by the analysis of organizational practice provided by Barnard (1938). These new approaches pointed out the existence and effects of informal, non-legitimized group processes within the organization. Friendship networks, cliques, and informal norms for work pace were all "discovered" by social scientists to be an important part of organizational functioning. Several field intervention studies (Marrow, Bowers and Seashore, 1967) attempted to use this knowledge to implement democratic management patterns within organizations (Likert, 1961; White and Lippitt, 1953). This view also contributed to the growth of organizational development practice as a professionalized form of management consulting focused on organizational structure and process.

Aside from the theoretical influence of these studies, they had another important effect. They tended to legitimate the possible choices by organization designers of non-bureaucratic, non-hierarchical modes of operation. Henceforth, researchers could look at participative organizations as potentially as prevalent, popular or effective as bureaucratic ones. Unfortunately, the empirical and the ideological have been hopelessly mixed in the literature on participative organizations (Locke and Schweiger, 1979), and the real effects produced by human relations approaches have been obscured. However, the human relations school did lead directly to the next major approach, contingency analysis.

Contingency Theory

The third major school of organizational analysis is represented by organizational contingency theories, which blossomed during the 1960's. These theories assert that there is not necessarily a single "best" organizational structure, either hierarchical or democratic, but rather that the structure should be adapted to the tasks being performed and the task environment.

*Tasks* are the things that individuals (with their tools) must do as part of work groups in order for the organization to achieve its purposes. In relating tasks to organization structure, tasks have been variously characterized as "certain" *vs*. "uncertain" (Lawrence and Lorsch, 1967), "stable" *vs*. "unstable" (Thompson, 1967), "uniform" *vs*. "nonuniform" (Litwak, 1961), "having few or many exceptions" (Perrow, 1967) or "involving few or many repetitive events" (Hull and Hage, 1981). There is a great deal of overlap in these characterizations.

Contingency theory in general argues that tasks which are certain, stable, uniform, have few exceptions, and many repetitive events are compatible with, and will be accomplished more effectively by, bureaucratic organizational structures which stress rules, specialization, formality and a well defined hierarchy. At the other end of the task continuum, organization structures emphasizing participation, less well-defined hierarchy, and open communication among members can more effectively accomplish more uncertain tasks. Tasks are, of course, not necessarily equivalent to "jobs" or organizational roles. A given role can consist of many or few tasks, which in turn may be in part certain and in part uncertain.

It should be understood that the description of organization tasks in contingency theory has not confined itself to the work done per se but has also included characteristics of the task environment, often external to the work group or the firm. In this more generic characterization of task, there many descriptive characterizations of task *environment*. Lawrence and Lorsch (1967) consider the "turbulence" or "stability" of product markets and of knowledge bases (concerning the organization's products and production processes). Perrow (1967) focuses on the *knowledge structure*, which he characterizes as "analyzable" or "unanalyzable". Litwak (1961) focuses more on the source of the social aspects of task, including its repetitiveness and its link to social values. Davis and Taylor (1976) discuss the direction and rate of social change and its influence on jobs. As a whole, these authors argue that turbulent, unanalyzable, unstructured environments at the macro level result in uncertain, unstable and nonuniform tasks at the micro level.*

Contingency theory has had implications for understanding innovation processes which are not always appreciated by contingency theorists themselves. For example, it has provided a way to understand why certain organization structures seem to co-occur with higher levels of innovation adoption, or with more productive research teams. If the processes and stages of innovation are construed as a series of organizational tasks, most of these tasks will be uncertain, non-uniform, and unanalyzable from

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* Chapter IV develops the discussion of the role of organizational environments in greater detail.

the perspective of the organization. Thus, certain types of structures might be predicted to be more compatible with different stages of innovation.

## Systems Theory

A fourth set of ideas and vocabulary has developed more or less in parallel with contingency theory, but emphasizes process and dynamic analysis rather than characterization and structural analysis. This approach is known collectively if loosely as the "open systems theory". Its application to organizations was first fully developed by Thompson (1967) and Katz and Kahn (1978), and is an extension of many of the principles of general systems theory (Miller, 1965b, 1965c, 1972) combined with the work of Parsons (1961) at the societal level.

A *system* is defined as any set of elements, linked in a pattern which carries information ordered according to some principles or rules. Organizations are work-performing, goal-directed systems in which the elements are individuals and their associated inanimate paraphernalia. All systems have both structures and processes. *Structures* are the relatively stable arrangements of elements in systems which can be described at any single point in time; the "role structure", "authority structure", "normative structure", "communication structure", "task structure," and others have all been distinguished by various researchers (Georgopoulos and Cooke, 1979). In contrast, *processes* are transformations in matter/energy or information relationships among system elements over time.

Obviously the structures and processes of systems have some relationship to the things that an organization does. One of the unique contributions of systems theories has been a better description of organizational tasks. For example, Georgopoulos (1972) defines seven categories of demands or problems to be addressed by organizations:

1) *Adaptation:* change to meet altered conditions in the environment;

2) *Allocation:* distribution of resources within the organization;

3) *Coordination:* assurance that system elements are all acting toward the same purposes;

4) *Integration:* the maintenance of a value and purpose structure common to the entire system;

5) *Strain:* coping with frictions between organizational parts;

6) *Output:* attainment of purposes relating to transactions with the environment;

7) *Maintenance:* keeping the system elements in working order.

It is important to note that these core system demands are not "problems" which are "solved" as such, but are recurrent issues confronting the organization, each of which may be more or less severe at any given time. They can also be translated into a much richer set of organizational goals and objectives than have usually been employed in traditional organizational research (Churchman, 1979).

As systems, organizations have *boundaries*, or perceived discontinuities between structures. Some boundaries are more easily defined, perceived, and accepted than others, and it is possible for different participants in the same organization to have different perceived boundaries (Cherns, 1976). As Aldrich (1971) notes the maintenance of a sense of "organizational boundaries" is part of the essential characteristics of an organization. When a boundary is defined, the structures and processes occurring within become part of the "organization" and everything else becomes the *environment*. Environments are defined primarily by exclusion.

A distinction is frequently made between the *relevant environment* and the larger surrounding environment.

Most analysts (e.g., Thompson, 1967; Mott, 1972) consider all social systems to be "open," although subject to considerable variation in the *degree* of openness. Such variations exist not only between organizations but among sub-parts of the same organizations. All organizational systems, however, have *some* degree of interaction with the world outside their boundaries. One of the major contributions of this approach has been to increase researchers' sensitivity both to the wide variations in activities within organizations and to the complexity of their external relations, and to highlight the difficulties of "bounding" behavior in space and time -- a point noted earlier in conjunction with the comments on defining appropriate levels and units of analysis.

## The Problems of Goals, Information, and Uncertainty

One of the implicit premises of classical theory is that organizations focus on a limited number of goals ( a *goal* being a state of affairs whose existence is valued by the organization), and attempt to "maximize" goal achievement. In Western culture at least, organizations, like people, are presumed to strive for "rationality"--that is, uncertainty-reducing information pertaining to efficient task accomplishment. Assumptions about the rational nature of organizations' behavior implicitly or explicitly underlie many analyses of innovation, particularly those in economics. However, the ability of an organization to achieve rational behavior requires nearly complete information at the very least, and even complete information does not guarantee rational behavior. In the economic model of perfect rationality, the decision maker is presumed to have the following information *a priori:*

- o The whole set of alternatives from which he will choose his actions, including knowledge of how each alternative works;
- o The set of consequences associated with each alternative and a "utility function" ordering consequences from the most preferred to the least preferred.

This rational concept of organization goals has come increasingly under attack in the literature.* For example, March and Simon (1958) argue that the actual operative goals at any given time are the result of a "satisficing" balance between a variety of discrete goals, some of which are only superficially related to the ostensible goals of the organization. Some interest groups in an organization may be attempting to replace outmoded practices in order to enhance efficiency and profitability, while at the same time other groups are trying to retain those practices in order to prevent dislocation of personnel. Which "dominant coalition" (Thompson, 1967; Hage, 1980) triumphs is an empirical question, not self-evident from theory. Moreover, there may be differences among goals depending on the hierarchical position and level of their referent (Barrett, 1970; Baldridge and Burnham, 1975). Finally, it is clear that decision alternatives do *not* necessarily exist *a priori*, but are frequently constructed creatively by participants in the decision as the sequence of events unfolds (Janis and Mann, 1977) -- a point particularly relevant to implementation analysis (see Chapter VII).

March and Simon (1958) suggest that "choice is always exercised with respect to a limited, approximate, simplified model of the real situation."

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* Chapter II noted some of the problems associated with using "goal" statements as effectiveness criteria or dependent variables in innovation analysis.

The "rational man" in decision theory is no longer a maximizer but a *satisficer:* he selects the first alternative that meets or exceeds all the criteria in his demand set (Simon, 1976). A comparable explanation of the same phenomenon is offered by Lindblom's (1959) concept of "muddling through". The kernel of these analyses is that decisions and choices in organizations are made on the basis of less than perfect information, with what information is available subject to variations in costs (Williamson, 1981), and in a milieu of partially conflicting goals that change over time.

Several reviews of the concept of "organization goal" are available (Perrow, 1968; Price, 1972; Mohr, 1973). It is worth noting that the concept is now generally recognized to include the full range of purposes to be found in the organization (Ghorpade, 1971; Steers, 1975). Distinctions are usually made between "official" and "operative" goals, between "formal" and "informal" goals, and, in Mohr's terms, between "transitive" (output) and "reflexive" (maintenance) goals. The concept is much richer than the simple formal/output view of goals suggested by some earlier work (e.g., Etzioni, 1960).

The multi-dimensional goal framework has had considerable empirical application. For example, Pincus (1974) analyzes the incentive structures operating on public education organizations and concludes that the ostensibly "rational" goals of efficiency and productivity are often secondary to "nonrational", or more correctly "non-efficiency-directed" system-survival goals (Yin, 1977; Feller, 1981). The goals for consumers of public services may include, for example, elimination of an agency if all the problems it addresses become "cured". Such a goal is not likely to be popular with most members of the organization. Clearly, if the operational goals of organizations are different and more convoluted than the publicly-stated ones, then the concept of "goal" needs empirical specification.

It should also be noted that to the extent that "rational" goals become inoperative, social systems may fall back on social interaction per se and the satisfaction of non-universalistic norms to guide behavior (Pfeffer, Salancik, and Leblebici, 1976). It is generally agreed that social interaction in groups is a primary vehicle for defining "social reality" (Festinger, 1954; Weick, 1979) and for members to achieve consensus about what is normative. In some organizations this may become the end rather then the means.

Innovation is one of the primary ways in which organizations seek to manage the environmental uncertainty within which they must operate, and fulfill their quite varied functions and goals under which they operate. Thus an organization may attempt to reduce the uncertainty and disruption of a falling market share by developing a new product or process innovation (Klein, 1977). Innovation is both a *response* to uncertainty, and a *source* of uncertainty. Inherent features of the process of innovation make "norms of rationality" largely inappropriate, or at least extremely difficult to apply.

## "Innovativeness" as an Organizational Property

As noted earlier (Chapter II), one of the guiding principles of early study of innovation was the idea that organizations (and individuals) which innovated more were inherently more effective or "better" than those that did not. The concept of "organizational innovativeness" as a global property of the organization has received a great deal of attention and has significantly shaped much of the analysis of innovation to date. This has imposed both costs and benefits on the field.

The metamorphosis of the concept of innovativeness is illuminating. In its original sense (Rogers, 1962), it was defined as "the degree to which an individual is relatively earlier than other members of his system in adopting new ideas". In this sense, the concept refers to both time and system boundaries. As the field progressed, the emphasis shifted from the study of single innovations to the study of adoptions of several innovations by the same adopter. Part of this shift can be traced to difficulties in retrieving single adoption dates for analysis (Coughenour, 1965), part to a desire for greater generalizability (Fliegel and Kivlin, 1966). Rogers and Rogers (1961) demonstrated the feasibility of creating general scales of innovativeness based on the adoption of several innovations, and thus established the concept of innovativess as a general characteristic of individuals or organizations.

When the concept of innovativeness was extended from the individual to the organizational level, it was usually associated with this "quantity of adoption" operationalization rather than one based on "time of adoption" (diffusion studies, as noted later, largely continued to use time of adoption measures). The reason was partly the greater ease of obtaining quantity data and partly the seldom-questioned assumption that "more innovation is better". At any rate, the "total number of innovations adopted" has become the major dependent variable in a whole group of studies.

Innovativeness may be measured through a closed-list method ("check off this list those innovations you adopted") or an open-list method ("tell us what innovations you have adopted") (Aiken and Hage, 1971). Allowance is usually made for size; small organizations which adopt a few innovations may be comparatively more "innovative" than larger organizations which adopt relatively fewer of those innovations for which they might be candidates. The analytical goal is to secure a single score or value which represents innovativeness. Sometimes a more sophisticated approach measuring a degree of *commitment* of the subject to the innovation is used, rather than a simple adoption dichotomy (as in Mohr, 1969).

This approach has proved valuable to the field in several ways. It forces the analyst to consider internal features of organizational systems as potential explanatory variables, and it sharpens the analytical focus beyond the interplays of vague "forces" characteristic of much of the early organizational change literature (e.g., Lewin, 1947). Unfortunately, it also imposes some significant limitations. The use of aggregate "innovativeness scores" tends to remove specific innovation decisions from their social and perceptual context, and to change the level of analysis in ways not generally allowed for. It also blurs the assessment of effects; preoccupation with the *quantity* of innovation without parallel concern for the *quality* of such processes and the depth to which they affect the organization's outcomes and operations does not add much to untangling the relationships between innovation and productive performance. Finally, the innovativeness approach has tended to rely heavily on correlation, usually without attention to implicit time-ordering of phenomena, and thus neglects the dynamics of innovation *processes* (there are a few exceptions, such as Hage and Dewar, 1973).

In the rest of this review, the concept of innovativeness will be referred to frequently. Readers are cautioned to be aware of the multiple referents of the term (quantity, quality, time, etc.) as well as of the problematical relationship of the term to other dependent variables of interest. But is is incontrovertible that much of what we think is known about "innovation processes" is actually what we think is known about "innovativeness" -- a rather different concept.

## The Key Concept of "Organizational Structure"

The structure of an organization "can be defined simply as the sum total of the ways in which it divides its labor into distinct tasks and then achieves coordination among them" (Mintzberg, 1979:2). Structure is most often contrasted with organization processes, but the relationships between organizational structure and process are difficult to specify with precision, and there is considerable empirical and conceptual controversy as to the distinction between the terms (Blau, 1962; Hall, 1972). "Structure" has usually been the more encompassing term, and has included such features as size, degree of hierarchy, number of sub-units and others. The distinction between structure and process is conceptual, not empirical -- almost any phenomenon can be analyzed as one of structure *or* process, and the choice of analytical mode depends on the questions being posed.

One analytical problem has been a tendency to define structure at the level of the overall organization, with little recognition that different groups within an organization interact with different portions of the environment and may in fact have widely differing *internal* structures. The operationalization and measurement of crucial task parameters has not continued apace with the conceptual growth of the field, and fr[illegible] [illegible]hodological standpoint there are considerable limitations to the [illegible] [illegible]ich has been done (Tosi, Aldag and Storey, 1973; Lynch, 1974; [illegible], 1972; Downey, Hellriegel and Slocum, 1975; Pennings, 1975). Accordingly, this review of the empirical literature on structure is illustrative and selective, not comprehensive.

Structure and Innovation

An early structural-functionalist study of innovation was that of Burns and Stalker (1961). In a multi-site comparison of industrial organizations, they found that those that were relatively non-bureaucratic ("organic") in structure were more amenable to technological innovation than those that were more bureaucratic ("mechanistic") in structure. However, the specific divergent properties of bureaucratic or non-bureaucratic organizations that contributed most to innovation were not well identified by the research. This study illustrates a weakness in much of the early work -- a single variable ("organic/mechanistic structure") was presumed to describe an entire organization and the manner in which it carried out a complex process.

Following Burns and Stalker, there have been a variety of structure and innovation studies at somewhat more detailed levels of analysis (Argyris, 1965). These studies have usually focused on three general variable domains: *complexity*, *formalization*, and *centralization*.*

Organizational complexity has been empirically linked to innovation. Unfortunately, complexity has been measured in a number of nonequivalent ways, most frequently as either the degree of professionalization (number

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* Generally excluded from this review is a detailed discussion of questions relating to organizational *resources*, because of considerable ambiguity in how such variables should be interpreted (Mohr, 1969; Bourgeois, 1981; Rowe and Boise, 1981). See the section below relating to organizational size issues.

of professional groups in the organization) or the diversity of specialists (Aiken and Hage, 1968; Hage, 1980; Heydebrand, 1973; Duchesneau, Cohn and Dutton, 1979) as the principal index. Although a relationship exists, the discrete processes involved are again left unclear, and the level at which the effects are felt has generally been less than adequately specified. A greater consensus among researchers on variables and their measurement and operationalization would help.

Some empirical evidence relates formalization (number of rules and specified procedures) *inversely* to innovation (Rothman, 1974). Duchesneau, Cohn and Dutton (1979) attempted to replicate the findings of several of the above referenced studies in research on the shoe industry but failed to show statistical support for the importance of formalization to innovation. However, despite the empirical evidence for the negative relationship it is unclear whether an *intentional* decrease in rules would have an effect of increasing innovation.

Evidence also links centralization, or the concentration of decision making activity and power (Price, 1972), to innovation. Hage and Aiken (1970) and Daft and Becker (1978) both suggest that the more power is decentralized the more innovative the organization is likely to be. However, centralization tends to be equated with the number of hierarchical levels in an organization, a less than adequate measure of the distribution of power or control (Tannenbaum, 1968). Moreover, there has been considerable confusion about whether centralization is a *structural* or a *process* variable. Its interpretation is largely in terms of process, reflecting how decision making power and influence are used; its measurement is largely structural, reflecting authority hierarchies and formal delegations of responsibility (Gordon *et al.*, 1974; Moch, 1976). But deriving process inferences from structure is, as previously noted, somewhat ambiguous.

In addition to various attempts to determine correlational relationships, some studies have actually manipulated structural variables and observed the effects on innovation processes. Experimental studies have the potential to begin to answer the question of whether structural variables have a relationship to change which is generic or innovation-specific. In such a field experiment, Tornatzky *et al.* (1980) found that the intentional involvement of line personnel in innovation decisions tended to increase the likelihood of the organization adopting the change. In another field experiment, Stevens and Tornatzky (1979) found that involving more people in the implementation process could increase the likelihood of innovation implementation (this also probably relates to Mechanic's (1962) observations on the "power of lower participants" in organizations). Both of these manipulations can be seen as aspects of centralization/decentralization (e.g., "participation"), and illustrate how the larger concept needs to be disaggregated into more discrete operational aspects.

Attempts have been made to relate various structures to different accomplishment of stages of the innovation process, particularly as they relate to different types of innovations. For example, Baker (1977) argues that a "phase-dominant" innovation process model, structured according to *organizational* needs or opportunities, is best suited to "unimodular" innovations (i.e., single-phase innovations involving only one or a few fields of technology); while a "project-dominant" model, organized according to the needs of the *project*, is best suited to "multi-modular" innovations (cutting across organizational boundaries, longer time horizons, and several fields of technology).

While research thus suggests that structural characteristics such as complexity, formalization and centralization are related to innovation, the literature fails to provide (1) a sense of which, if any, of the structural features contribute most to the phenomenon, and (2) which are most responsive to intervention. Moreover, this literature has tended to ignore interactive or contingent relationships between innovation characteristics and organization characteristics (for example, "flat" structures may be correlated with many small incremental innovations, pyramidal structures with a few, large-scale innovations). Recent works by Mintzberg (1979) and Hage (1980) are attempts to overcome these limitations with specific, innovation-related hypotheses which should now be subjected to empirical test.

A more telling criticism of the empirical literature involves the variety of ways in which various structural variables have been operationalized, measured or manipulated. Some meta-analytic work aggregating various findings and approaches to organizational dimensions is needed (Glass, 1978). It might be ultimately possible to create empirical typologies of organizations based on agreed-upon organizational parameters. The methodological "guidelines" offered by McKelvey (1975) are relevant to both of these research issues.

## The Special Problem of Size

Studies dealing specifically with the organizational variable of size have not been included in the previous sections of this chapter. Size turns out to be a much more ambiguous concept than its apparent concreteness in measurement terms would suggest. Most researchers would agree that size is often little more than a *proxy* variable for more meaningful underlying dimensions such as economic and organizational factors, particularly resources (Duchesneau, Cohn and Dutton, 1979). Many of these issues have been reviewed by Kimberly (1976b) but need clarification as they apply to innovation issues.

The general point is that any aggregate index of size (number of employees, amount of budget, gross receipts, etc.) is correlated with other intraorganizational variables to some degree (frequently a high degree), but does not reflect directly the degree of vertical hierarchy, the degree of internal complexity, or similar variables, or capture much about the *process* of internal decision making. For example, one could visualize two hypothetical organizations each with a thousand employees, and thus ostensibly equivalent in size. However, one might be strictly organized into sub-units such as marketing, sales, production, and research, each with its own distinctive structure (like many large retailing firms), while the other might employ a unitary structure; the comparison between them would probably break down in many crucial areas. Given previous comments on multi-level analysis and the need to concentrate on the intricacies of decision processes, the employment of a discriminating variable as crude as size per se seems inappropriate. As noted earlier, size can often confound the measurement of innovation *rates* as a measure of innovativeness; proper comparisons between such rates need some form of normalization, although the basis for selecting a normalizing variable is usually more arbitrary than analytical.

Hull and Hage (1981) offer one alternative to simplistic analysis of size by using a less ambiguous measure. They argue that the "number of repetitive events occuring withing an organization over time", which they call *scale*, is more important than number of employees, number of sales dollar, or number of patients. While scale often correlates with size, the two concepts are analytically distinct. Scale is an indicator of the amount of work done in an organization rather than its inputs or outputs. Scale thus would seem to indicate more about the internal functioning of an organization than size as it is usually measured. It is an open question, however, as to how far this concept can be extended. While it may prove useful in distinguishing among, say, manufacturing settings where numbers of unit operations are clearly specifiable, its application to other less routinized settings (such as white-collar offices, for example) is a matter for further study.

Regardless of the measure used, there is one area of research in which size (using any convenient measure) is a useful descriptor -- to delimit a class of *small firms*. Below a certain level of size, one can probably detect a major *qualitative* difference in the organization. The small business with less than 20 employees would be difficult to operate as a classical bureaucracy. Unfortunately, the literature has not been precise in identifying the underlying structural and process components of "smallness", and in specifying in other than general terms where smallness begins. This has hampered targeted intervention involving structure and process variables. Chapter VIII returns to the special problems of small firms and their important role in the innovation process.

## Interorganizational Interactions and Innovation

As the stage-process model of innovation discussed in Chapter II suggests, innovation is often an *inter*organizational process (Benson, 1975; Hall *et al.*, 1977) involving transactions among organizations. As the innovation process proceeds from R&D to marketing and dissemination, and to implementation, different organizations or organizational units are often involved. These organizations are typically involved in "trade relations" with each other. Intraorganizational research alone fails to account for much of the variance in organizational innovation. The success of NASA's space program, for example, has been attributed as much to its authority over and ability to manage its own laboratories and the thousands of private sector contractors working for it as to its technical developments per se (Doctors, 1969).

Unfortunately, empirical research on interorganizational innovation behavior has been limited. There are many elegant concepts such as "dynamic loosely coupled systems", "boundary spanning," "equilibrium", and "interorganizational networks", but they tend to be operationally ill-defined. In addition, most empirical work has studied interorganizational concepts from the point of view of a focal organization rather than include its context directly, an approach which has some conceptual and methodological failings (Cummings, 1983).

The range of interorganizational studies has been quite wide, and it is difficult to agree on one taxonomy of approaches. One early attempt by Marrett (1971) distinguishes five complementary approaches on the basis of the unit of analysis or focus of study employed:

1) *Structural traits*: intraoganizational characteristics (Levine and White, 1961; Aiken and Hage, 1968);
2) *Comparative properties*: similarity of characteristics (Miller, 1952; Reid, 1964);
3) *Relational properties*: the nature of their linkages (Guetzkow, 1965; Leadley, 1969);
4) *Formal contextual properties*: impact of the extra-organizational environments (Evan, 1966; Warren, 1967; Turk, 1970);

5) *Non-organized contextual properties*: social processes and political, economic and demographic factors (Levine and White, 1963; Evan, 1965; Clark, 1965).

Other recent attempts have been made to construct conceptual frameworks to integrate the admittedly disaggregated literature. For example, Zeitz (1980:72) offers a dialectical model of social systems. He suggests that current interorganizational theories emphasize stable patterns of behavior which ignore the "tremendous variety", "pervasive conflict" and "confounding variables" present in interorganizational relationships, and outlines several principles of dialectical interaction as they relate to interorganizational relationships. Ouchi (1980), extending the earlier work of Williamson (1975), offers a contingency theory approach to exchange relations based on two variables: goal incongruence and performance ambiguity, which are seen as determining the efficiency of transactions between individuals, groups or organizations. Defining organizations as "any stable pattern of transactions", Ouchi outlines three basic mechanisms for effectively controlling or mediating transaction costs: markets, bureaucracies, and "clans", each of which may be optimally efficient depending on exchange parameters. Finally, Provan, Beyer and Kruytbosch (1980) combine elements of the resource dependence and organizational set approaches to interorganizational relations in a study of other environmental linkages as a source of power; they find that agencies with strong links with other community elements are more powerful (e.g., successful in obtaining resources from the parent organization) than those without such ties.

Two facts stand out in any review of interorganizational relations as a factor in innovation processes. First, most studies have focused on *exchange* relationships, or transfers of resources between organizations. Second, much of the interorganizational literature has had nothing to do with innovation per se. The exchange relationship is seen as "voluntary activity between two or more organizations which has consequences, actual or anticipated for the realization of the respective goals and objectives" (Levine and White, 1961). If one organization needs certain resources held by another, it will try to enter into an exchange relationship with the resource-holding organization. This concept forms the basis of the common resource dependence view of interorganizational relations. Since organizations are not self-sustaining entities, they are forced into relationships with other organizations to obtain resources including money, skills, and access to markets (Aiken and Hage, 1968). In contrast, the system change model views interorganizational relations more as an organization's response to external intervention which has createa a problem or opportunity. In this model the impetus for the exchange is "internally directed from the environment and the focus of the exchange is environmental issues" (Van De Ven, Delbecq and Koenig, 1976).

While the concept of exchange seems conceptually compatible with the study of innovation processes, most of the existing empirical work is either limited or not directly relevant. For example, sequential work flows, such as those occurring in the innovation process where the research development and marketing activities are handled by different types of organizations, have not been studied (Hetzner, 1980). Unfortunately, studies of the exchange of "innovative information" have typically dealt with analysis of networks of individuals within a scientific specialty (Allen 1970; Griffith and Mullens, 1972), and overlooked interorganizational transaction mechanisms. Moreover, explicitly interorganizational studies have not generally dealt with innovation, but rather with how best to achieve "coordination" among fragmented organizations such as health or social service agencies (Zeitz, 1974).

Only a few studies deal explicitly with interorganizational relationships as they relate to innovation as an exchange activity or outcome. One example is Aiken and Hage's (1968) analysis of 16 health and welfare organizations, which finds correlations between factors such as programming, organizational complexity, internal communication, centralization, and innovativeness. In the context of studying the diffusion of social technology (a community care program for the mentally ill), Tornatzky *et al.* (1980) analyze the structure of the information networks between potential adopting organizations, finding that existing networks emphasized peer to peer interactions and were determined by geographic proximity. This is consistent with the findings of Eveland, Rogers and Klepper (1977), who detected only interactions *within* local areas to characterize the interorganizational network in the case of the computer-based technology they studied.

One of the major stumbling blocks to the further development of this line of research has been related to level of analysis and unit of analysis issues. While such issues are endemic to all innovation process research, they have been particularly troublesome in the area of interorganizational relations. This fact has been explicitly recognized in the literature, at least at a conceptual level (Benson 1975, 1977; Van de Ven, Emmett and Koenig, 1974; Wamsley and Zald, 1973; Zeitz, 1974, 1980; Kimberly and Evanisko, 1981). One question has been who, or what, is the correct "transaction agent". Some questions have been raised about the change in focus of analysis from the individual to the organization; interorganizational relations theorists such as Turk (1977) have redirected their focus to the organization as the constituent unit of decision making without wholly convincing empirical and analytical reasons. Klonglan *et al.* (1976) question the lack of attention to hierarchy as a mediating factor in selecting units of analysis. Their study of interorganizational relations across three levels of hierarchy (state, district, and county) suggests a difference in the type and intensity of interactions at each level. They conclude that previous studies which have combined results across levels have obscured important differences.

Another issue here is whether the process should be viewed from a systems or a "focal organization" perspective. Some organizational contingency theorists preoccupied with environmental uncertainty have tended to focus on a single "focal" organization in concert with its "environment" (Lawrence and Lorsch, 1967; Duncan, 1972; Downey, Hellriegel and Slocum, 1976). Specific organizations in the focal organization's environment are not identified, but are lumped together in composite categories such as direct relationships (i.e., with customers, suppliers, etc.) and indirect relationships (i.e., with regulatory agencies). This has tended to obscure the fact that interorganizational interactions are discrete behavioral events that involve sub-units or people within organizations and some tangible or symbolic medium of exchange.

By contrast, organization-set research distinguishes between the *specific* and *general* environments of the organization, and between research dealing with limited sets of organizations versus research dealing with entire systems of organizations. The organization-*set*, or specific environment, is defined by immediate, continguous, task-related interactions engaged in by a focal organization (Evan, 1966; Jacobs, 1974; Schmidt and Kochan, 1977). In this approach, public policy actions, technological factors, and economic and socio-cultural conditions are often considered as part of a more diffuse general environment. The organization-set concept may be appropriate for understanding certain kinds of innovation. However, since it is defined from the perspective of a focal organization, it tends to ignore the potential and actual interactions and importance of a larger array of organizations and individuals in the general environment. The focus on trees tends to blur the larger interorganizational forest.

In order to deal directly with the issue of public policies and actions from an interorganizational perspective it is necessary to go beyond the level of immediate organization sets to deal with the system or *network* level (Marrett, 1971; Van de Ven, Emmett and Koenig, 1974; Wamsley and Zald, 1973). What organizations or individuals to include in the system is an empirical issue for which the methodology of social network analysis is ideally suited (Farace and Mabee, 1980). This methodology is designed to determine the extent of interaction between groups or individuals over time. In contrast to other approaches, the typical unit of analysis is the interactive node or link (Coleman, 1958). While this analysis has been occasionally applied to the study of innovation (e.g., Wuthnow, 1981; Tornatzky *et al.*, 1980), there have been some limitations in the generalizability of findings. The problems include homogeneous populations, unit of analysis, and small numbers of cases and limited focus of organizations (Allen, 1970; Garvey, Lin and Nelson, 1970; Griffith and Mullens, 1972; Granovetter, 1973; Beniger, 1979).

One of the results of the network analysis approach has been an increased awareness that the next methodological and conceptual step for the study of interorganizational relations is to use as the unit of analysis the *links* between a much larger array of organizations. Thus, not only must the study be broadened to include *systems* of interactions, but the focus of data gathering must be on discrete relations embodied by these links. In this way, perhaps, a microanalytic data base on links can also yield macroanalytic inferences about networks of interorganizational relations.

## Summary

Organization theory is a complex and divergent literature which deals with many phenomena aside from innovation. Given its diversity, it offers few clear prescriptions for the conduct of innovative processes, but much in the way of heuristic value. It has contributed enormously to the development of analytical frameworks, definition of key variables, and specification of organizational models. Any systematic analysis of innovation must be carried out within the context of this body of ideas. As subsequent themes are developed, the vocabulary and ideas presented here will be drawn upon; the innovation process is clearly an *organizational* activity of major importance.

## CHAPTER IV

## CONTEXTUAL INFLUENCES ON TECHNOLOGICAL INNOVATION

This chapter considers various influences originating outside the innovating organization that affect the innovation processs within.* The role of external influences (or environmental conditions) has been a common theme pursued by various researchers in the field. For example, Allen (1977) has studied the role of various sources of external information in the functions of R&D and engineering in the firm; von Hippel (1978) has described the conditions under which firms' external customers are the source of innovative ideas and products; Eveland, Rogers and Klepper (1977) have discussed the influences among organizations jointly involved in the implementation of new technologies.

All of these examples illustrate an important characteristic of this line of research: that is, "environmental" influences on innovation in an organization range all the way from economy-wide market forces or government regulations down to discrete interorganizational transactions, such as suggestions for product redesign by users or transfers of technical personnel. The integrating concept is that all such variables are *external* to the innovating organization but are assumed to affect *intra*organizational

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* The influences discussed in this chapter are *generic* rather than specific. Chapter IX discusses a series of particular governmental initiatives which operate within the analytical framework outlined here.

processes (Insull and Moos, 1974; Moos, 1975). External influences are significant determinants of organizational growth and decline (Freeman and Hannan, 1975).

## Analytical Approaches

Within this general orientation, three main conceptual traditions of research on the relationships betwen organizational environments and innovation can be distinguished: (1) diffusion research; (2) the microeconomic theory of the firm; and (3) sociological or sociopolitical analysis, usually guided by general systems assumptions. These approaches are dissimilar in vocabulary, but in fact describe many of the same phenomena and come to some interestingly parallel conclusions. These are discussed in turn, along with some concluding observations on sector-level effects on organizational environments.

### Diffusion Research

*Diffusion* is the pattern by which new ideas and practices spread through a population of potential adopters. The key point which differentiates diffusion research from, say, innovativeness research or other innovation process models is that diffusion takes as its starting point the *innovation* rather than the *organization*. This approach has a long and distinguished history (see Rogers (1983) for a complete description of its development and content). With the work of Ryan and Gross (1943) on the adoption of hybrid seed corn, diffusion research became well entrenched in American social research. Its major theme is that *communication* is the basic process by which people become aware of new things and decide to use them; therefore, the dynamics of the communication process are important to understanding innovative behavior.

The basic theme has been developed in either of two general directions. One emphasizes the *population* aspects of the problem and the mathematics of population behavior; this end of the spectrum abuts the field of population ecology. The other direction concentrates more on the adopter as an individual unit, emphasizing that an internal decision process of more or less complexity is involved. The most widely used framework for analysis of this process is probably that of Rogers (1983), who distinguishes five stages (knowledge, persuasion, decision, implementation, and confirmation). Both directions have contributed to innovation research.

This approach has been particularly fruitful in its analysis of the role of communication networks as a special sort of environmental feature. Coleman, Katz and Menzel (1966) offer evidence that physicians who are more central in professional networks tend to adopt innoavtions more readily than those who are not. Becker (1969, 1970) finds that the nature of the innovation seems to affect this pattern, with more central people being likely to adopt only more "rewarding" innovations. Counte and Kimberly (1974) note that trust and credibility in source-relationships are particularly important.

The original applications of diffusion study were to the behavior of individuals. However, as Katz (1962) noted at that point, increasing applications of this approach have been made in situations where the "adopters" are not individuals but organizations. Diffusion analysis is presently complicated not only by unit of analysis questions but also by problems of the definition of the innovation, classification of innovations, and basic differences between the economic and sociological modes of analysis (Warner, 1974).

In practice, diffusion analysis has been applied with impartiality to situations in which adopters are either individuals or organizations such as firms (Utterback, 1974; Martino, Chen and Lentz, 1978) or government agencies (Feller, Menzel and Engel, 1974; Feller and Menzel, 1976). This lack of discrimination between the individual and organizational situations causes some problems. For example, the data gathered by Becker (1969) are dominated by variables describing the personality and location of the health officer in his communication network, while the dependent variable (adoption of innovation) is an *organizational* property. Thus, within this approach one is either forced to "personalize" the organizations under study or simply to assume that populations of organizations and individuals behave in the same ways, an approach used in the state government innovation studies of Walker (1969) and Gray (1973).

Two other pitfalls of applying the diffusion model to organizational innovation are worth noting. First, it is easy to move from a sense of "adoption" as an act of individual will to a consideration of innovation as simply a statistical phenomenon. The prevalence of the logistic curve in diffusion analysis has been so widely noted that it is not difficult to mistake the description for the cause, and assume that membership in a population is reason enough for adoption. The mathematical approach of Hamblin *et al.* (1973), which postulates a series of highly predictive but interpretationally barren sets of equations describing adoption probabilities, is the logical outcome of this road. This mode of analysis is certainly useful, particularly in market research, but is not very helpful in understanding *process* issues.

Moreover, it is often difficult to separate the effects of diffusion as a communication phenomenon from the effects of intraorganizational dynamics, as Naroll (1965) points out from an anthropological perspective. Where diffusion ends and organization behavior begins is hard to identify, particularly where the communication processes themselves are hard to retrieve (Granovetter, 1973).

In sum, diffusion research has been one of the major traditions to investigate innovation. It has helped strengthen the understanding of communication and the flow of ideas through organizational environments. It has, however, also occasionally hampered understanding of the presence of variability in both innovations and organizational contexts, and has suffered from an excess of assumptions about the similarity of adopters and their world-views. It is clear that understanding diffusion is only a part, albeit an important part, of understanding the complex role of environmental influences on innovation dynamics.

## Microeconomic Theory

Economists were perhaps the earliest to recognize explicitly the importance of the environment to the behavior of organizations. The microeconomic model is in some ways more attractive than most organizational theory models because it purports to be predictive, rather than merely descriptive. However, like the more mathematical varieties of diffusion analysis, its predictive features depend on assumptions involving a high degree of abstraction and remoteness from reality. This greatly reduces the operational value of the model outside of applications such as price and market share determination. It has very little to say about intraorganizational processes.

The basic model is that of economic units (*firms*) with essentially identical products or services competing in markets, the basic focus of analysis. The *degree of competition* is the critical descriptor of a market. Competition in turn depends on the number of firms in the market, the extent to which any given firm differentiates its product to enhance its utility to potential buyers, and the minimum efficient scales of production and distribution as they affect the size of the market. The basic categories of markets, characterized by increasing degrees of competition, are monopoly, oligopoly, imperfect competition and perfect competition. The aggregate profit of firms in a market is an indicator of the economic dominance (or lack of competition) of its constituent firms; in theory, it ranges from zero under perfect competition to its maximum possible level under monopolistic conditions.

It is worth stressing that despite an awareness in the economics literature that product differentiation through attractive improvements -- one of the determinants of market dominance -- can be achieved with active efforts to innovate (i.e., by choosing agressive R&D strategies), the basic economic model does not deal with this source of change. Instead, the model treats technological change as an external force and has little to say about how it is shaped by intraorganizational processes.

In addition, the basic economic model does not really consider the impact of the external environment on organizational behavior. It deals with organizational behavior only in the most rudimentary way, and the only "behavior" which counts is the firm-level "decision". The organization is treated as if it were a single individual pursuing a single goal or decision criterion (usually profit), rather than many individuals or groups of individuals with multiple, heterogenous, and partly conflicting criteria.

No organizational characteristics of process or structure which mediate the effectiveness of decision processes are treated in the basic model.

## Recent Theoretical Work in Economics

Expansions of the microeconomic model into aspects of organization behavior began with March and Simon (1958), and include the work of Cyert and March (1963) and Williamson (1975). While the focus is still on the role and formation of economic goals rather then on broader organizational dynamics, more common ground is emerging between microeconomic theory and systems and organization theory. For example, both Levine and White (1961) (who represent the organization theory perspective) and Williamson (1975) (who represents the economic analysis tradition) have focused on the exchange relationship, and Ouchi (1977) has further developed common themes in both bodies of analysis.

Recent work in microeconomics has begun to deal directly with the reality of technological change as an environmental condition and, more importantly, as a deliberate element of firm strategy. Nelson and Winter (1974) and David (1974) have outlined rational models of how this search process tends to occur. Rosenberg (1976) and Nelson and Winter (1977) both suggest that firms will continue to produce a given product until factor prices change (in response to changing environmental conditions) in such a way as to reduce profit significantly. Firms will then begin active search for ways of saving inputs or improving output quality. This entire process is riddled with uncertainty about future input prices, about the outcome of the search process, and about the marketability of the resulting technical products.

The fundamental possibility explored in this new economic literature is whether traditional equilibrium-oriented models should be discarded for more evolutionary models of technological innovation that explicitly consider risk, uncertainty, and firm strategy. Kamien and Schwartz (1974; 1982) retain the basic microeconomic market model, while directly incorporating aggressive R&D (invention) and defensive R&D (imitation) as strategies. Klein (1977) offers a conceptual model explaining firms' reactions to a changing technical environment which integrates organizational variables with the market model of oligopoly. This model explores the kinds of incentives and random factors that affect firms' future courses of action. It offers a rationale for both defensive and aggressive R&D and a new view of the intensity of competition.

In a parallel line of inquiry, there has also been significant empirical work investigating the effects on innovativeness and innovation of the distribution of sizes of firms in an industry, both within and across industries. Two conflicting hypotheses are represented in size-distribution research. One hypothesis is that an increasing concentration of firms enables those firms to restrict entry by others and reduces the incentives of the dominant firms to undertake R&D and innovation. A contrasting argument is that some critical mass of firm resources is necessary both for efficient operations and effective innovative activities such as R&D, since certain development projects may require large outlays that only large firms can afford.

Neither of these hypotheses has been strongly confirmed through empirical research, although the latter appears to characterize some kinds of development in some industries, such as petroleum refining, steelmaking (Gold, Pierce and Rosegger, 1970; Boylan, 1977), and some chemical process areas (Kamien and Schwartz, 1975). The incentives are greatest where the innovation can be applied to products or processes commanding large market shares. Such may be the case with incremental product improvements and process technology (Abernathy and Utterback, 1978).

Emerging evidence also challenges the traditional view that the interaction between an organization and its environment is passive and that given markets are stable (Freeman, 1974). Carter and Williams (1959) and Science Policy Research Unit (1971) have found that the nature of communications with external individuals and organizations who have some critical relationship to the firm contributes significantly to explaining the success of innovations.

Another important finding concerns the strategic nature of R&D undertaken by firms. As noted earlier, R&D programs can be described as aggressive or defensive in nature; that is, either "invention" or "innovation" oriented. The distinction is that firms with aggressive strategies attempt to be the first to invent and develop new products, while defensive firms let others take the lead but follow that lead vigorously when its value is demonstrated. Using an aggressive strategy is likely to allow the firm to earn a greater profit than their imitators, but at the expense of higher expenditures on R&D. However, few large firms fit this description clearly. One often suggested reason is that basic research results are difficult for individual firms to appropriate for their exclusive use.

On the other hand, the major rationale for conducting defensive R&D programs is related to uncertainty. Defensive R&D will enable firms to react to major new inventions being developed elsewhere, and to make minor improvements in existing products and processes without taking major risks. This R&D strategy has been found to characterize most medium to large firms' R&D programs (Nelson, Peck and Kalachek, 1967). A defensive R&D strategy is not necessarily indicative of a low commitment to the idea of R&D as such.

Findings from Systems and Organizational Research

The systems and organization theory literature on organizational environments has considerable parallels to the microeconomic literature. For example, the types of organizational environments discussed by Emery and Trist (1965), who are systems theorists, have at least a plausible correspondence to market structures; "placid randomized" environments resemble perfect competition or monopoly situations, "placid clustered" environments resemble imperfect competition, and "disturbed reactive" environments resemble oligopolies. However, their "turbulent field" environment seems to have no clear parallel in economic analysis.

However, this literature has at least one feature distinguishing it from economics -- that is, the greater importance of uncertainty as an integrating concept. There is little preoccupation -- as in the theoretical economics literature -- with hypothetical states or placid environments. The systems literature, rather, suggests that in fact uncertainty is the *dominant* distinguishing feature of organizational life. Terreberry (1968), for example, argues that the categories of environments defined by Emery and Trist represent in fact stages in evolution from the placid randomized to the turbulent field; she also asserts that turbulent fields are becoming the dominant type of environment.

The dimensions of environment discussed by system theorists encompass but extend the microeconomic concept of markets. Concepts common to the two modes of analysis include transactions of labor, material, and capital.

The system view addresses the interactions among distributors of products or services, users of products or services, equipment suppliers, parts suppliers, competitors for raw materials, competitors for suppliers, competitors for customers, government regulatory control, public groups, and producers of both product technologies and process technologies (Lawrence and Lorsch, 1967; Duncan, 1972; Downey, Hellriegel and Slocum, 1975; Hetzner, 1980).

The "population ecology" approach (e.g., Hannan and Freeman, 1977) is a theoretically rich approach for describing the behavior of populations of organizations over time; it combines elements of diffusion and economic research with organizational analysis. Its long-term utility to the understanding of innovation *processes* is, as yet, undetermined.

There have been attempts to sort out which sources of environmental uncertainty are most important. Pfeffer and Salancik (1978:69) suggest environmental uncertainties are not in and of themselves important except as they affect the internal processes of the firm:

> It is a problem for organizations only when the uncertainty involves important interactions with other environmental elements that are important for the organization.

An unstable labor supply, for example, is important only if an organization is highly dependent upon this labor supply and then only if it is recognized by the organization as a factor in the decision process -- that is, if it influences organizational structure and functioning. Several studies have shown that in comparing organizations within and across different types of environments, the structure and functioning of those organizations which succeed seem to match some characteristics of their environments (Woodward, 1965; Burns and Stalker, 1961; Harvey, 1968; Lawrence and Lorsch, 1967, 1969; Duncan, 1972; Downey, Hellriegel and Slocum, 1975;

Meyer, 1979). Successful performance under a high level of environmental uncertainty tends to be associated with less structured, less formal, and decentralized organizations, employing a relatively "professional" work force. Success under low levels of environmental uncertainty is, on the other hand, associated with structured, formal and hierarchical organizations and a relatively unskilled work force.

In addition to sorting out environmental factors as perceived by participants, it is also necessary to obtain more "objective" indicators of environments and uncertainty. Pfeffer and Salancik (1978) view the basic structural elements of environments as *concentration* (the distribution of power and authority), *munificence* (availability of resources), and *interconnectedness* (interaction network) of environments. These three characteristics are seen as determinants of conflict and interdependence among actors (organizations and individuals) in a social system. Conflict and interdependence, in turn, determine the degree of uncertainty described earlier in this chapter.

A major problem is that the concept of environmental uncertainty lacks clarity. A level of analysis problem complicates the operational definition of variables describing both structure and environment: relatively "mechanistic" organizations can (and probably usually do) have "organic" subsystems, and the "environment" addressed by an organization is seldom homogeneous across different subsystems. To characterize the structure or environment of a large organization as being of only one particular type makes very little sense. Some parts may be quite placid, others quite turbulent. The question is which organizational subsystem interacts with which piece of the environment. One organizing concept for this patterning is the idea of *accountability* (Etzioni, 1975). Under this formulation, the key issue is the relationship of an organizational unit with some identifiable point in the environment; this relationship is characterized by certain mutually agreed-on terms. Variables describing these interactions can then be used to account for organizational decision making.

Analytical difficulties notwithstanding, the increased interest in organizational environments has important implications for both the study and management of innovation. For managers involved in innovation, attention to environments implies that they must now be concerned with managing external as well as internal relationships, and that external structures and processes may be more important determinants of behaviors such as innovation than internal structures and processes. For innovation researchers, viewing innovation exclusively as an intraorganizational process unaffected by environmental conditions cannot be appropriate in situations where the dependence of organizations on their surroundings is high.

## Distinguishing between Public and Private Sectors

Applying these concepts of organizational environments in cross-sectoral (public vs. private) comparisons raises some interesting problems. Virtually all microeconomic research and much organizational research has focused on private organizations (an exception is the implementation literature discussed in Chapter VII). A common conclusion is that because of the presence or absence of market forces private and public organizations comprise two entirely different domains of inference, and that one should not expect to be able to generalize between sectors.

This assertion is more assumed than proven (Roessner, 1979). In practice organizations of both types often behave in strikingly similar ways, and organizations in both sectors increasingly affect each other's actions. Interorganizational networks tend to include both public and private organizations; the environment of nearly any organization is made up of participants in both sectors. This section briefly looks at both real and apparent differences between the sectors, and suggests some implications of these differences for the study of innovation. Figure 5 summarizes the distinctions made in this section.

A common distinction between public and private organizations is made on the basis of their ownership (Becker and Gordon, 1966). Public organizations are those over which no property rights are vested in any group smaller than the society as a whole. This usage, while frequently encountered in the political literature, is not perhaps as precise as might be desired, since the scope of property rights is not very clear. The term "public sector" is also frequently used to cover all organizations which do not formally seek "profits" as part of their goal set -- this would include, in addition to governments, the range of nonprofit and not-for-profit groups which are not socially owned but which try to serve societal purposes rather than those of a limited group of formal owners. Moreover, it is sometimes used to embrace as well the nominally profit seeking but in fact highly constrained regulated monopolies such as telephone companies and utilities.

These distinctions of ownership and goals are often quite fleeting at an operational level. For example, it can be argued that all normal organizations seek to aggrandize their resources; public agencies accumulate appropriations and create client demands, while private firms capture markets and improve profit margins. In fact, the "system resource" model of organizational effectiveness (mentioned earlier in Chapter II) is based

# THE IMPLEMENTATION OF INNOVATION

## DIFFERENCES BETWEEN PUBLIC AND PRIVATE SECTOR CHARACTERISTICS

| | PUBLIC SECTOR | PRIVATE SECTOR |
|---|---|---|
| NORMS OF RESPONSIVENESS | RESPOND TO PUBLIC CONCERN | ANTICIPATE PUBLIC CONCERN |
| LOCUS OF RESPONSIBILITY | COLLECTIVE | INDIVIDUAL |
| "PUBLIC GOODS" | INAPPROPRIABLE GOODS | APPROPRIABLE GOODS |
| PLANNING HORIZONS | ANNUAL BUDGET CYCLES | SHORT TERM vs. LONG TERM |

FIGURE 5

explicitly on this interchangeability of effectiveness criteria (Yuchtman and Seashore, 1967).

In another version of conventional wisdom, the difference between private and public organizations lies in the idea that public agencies are "bureaucracies", while private organizations are not. *Bureaucracy* here generally implies an organization which is rule-bound, generally unresponsive, and essentially immune to the presumably rational market forces. In his generally negative discussion of bureaucracy, Downs (1967) drew exclusively on public organizations for examples. But others have explored bureaucratization in the original, more neutral, sense of the term (Weber, 1947), as a set of characteristics possessed by *all* organizations to varying degrees (e.g., Litwak, 1961). Bureaucratization in this sense is approximately equivalent to the "mechanistic" dimension described earlier. It does seem clear that there is no single absolute characteristic of behavior or structure (as opposed to legal mandate) which separates organizations in the two sectors; bureaucracies and non-bureaucracies are found in both areas.

In general, it seems that the differences, such as they are, between public and private organizations may be more apparent than real in many key regards. There is probably as much *within-sector variability* (e.g., steel companies *vs.* computer software firms) as there is *between-sector similarity* (e.g., private and public hospitals). If this is true, it suggests that cross-sector comparisons in the study of innovation processes are not only feasible but can be quite enlightening, notwithstanding the fact that very few such comparisons have been made. This literature review draws on studies from both sectors to illustrate key points, particularly relating to structure and process. In cross-sector comparisons and contrasts, one should concentrate on those variables which are likely to be related to public *vs.* private sector location.

As one approach to such an analytical framework, Bozeman (1981) has suggested a set of "dimensions of publicness" which can be used where cross-sector generalizability is sought:

1) *Dependencies*: the degree to which resources are a reward for output;

2) *Creation mechanisms*: the nature of the mechanisms which exist for formal creation and dissolution of activities;

3) *Accountability* for process rather than for output;

4) *Goal dependence*: reliance on external sources to set goals and legitimate purposes.

These are seen as dimensions in which one end represents the extreme "public type", the other the extreme "private type". In practice, most organizations (and components of organizations) fall somewhere between.

A good deal of the difference, as implied earlier, depends on the level of aggregation of the organizations under study. When one compares entire firms with entire agencies, apparent differences are likely to stand out more clearly than if one compares, say, sections or working groups. The latter are likely to concentrate their attention on intermediate or instrumental objectives which are only loosely related to the ultimate or terminal objectives of either private profit or public service. Given that a large part of the behavior germane to organizational innovation is in fact "local behavior" which does not involve the entire organization (Downs and Mohr, 1976), cross-sector generalization may be even more conceptually defensible. This is probably most true in cases of process innovation (e.g., office automation or other managerial tools). Firm decisions about new product lines and governmental decisions about new areas of service are probably less comparable. The process of determining the applicability of these dimensions of "publicness" is one of assessing differences between organizations in the two sectors, broadly defined.

Artifactual Differences

Some commonly asserted distinctions are probably not quantum differences but, at best, matters of degree:

The presence of entrepreneureal behavior: While entrepreneurealism is commonly accepted as a norm of the private sector, it is in fact a relatively rare phenomenon, characterizing only a few organizations and then only at particular points in their life cycles (Kimberly and Miles, 1980). On the other hand, entrepreneureal behavior, on behalf of both individuals and organizations, has been documented extensively in public agencies (e.g., Lambright, 1980). It is probably too limiting to construe entrepreneureal behavior as profit-seeking in the conventional sense. More correctly, this behavior should be seen as *resource aggrandizement* (in people, money, ideas) or as an attempt to widen the scope and power of an organization and hence improve its ability to maneuver. A key part of the role of either the public or private entrepreneur is the creative maintenance of conflicts among one's competitors, to exploit power vacuums or economic niches (Sieber, 1974; Rogers and Molnar, 1976). Entrepreneureal behavior is also related to personal characteristics that may transcend sector or setting, such as risk taking and achievement motivation.

Permanence: It is commonly believed that public agencies last considerably longer than do private firms, and there is some evidence that this is true. Kaufman (1976) traces the major components of seven executive agencies in the Federal government over a period of fifty years, and finds considerable evidence for long-term survival. However, this permanence is probably more true on the gross level than on the operational level. Major organizational units may persist, but the discrete tasks they perform are likely to shift over time and to be reorganized frequently. This is probably more true in areas of government where the public role is less established (such as housing, energy, or environmental regulation) than in areas where the public role has become more institutionalized, such as public health, agriculture, or taxation. In terms of sheer organizational mortality, survival rates are probably higher for the public sector generally, although this may be changing in the current political climate.

Personalization of gain: Managers in private organizations can profit (or lose) personally from their efforts, while government managers presumably cannot. In terms of direct compensation, this is perhaps true, though it is worth noting that the vast bulk of private managers are in salaried positions where the direct marginal returns to effort by an individual are often ephemeral. But certain similarities are striking. In both sectors, the major currency which managers gain or lose is personal reputation, career mobility, and opportunities for rewards. These depend largely on the success or failure of their organizations. For many managers this is a more salient part of compensation than salary. Given the tendency for senior managers to move between sectors at various points in their careers, the personalization of reward in a narrow sense may be a decreasingly salient distinction (Malek, 1978).

One qualification should be noted. The manager of a *small* business firm is likely to have personal rewards and costs more directly tied to organizational success than are either public sector managers or managers in large firms. This may be related in turn to the apparent innovativeness of small firms, discussed elsewhere in this review.

Freedom to shift goals: Some analysts have suggested that public organizations are more constrained than private ones in redefining their goals. Again, this is true on a gross level but less true when one looks at specific organizations. Government programs are theoretically constrained by legislative mandates. But the essence of administration is in the interpretation of those mandates, and agencies not infrequently redefine mandates, sometimes with legislative authority, sometimes without. A classic case of this behavior is the experience of the Agricultural Extension Service (Rogers, Eveland and Bean, 1976). It is this administrative flexibility which has stimulated much of the research on implementation (see Chapter VII). Considerable variability in de facto program goals and program operations have been uncovered by this work. In fact, one of the problems that has plagued the oversight of public programs has been the shifting nature of many program goals and the resultant low "evaluability" of programs (Nay and Kay, 1982). It is difficult to assert that public agencies have more goal stability than large firms, where the tendency to perservere with outmoded products and strategies is common and well documented (e.g., Utterback, 1971).

Public control: It should be hardly necessary to note that the increasing accountability demanded from private firms by the public, either acting through government or through other agencies, has blurred the public/private distinction still further. Private firms are increasingly affected by public agencies, not only in the quality and safety of their outputs but increasingly in internal processes such as procurement policies and personnel practices as well. In addition, there has been in recent years a significant increase in the number of worker-owned or worker-managed firms (Tannenbaum and Conte, 1977), a trend that stretches the definition of "private" ownership and the resulting constituency of the firm. It is still an open question as to how worker ownership has affected management entrepreneurealism, product innovativeness, strategic planning, and implementation of new process technologies. The accountability of government is also being increased by various policy devices. Mechanisms such as sunset laws, sunshine laws, and freedom of information rules have resulted in more direct scrutiny of government agencies by both the media and the public at large, and evaluation systems have made public a good deal of information regarding the systematic effects of programs (Rossi and Williams, 1972; Cook *et al*., 1975; Hatry, 1977).

Real Differences

Some differences between public and private sectors are probably more consistent and operationally significant:

Norms of responsiveness: In general, society believes that government should *follow* public concern rather than *anticipate* it. Successful instances of anticipatory government are few. Firms, on the other hand, are explicitly supposed to anticipate what the market will support and move to supply it even before people see a need for it. This phenomenon of responsiveness should be distinguished from entrepreneurealism, noted above. Responsiveness refers to the societal purpose being pursued, entrepreneurealism to the behavior of the individuals involved.

Locus of responsibility for consequences: In general, the individual responsibility for consequences is probably greater in the private sector. The norm of public agencies is collective responsibility, and it is seldom, except in cases of flagrant illegality, that personal responsibility for an organizational action will be sought. In private firms, responsibility is likely to be assigned to individuals rather more frequently. While it may be difficult to assign personal responsibility (given the long links of causality in any complex organization), the tendency and mythology of the private firm is to attempt to do so. It is also interesting to note that the recent experiment of the Federal personnel system with an individual-responsibility centered reward system for senior executives is explicitly based on private-sector assumptions. Whether these assumptions are transferrable is currently under investigation (Gaertner and Gaertner, 1982).

Concentration on "Public Goods": In general, the concerns of public agencies are focused on public goods -- that is, those products and services which cannot be uniquely appropriated to the benefit of one restricted group (e.g., highways, schools, prisons). Firms, on the other hand, concentrate on appropriable goods.

Planning Horizons: Both sectors recognize that organizations pursue multiple purposes, but they react rather differently to that fact. On one level, private firms are supposed to pursue profits, and any purpose which does not contribute to the "bottom line" is considered as at best a compromise goal. On the other hand, firms *do* explicitly consider a range of other goals -- market share, item profitability, time horizons, etc. -- which are not directly relevant to maximizing momentary profitability. If this were not so, little R&D would be done. In fact, one of the criticisms that has been made of larger American firms is that they focus excessively on short-term profits while ignoring other ostensibly public goals such as increasing general knowledge, training scientific personnel. This criticism is premised on the fact that these public goods enable private firms (in the aggregate) to reach long-term private goals; this "social return" of research is significant (Mansfield, 1968).

What differences may exist in the planning horizons of private vs. public organizations are ambiguous at best and unknown at worst. Public sector organizations are tied to annual budget cycles and an incremental budget process that constrains what little long-term planning is possible (Wildavsky, 1964). On the other hand, firms must presumably balance the short term against the long term, and how they do this is not well known. Hayes and Abernathy (1980) suggest that in fact the public and private sectors are becoming increasingly alike in having short term time horizons. In addition, all organizations, public and private alike, must deal with changing patterns of general social and economic forces (Bell, 1973).

Summary

The research literature reviewed here illustrates that innovation is a process that involves many levels of activity and foci of analysis. While innovation behavior is largely intraorganizational, this behavior is initiated in response to some stimulus event or to achieve some instrumental goal. Environmental stimuli such as discussed here are particularly significant for innovation. Whatever model or vocabulary is chosen to examine environmental phenomena, they must have their place in any innovation process model.

## CHAPTER V

## ACTORS IN THE INNOVATION PROCESS

Other sections in this review have described sources of uncertainty in the innovation process and outlined various organizational variables pertinent to the management of those uncertainties. However, when data on innovation processes are aggregated to the organizational or group level, the role of individuals acting within those organizations can be obscured. The uncertainties of innovation are ultimately handled by *people*, either acting alone or in the context of a work group, not by abstractions called "organizations". The success of any innovation depends on the participation of any number of individual actors who are able to carry a new idea through the innovation process, from research and development through commercialization and implementation. This chapter will review data on how innovation processes are shaped by the individuals who participate in them, and note some limits on the efficacy of that behavior and on this level of analysis itself.

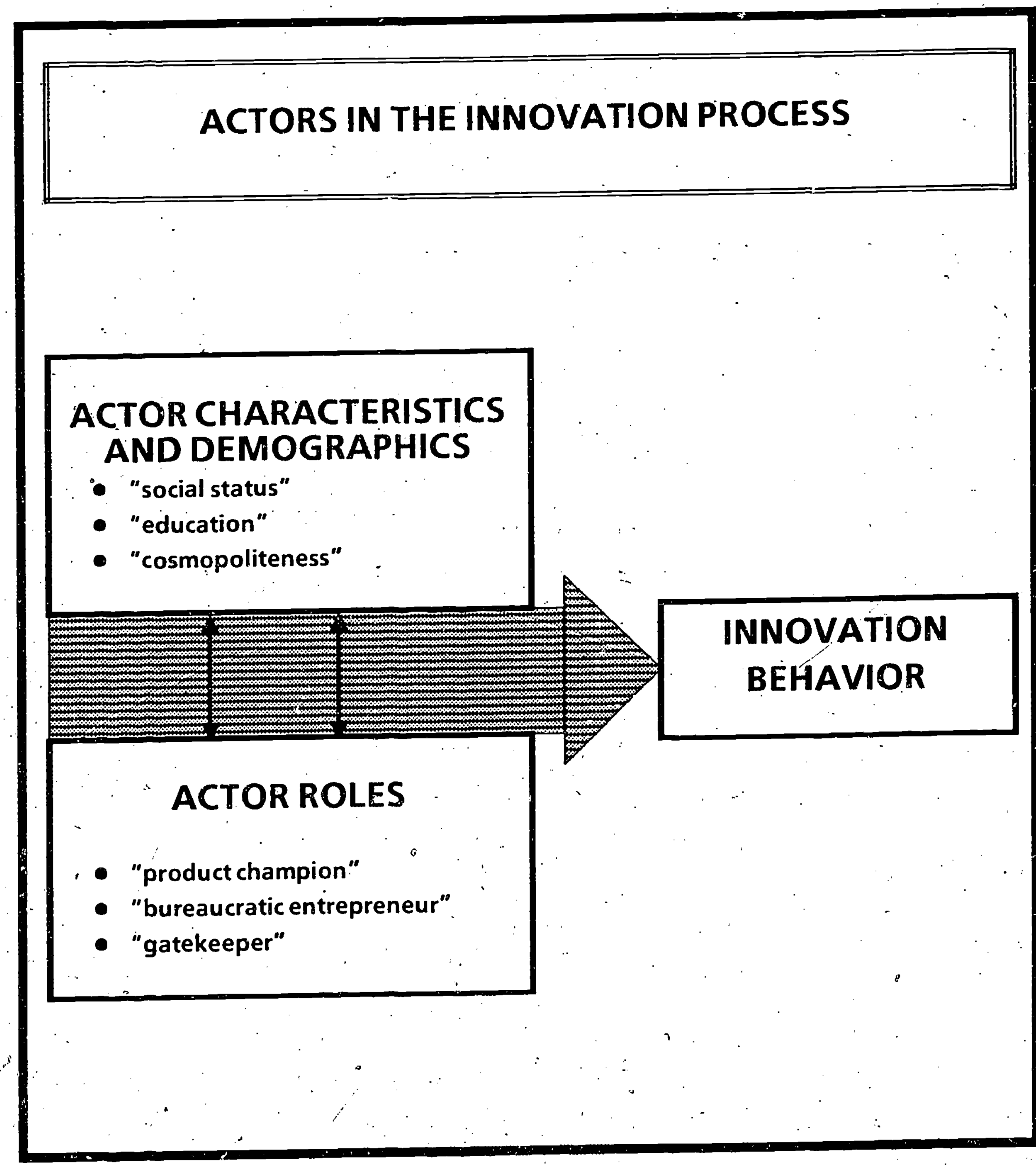
The de-emphasis of the role of individuals is a recent development. Much of the early analysis of innovation was carried out within the "diffusion paradigm". This analysis focused almost exclusively on variables operating at the individual level (e.g., Rogers, 1962; 1983) and paralleled similar descriptive analyses of individual innovations, described earlier.

Personal characteristics of independent inventors or innovators, particularly aspects of their values, backgrounds, personalities and demographics, were the principal focus. More recently, attention has been directed to individuals as they act out various *roles* in the innovation process such as technical manager (Gee, 1976), entrepreneur (Roberts, 1969), bureaucratic entrepreneur (Lambright, Teich and Carroll, 1977), boundary spanner (Keller and Holland, 1978), gatekeeper (Allen, 1977), product champion (Chakrabarti, 1974), purchasing agent (Bean and Mogee, 1976) or user (von Hippel, 1976). This review of the studies will focus on aspects of both personal characteristics and roles. Figure 6 depicts graphically the interactions of these two foci.

## Actor Characteristics

Researchers have observed many consistencies in the demographic characteristics, psychological/personality traits, and job skills of individuals involved in the innovation process. The prominence and visibility of individuals is, of course, likely to be greater at some stages of the process (such as initiation or invention) than at others. Technical "gatekeepers" and entrepreneurs, for example, are usually in their 30's, hold at least a master's degree and have had some R&D work experience with emphasis on development research (Roberts, 1969; Allen, 1977). Udell *et al.* (1976) compare inventors and noninventors, using Gough and Heilbrum's (1965) Adjective Checklist, and find that inventors are more emotionally adventurous, achievement-oriented, independent, resourceful, creative, and personally goal-centered and hard-working than noninventors. Roberts (1969)

FIGURE 6


ACTORS IN THE INNOVATION PROCESS
ACTOR CHARACTERISTICS AND DEMOGRAPHICS
"social status"
"education"
"cosmopoliteness"
INNOVATION BEHAVIOR
ACTOR ROLES
"product champion"
"bureaucratic entrepreneur"
"gatekeeper"

finds that entrepreneurs have a high need for achievement and only a moderate need for power. Keller and Holland (1978) find that boundary spanners are characterized by high performance, high job satisfaction, and "orientation toward doing something different". Finally, many personal skills have been attributed to effective organizational personnel who are actively involved in innovation, such as knowledge about the needs of the firm, technical competence, political astuteness (Chakrabarti, 1974), leadership (Fiedler, 1967) and great diversity in job activites.

Within the framework of the *diffusion* of innovations (described in Chapter IV), the work of Rogers and Shoemaker (1971) has been extremely influential. These authors reviewed hundreds of studies and used summative techniques to identify the personality and demographic characteristics most associated in these studies with "innovativeness" as expressed in three crucial activities in the diffusion process: adoption, opinion leadership, and change agentry. Thirty-two generalizations associated early adoption with various demographic, personality and other characteristics of individuals. Early adopters tended to have, among other traits, higher social status, more favorable attitudes towards credit, change, risk, education, and sciences, greater intelligence, more social participation, more change agent contact, more exposure to mass media and interpersonal communication channels, less fatalistic views, more cosmopolitan backgrounds, more highly integrated links with the social system, and more information and knowledge about innovations.*

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* There is evidence that these characteristics may interact with innovation characteristics or social contexts in non-linear ways (Becker, 1970).

For successful opinion leadership and change agentry, the individual characteristics were similar. Followers seek opinion leaders with higher social status, more education, greater mass media exposure, and more change agent contact, and who are more cosmopolitan and innovative. Change agent success was positively related to individual characteristics such as social status, education, and cosmopoliteness.

Several methodological limitations should be noted regarding this body of research. The first concerns the operational definition of the dependent variable used in these studies. This review has already discussed problems involved in measuring innovation; these problems are particularly manifest in the innovator characteristics literature. For example, the use of a "yes-no" measure of adoption obscures the reality that innovations are adopted in different ways, for different lengths of time and with different effects. This line of analysis has rarely employed longitudinal measures of implementation; it is almost entirely a literature relating individual characteristics to a dichotomous adoption measure.

The traditional individual characteristics literature has also seldom allowed for different units or levels of analysis. In its focus on individual variables, it has usually ignored the nesting of these variables in social contexts. This second limitation was of course noted by Rogers and Shoemaker (1971, p.80):

> ...the focus of the reviewed research has been upon individual, intrapersonal variables. This largely excludes social structure and interpersonal variables.

A third methodological issue concerns the "vote counting" method used to aggregate findings. As Glass (1978) notes, the vote-counting method can be extremely misleading, since the use of a statistical significance criterion biases the tally in favor of large-sample studies and disregards or obscures information concerning the relative strength of effects. Finally, it is extremely unlikely that any set of generalizations represent *independent* characteristics of actors. A more useful profile of innovators and non-innovators could be developed if multivariate techniques were employed to aggregate variables. It is possible that a limited typology of innovator characteristics could be developed based on a few factor or cluster measures. This might be a way of integrating the individual characteristics literature with that regarding the roles people play.

It should also be noted that the innovator characteristics literature is premised on a trait-style conception of personality that no longer has wide currency in the personality psychology field. It is questionable whether a set of personality traits which have cross-situational stability can be identified or used predictively (e.g., Mischel, 1973). This implies that a framework for looking at individuals in an *organizational* context is required.

## Actor Roles

The sociological concept of *role* -- that is, the position individuals have relative to other people in an interpersonal system and the expectations about their behavior held by others -- is a central part of the theory of organizations, and important to understanding innovation in organizational settings. A number of aspects of how individuals function in organizations can be conceptualized either as individual characteristics or as role features. For example, one might look at "entrepreneurs" as a specific type of individual, or look at "entrepreneureal behavior" as a repertoire of activities carried out by individuals occupying such positions. The choice of a viewpoint depends on the purposes of the analysis and the predilections of the analyst. However, it should be noted that the concept of social roles is one which permits multiple units and levels of analysis to be examined simultaneously. As such, it is much more congruent with a stage-process model of innovation, and it allows internal dynamics and conflicts to be examined directly (Whetten, 1978). It focuses on the system and how it works, rather than on atomistic units within systems. The concept of role also provides a framework within which the elements of cross-situational instability are not only normal but predictable.

Actors in the innovation process perform vital roles that are both formal and informal. For example, Allen (1977), Keller and Holland (1978), and Chakrabarti (1974) have all observed that a small number of people in innovative organizations are relied upon by others to serve as important sources of technical information. These "gatekeepers" have the ability to absorb complex technical information and to translate it into a more understandable form for co-workers and top management. Persons who perform this role have a particularly important function in building awarenesss of new products and processes during the early stages of innovation.

Another important informal organizational role is that of the "product champion" who links the different phases of the innovation decision making process (Chakrabarti, 1974). In a case study reported by Tornatzky *et al.* (1980), two administrators in a state mental health office functioned as "bureaucratic entrepreneurs" in implementing innovations in hospitals in their state. Similar findings have been reported regarding innovations in urban mass transit (Rogers, Magill and Rice, 1979). Other authors note the importance of the role of "defender" against innovation (Klein, 1977), the inverse of the product champion.

There are important interactions between characteristics of certain role incumbents and various parts of the organizational milieu. For example, Udell *et al.* (1976) describe a number of problems facing independent inventors, which stem from the nature of their task environment and from typical features of their organizational climate. The inventor is usually ignorant of the needs of potential user firms, due to the inadequacy of communication networks between organizations and inventors, and therefore has difficulty locating an organization which is interested in his/her idea (von Hippel, 1978).

As a corollary, independent inventors rarely receive evaluative feedback concerning the technical feasibility of their ideas, information concerning appropriate modifications to improve the firm-invention match, and other data which could increase the probability of acceptance. Chakrabarti (1974) describes several pervasive problems faced by the "product champion" with an organization. For example, he is often seen as an outcast by other members of the organization, and as an advocate of ideas which seem unrealistic. Bean and Mogee (1976) discuss similar clashes between the purchasing agents and engineers over cost and performance considerations. Roberts' (1969) study of new business ventures finds that research lab personnel frequently exhibited strong biases against young entrepreneurs.

Researchers in this area have been able to identify important organizational roles and various personal characteristics of actors involved in the innovation process (as noted, these distinctions are not absolute).

But relatively little work has been done in examining the relative importance of individual factors as opposed to factors associated with the environment in which innovation takes place, or the extent to which situations determine which characteristics are important and which not. Research designs need to allow for the attribution of relative proportions of variance to either situational or individual difference factors.

Relatively few studies have used techniques to disaggregate these effects in the investigation of innovation processes. Two notable exceptions are the studies by Romeo (1975) and Duchesneau and his colleagues (Duchesneau and Dutton, 1977; Duchesneau, Cohn, and Dutton, 1979). But even here the conclusions tend to be ambiguous. Duchesneau and Dutton (1977) note that many "individual-difference" variables may actually operate as *proxy* variables, i.e., measurable quantities which represent more fundamental processes. This is related to Mansfield's (1971) suggestion that the education of the president of a firm is important only because a highly educated president is better able to understand the implications of innovations, to be more flexible intellectually, and to have more extensive outside contacts. In this sense, the age of the president is a proxy for willingness to take risks. In a similar set of findings from the area of mental health innovation (Fairweather, Sanders and Tornatzky, 1974; Tornatzky *et al.*, 1980), some personal and demographic characteristics (e.g., age, number of job moves) were found to be related to innovation, and they too may have constituted proxy variables for values about risk-taking.

## Actors Disaggregated and Aggregated

The discussion thus far has moved from the characteristics of individual actors (demographic, personal, and social) to the roles that individual actors play in relationship to the situational realities of the organizational setting. This in turn raises an issue that has both conceptual and methodological implications for this line of research: what is the proper unit of analysis for examining the innovative process, or rather, who are the "actors" involved, and what degree of autonomy do they exercise?

It seems intuitively obvious that in an organizational setting some aggregation of individuals is generally the actual "actor", and that the notion of a single, unencumbered decision maker may be largely a myth -- at least in the sense of one who makes the major "adoption decision". Hage and Dewar (1973) found that the collective ideas of the "inner circles" of organizations to be at least as important, sometimes more so, in influencing innovation than the ideas of chief executives. Individuals certainly act in a manner constrained by other parts of the system; however, they usually manage to place something of themselves uniquely on the situation (Endler, 1973; Endler and Magnusson, 1976). The role of group dynamics phenomena (e.g., Cartwright, 1973) in innovation processes has been speculated on but not resolved (Bion, 1961).

One influential treatment related to this problem has been Downs and Mohr's (1976) argument for the "innovation decision design", that is, the study of a single organization vis-a-vis a single innovation. What is unclear, however, is the definition of "organization" and whether this connotes the work group, the larger organization, the informal peer structure, or something else. Analyses of "dominant coalitions" (Thompson, 1967; Hage, 1980) are conceptually integrated into organizational theory, but the operational and empirical bounds of such coalitions are obscure. In a similar manner, Rogers (1975) criticizes the "dominant paradigm" in innovation research, including the predominant focus on the individual as the unit of analysis, but provides few suggestions aside from the use of network analysis to determine who interacts about particular issues and the use of such de facto organizations as analytical units.

These questions will need to be settled empirically. As long as researchers continue to collect data about and from several individuals in organizations they will also need to decide what are the most useful ways to aggregate or disaggregate these data (techniques for using multi-level data appropriately need to be employed). Evidence is ambiguous as to whether one can predict the course of innovation better on the basis of data from the legitimated authority figure, from the informal product champion or defender of the status quo, or from some group mean seen as a proxy for a group norm. In one cluster-analytic treatment of data from different levels of aggregation (Fairweather, Sanders and Tornatzky, 1974), responses from the director of an organization (a hospital) tended to fall in different variable domains, and be differentially related to innovation, than were findings based on aggregate data from the staff at large. Hill (1982) has studied a complex training innovation which could be adopted by either individuals or groups, and finds that the degree of individual adoption was not related to the degree of collective adoption. It is also likely that different actors play different roles at different stages of the process, and this will undoubtedly complicate drawing inferences from data gathered from named individuals.

## Summary

Who the "actors" are, or what is the most meaningful "adopting" unit in an organization, is still conceptually and empirically muddy. But for purposes of stage-process analysis, both individual actors and larger innovative units are relevant units of observation for looking at interactions of people, roles, and systems.

# PART III

# THE SEQUENCE OF INNOVATION ACTIVITIES

# CHAPTER VI

## TECHNOLOGY GENERATION, CHOICE, AND DESIGN

Other parts of this review have considered perceptions and decisions about technology, the actors involved in those decisions, and the environment within which they take place. This part focuses in turn on the *activities* involved in innovation; this chapter, in particular, on *generating* technological innovation and on detailed *application* of technology. The early phases of the innovation process from the perspectives of both the producer and user of technology, the generation of technological knowledge, and the selection of technologies from an array of alternatives will be considered. Of necessity, only a fraction of the extremely diverse literature will be covered. This focus emphasizes those parts of that literature which are most germane to the stage-process model of innovation developed in Chapter II.

### R&D Management: Producing Technology

One logical starting point for analysis of innovation processes is the act of creating technical ideas which are later applied. Early research on this problem tended to focus on innovation producers as individuals, and the analysis of "inventors" (see Chapter V). As researchers began to untangle the complexities of organizational innovation, attention focused on the organized generation of ideas, and toward how individuals and the social roles they enact interact in the research process. The field which considers such questions is generally known as "R&D management" or "research on research".

By one definition, R&D management is "concerned with the organization and management of technological innovation processes" (Radnor, Ettlie and Dutton, 1978). Typical issues treated in this literature include the structure of R&D organizations (Keller, 1978), processes of problem definition and idea generation (Baker, Seigman and Rubenstein, 1967), project selection and planning (Baker and Pound, 1964), resource allocation, and the performance and productivity of scientists and engineers (Blois and Cowell, 1979). These topics reflect the concerns of formal R&D in large industries, where much of R&D management research has been conducted. Such R&D has a relatively long time horizon, its outcomes are uncertain but potentially broad in impact, and it can utilize a possibly disproportionate share of the organizations's resources. As suggested in Chapter IV, the generalization of such findings to non-industrial settings is debatable; in any event, public agencies conduct relatively little R&D related to their own problems (National Science Foundation, 1980a).

Despite the growing body of knowledge about the inner workings of organized R&D, researchers seem only to agree that there are no hard and fast ingredients in successful innovation. The placement and function of R&D within the firm is often contingent on features of the larger organization (e.g., complexity, formalization, and centralization), corporate strategies for dealing with technological change, and the technological and market environments. The micro-organizational structure of a specific project, on the other hand, seems to depend on the type of R&D (basic research, applied research, etc.), and with whom in the organization R&D must interact (marketing, production, etc.). As a further complication, organizational conditions which are related to better performance by individual scientists and engineers may not be conducive to overall group performance.

In recent years, American industry has been severely criticized for the limited time horizons involved in its planning processes (e.g., Hayes and Abernathy, 1980). A major manifestation of planning is the company's orientation to research and development in general and to longer-range R&D in particular. For example, Ettlie (1982, 1983) has found that strategic R&D policy planning is related to innovation and productivity in the food industry. Studies of Japanese management (e.g., Cole, 1982) have also highlighted their R&D planning as a major contributor to their international competitiveness. Such findings illustrate that R&D management issues are important not only at the project or laboratory level, but also at the level of corporate strategy and planning.

There are several approaches to research on the R&D process. One analysis is that of idea and information flow (Kelly and Kranzberg, 1978). Researchers have traced the flow of technical information and its impact on the creation and development of ideas and on managerial decisions regarding the selection of ideas for development and allocation of limited resources (Myers and Marquis, 1969; Utterback, 1973; Rubenstein, 1968; Baker and Freeland, 1972).

A more or less consistent set of findings emerges from the idea flow literature. First, the primary means by which technical information reaches the firm is through oral and *informal* communication rather than formal media (Utterback, 1971; Gruber and Marquis, 1969). Second, it has been observed that information seeking practices differ between basic and applied researchers, reflecting differences about objectives and time horizons (Gerstenfeld and Berger, 1980).

These findings correspond with those of Johnston and Gibbons (1975) that basic researchers spend more time formulating and defining problems, and that their information sources tend to be peer-reviewed journals and conference proceedings. The applied researcher, by contrast, works with a well-defined problem and must quickly find an acceptable solution. Time limitations require easy access to pertinent information. The applied researcher will frequently communicate orally with fellow project team members and other experts within the organization. Use of printed material by applied researchers is often limited to in-house technical reports (Marquis and Allen, 1967). It appears that different types of R&D call for different organizational forms.

The field of R&D managagement research has also recognized that factors external to R&D as such also contribute to the success of the R&D program. R&D may be different from other functions in the firm, but it still must be integrated with these functions and be responsive to external environmental influences. Issues include: (1) the R&D/environment interface; (2) intraorganizational linkage processes; and (3) project selection and initiation.

The R&D/environment interface has been typically treated in terms of communications links. The concepts of "gatekeepers" (Allen and Cohen, 1969), "key commmunicators" (Pelz and Andrews, 1966), and "boundary spanners" (Keller and Holland, 1978) illustrate the importance of a relatively small number of individuals for communication of outside technological knowledge to the R&D unit (these roles were discussed in Chapter V).

The literature on intra-organizational linkages (various concepts such as liaison relations, coupling, "linking pins", etc.) deals with the flow of information, resources, personnel, and work between R&D departments and other units within the firm. The most recent and comprehensive example is Souder's (1977) application of contingency theory to the study of R&D management, which suggests that certain kinds of interdepartmental linkage structures may be more effective than others in facilitating the effective deployment and marketing of new technologies. Young (1973) examines researcher-marketer dyads to understand new products' failure, and finds that the two groups disagreed on such issues as the definition of the product's market, the relationship of the product to the firm's objectives, and marketing specifications. Further work on the interaction between R&D and other functions such as production, finance, and corporate planning would improve our understanding of "organized innovation."

The related issues of need identification, problem definition, and project selection have also received attention. The assumption that good ideas are automatically communicated to and addressed by R&D sections has been challenged. Ideas, and even the initial stages of R&D work, have been found to occur outside the firm producing the innovation (von Hippel, 1978). Hollander (1965) observes that minor technical changes are developed by plant personnel and equipment manufacturers, while the R&D department is the locus of major change. In some cases, R&D work is predominantly influenced by cost-reducing opportunities (Abernathy, 1978), rather than by technological opportunities.

While these areas do not cover all R&D management research, they do suggest dominant themes. By focusing on early stages of technology production, it becomes apparent that many of the social, organizational, and contextual variables that are important in other stages of innovation operate here as well. The R&D process is in many ways a microcosm of innovation processes of greater scope, complexity, and effect. Unfortunately, in its present state, with widely diverse sets of concepts, units of analysis, and research methods being employed, "the knowledge that has been created (is) difficult to synthesize in policy relevant and actionable ways" (Radnor, Ettlie and Dutton, 1978).

## Designing Technology Systems

In the earlier description of stage-process models of innovation, it was noted that many models tend to oversimplify the complexity of the phenomenon and must be extended in significant ways. The limited concept of "adoption", for example, makes sense only if extended to include implementation, routinization, and phenomena related to technology deployment. However, more detailed analysis of adoption decisions per se (where they can be correctly defined) is also needed. Assuming that some discrete decision is made, that decision often is less a matter of dichotomous selection of this technology *vs.* that, but rather a selection from an array of alternatives, each with its own advantages and limitations. In these situations the adoption process is likely to involve rather extensive technology design efforts on the part of the user.

This section examines methods for making design choices among process technologies, when there is a potential array of alternatives rather than one predominant option and where adaptation rather than adoption is paramount. Conceptual models of the choice of process technology can generally be categorized as one of two major types: (1) technology choice models, based on the economics literature (e.g., Stewart, 1977); and (2) socio-technical systems design models, based on industrial engineering, psychology, and sociology (e.g., Pasmore and Sherwood, 1978). These models are concerned with major process choice issues that include both material technology and social organization. Both emphasize the interactions of technical and social choices, as Figure 7 illustrates, but they do so in rather different ways and on the basis of rather different basic assumptions.

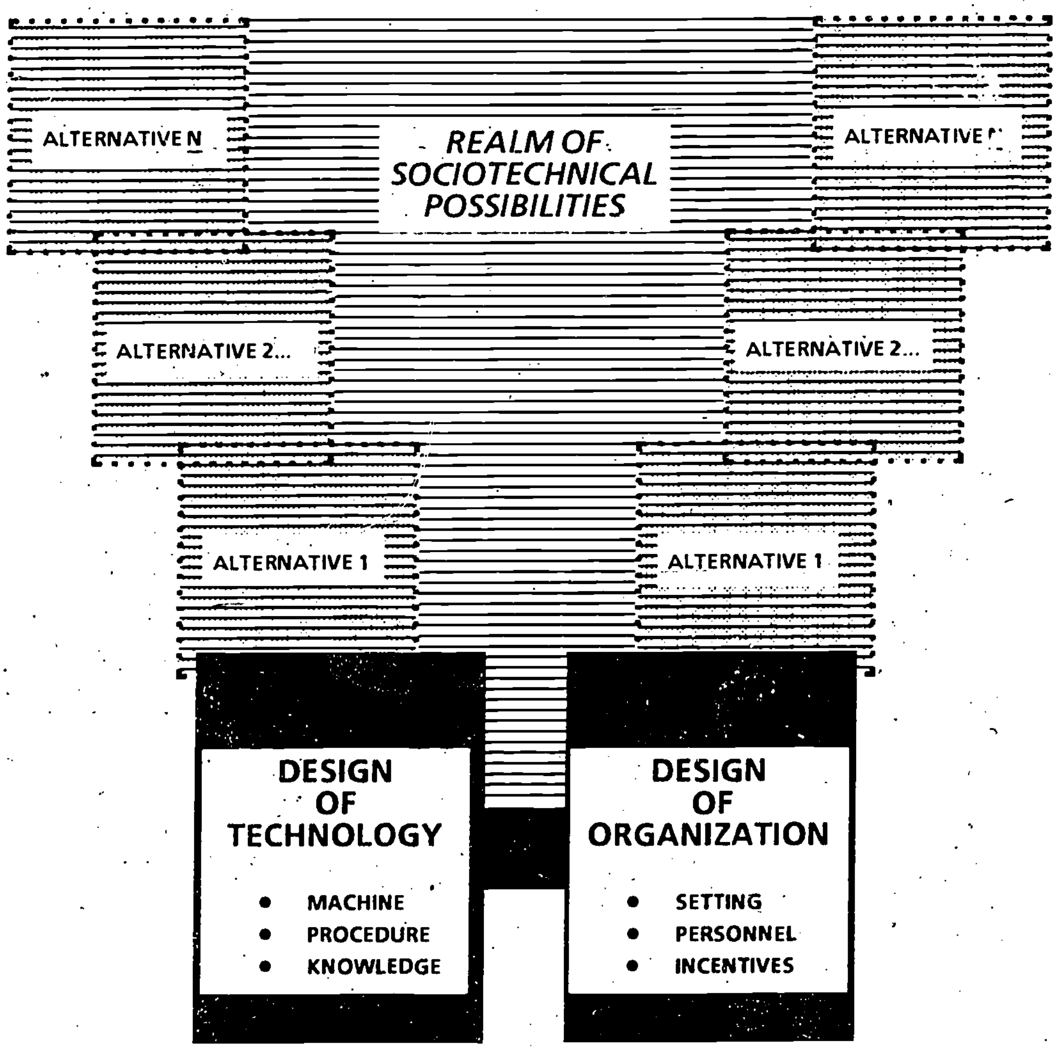
Technology Choice

When employed as a pure economic concept, the technology choice argument states that for a given product there are a variety of interchangeable combinations of capital and labor which are equally efficient depending on the relative prices of capital and labor. It is further assumed that each choice of technology is associated with a given level of labor need, and that the labor need and social organization of work are fully specified once the technology is chosen. Explicit assumptions are made that alternative technologies exist, that they are available, that decision makers know about these alternatives, and that the social organization of production is not manipulable independent of the machine system.

The actual array of alternative production possibilities for a particular product is probably somewhat less than suggested by this theory. Rosenberg (1976), for one, suggests that the range of production possibilities for most products is small, limited to relatively major choices augmented or modified somewhat by R&D. In development economics, where the concept of technology choice is often applied, some argue that the extent of actual choice is even more attenuated.

FIGURE 7

# SOCIOTECHNICAL DESIGN AND CHOICE
## OR
# INTERSECTIONS OF TECHNOLOGY AND SOCIAL CONTEXT



There are at least some alternative production possibilities for many products. In developing countries, alternative technologies have been used in small-scale village-level industries such as sugar production, grain milling, weaving, shoe production, road building, and cement block manufacture (Stewart, 1977). In less traditional industries like canning and fertilizer production, a narrower range of possibilities has been developed.

The practical range of production possibilities depends on the product and the extent to which one technique is clearly more efficient than others. For chemicals or other continuous processes, there are only a limited number of alternatives available or that could be made available through R&D. For all practical purposes, for example, there is currently only one way to refine oil, and it is very capital-intensive. By contrast, in discrete parts manufacturing there are greater possibilities for variations in final products, and generally less interdependence between subcomponents of the production process. As a result there are a greater variety of production alternatives available (e.g., group technology, CAD/CAM, flexible manufacturing). In assembly operations, technologies may vary from entirely hand assembly (in developing countries) to automatic assembly operations (in the developed countries). However, some existing techniques, whether labor or capital intensive, may logically preclude certain choices (Abernathy, 1978).

Despite the potentially large range of production possibilities in discrete parts manufacture, the rate of adoption and utilization of some of these possibilities has been slow. This raises the question of whether or not alternatives are in fact alternatives. Since some less used options have excellent records of economic return (e.g., group technology) it is questionable whether profit maximization can adequately explain decisions concerning alternative production technologies in the fashion posited by the economics-based technology choice model.

As noted, the technology choice model assumes that the organization of work is fully specified once the technology is chosen, and that one and only one organization can efficiently operate a given technology. Some of the early organizational work on technology (e.g., Woodward, 1965) seemed to encourage this view. In reality, the range of production possibilities is limited primarily by the *organization* which operates the technology. Research in the sociotechnical systems design perspective indicates that alternative social systems can efficiently operate almost any given material technology, and moreover that there are permissable and often efficient variations within related organizational forms. Hickson, Pugh and Pheysey (1969) argue that work organization is a function of organizational size and not operations technology. Trist and Bamforth (1951), Davis and Cherns (1975), and others indicate that specification of work organization is very much a choice process and not an imperative of either the technology or the number of employees.

Resolution of the technological imperative vs. organizational variation points of view depends largely on the level of aggregation of organizational behaviors chosen for analysis (see Chapter II). In one sense, all assembly-line production systems are identical in operation. However, if one looks below the surface one can identify a great many different kinds of specific social patterns, all of which are recognizable as assembly lines.

The assumptions of the economic model of technology choice about the process of decison making are equally oversimplified. Even when the model considers inputs beyond just capital and labor inputs, such as energy, the level at which these inputs are considered is quite abstract. Labor is treated as undifferentiated as to skill. Management requirements are ignored. Likewise, various capital requirements such as ease of maintenance and embodied skills are not considered. Various external conditions such as the size of the market, its organization, cultural and social traditions, and the organization of the labor force also may influence the decision making process, but do not appear in models of technology choice.

The assumption of profit maximization as the only significant decision criterion is also questionable. Studies show that small-scale enterprises tend to be systematically more labor-intensive than large enterprises (United Nations Industrial Development Organization, 1969). Morley and Smith's (1974) study of multinational decisions in Brazil indicates that branches of multinationals tended to use the same technology that is used in their home country, and that there is no search for the more labor-intensive technology that would theoretically be more efficient.

In sum, the pure economic model of technology choice tells us only a little about how decisions about process technology are made. Attempts to verify this model empirically do, however, suggest a number of important issues. First, process technology does involve a choice among alternatives. Second, these alternatives are both technological and organizational in nature. Third, the criteria used in evaluating these alternatives include more than just economic factors.

## Sociotechnical Design Perspectives

A second major model focused on the issue of process choice is *socio-technical systems design*. Classical organization theory generally viewed organizational design as a machine design problem (Bright, 1958), in which people and machines were thought to be interchangeable. The basic premise of the sociotechnical approach, by contrast, is the interrelatedness of the social system of an organization, its material technology, and the environment in which it operates (Pasmore *et al.*, 1980). Theorists in this field have attempted to identify the most appropriate social and organizational configurations relative to a given technology for accomplishing a given task, and to recognize how technical and social systems affect each other as they evolve over time. Unlike classical theory, the sociotechnical approach does not accept either the technology or the social system as a given. Nor does it postulate that system designs are ever fixed; rather, sociotechnical systems are seen to be in constant flux as social and technical elements change. Thus, this approach emphasizes the *process* of design as much as it does the design itself.

Sociotechnical design concepts are drawn from research on human motivation, industrial engineering, systems theory and organizational design. The literature, which is extensive, falls into four broad categories:

1) Descriptions of the characteristics of sociotechnical systems;

2) Principles of system operation;

3) Interventions in designing or measuring the effectiveness of sociotechnical systems;

4) Model development.

System Characteristics: The two primary elements of sociotechnical systems as discussed in the literature are, obviously, the social system and the technical system. The *social system* is comprised of organizational roles and their interrelationship; the *technical system* consists of the tools, techniques, procedures, skills, knowledge and other devices used by members of the social system to accomplish organizational tasks (Pasmore *et al.*, 1980). Theories about and techniques for manipulating the technical subsystem are more uniform and better articulated, and currently there is no consensus about how to analyze the social elements of a sociotechnical system. Cherns and Wacker (1976:1) conclude:

> ...we are able to specify in considerable detail the requirements that the technical system of an organization places on its social system, but we have no adequate way of describing that social system, let alone identifying its characteristics.

This is despite the development of several instruments ostensibly designed to assess social systems, such as the Job Description Survey (Hackman and Oldham, 1974) and the Survey of Organizations (Taylor and Bowers, 1972).

Related to this literature is research on the "quality of work life" (Davis and Cherns, 1975; Taylor *et al.*, 1973; Taylor, 1977; Hackman and Suttle, 1977), which emphasizes the importance of "human needs" in the design of work (e.g., the need for challenging work, task variety, support systems, rewards, feedback and self direction). Sociotechnical designs have as a basic goal the improvement of quality of life for participants, including but not limited to traditional economic efficiency criteria (Czikszentmihalyi, 1975).

Autonomous work groups are widely utilized in redesigning organizations according to sociotechnical principles, and the literature on their impact on worker productivity is extensive. For example, the early work of Trist and Bamforth (1951) demonstrated that semi-autonomous work teams could better operate new mining techniques than could traditional organizational structures, although both could employ the same varieties of machines. Similar conclusions were drawn from the research of Rice (1958) in the textile mills of India and in the Tavistock Institute projects to increase national productivity in Norway (Emery and Thorsrud, 1969). These studies suggest that more than one social/organizational system can effectively operate specific technologies. More importantly, the literature suggests that some combinations of social and technical considerations are more effective (productive) than others.*

Principles of System Operation: Three "principles" of sociotechnical design have received extensive coverage in the literature:

1) *Joint optimization* (Davis and Trist, 1972; Cummings and Srivastva, 1977);

2) *Minimum critical specification* (Cherns, 1976; Taylor 1980);

3) *Organizational choice/equifinality* (Trist *et al.*, 1963; Cooper and Foster, 1971).

The principle of joint optimization states that for optimum organizational effectiveness, both social and technical system requirements should be met concurrently. The open system perspective expands this principle to include attention to environmental demands as part of both social and technical systems. That is, organizations must also be able to respond to anticipated and unanticipated environmental changes (Pasmore *et al.*, 1980) and to the accountability demands inherent in interorganizational systems. In practice, however, joint optimization is difficult, and organizations tend to optimize internally around the technology by choosing a technology or set of technologies first, and then designing the social system to "fit" the technology (Randolph, 1979).

The principle of minimum critical specification states that constraints on design should be limited to only those rules which are essential to organizational functioning. In contrast to other approaches, the rules for sociotechnical systems are seen as evolving over time. There is little effort to rationalize the system completely, or to specify *a priori*

* Hackman (1982) has noted that in practice sociotechnical analysts virtually *always* recommend autonomous work groups, and has questioned whether or not there may be an element of ideology at work -- a point acknowledged in principle by Trist (1982).

the choice options raised by various contingencies. If the process of design is adequately organized, the results should be adequate as well.

The concept of organizational choice/equifinality suggests that there are many paths to the same goals, thus focusing concern away from the details of system operation. In contrast to the economic-based technology choice model, which postulates that there is a single optimum technology for any given process, this principle suggests that there is no "optimal technology" but rather a choice of alternatives (Pasmore *et al.*, 1980).

In effect, these principles vary from abstract standards (e.g., joint optimization and choice/equifinality) to guidelines which can be operationalized (e.g., minimum critical specification). In general, however, the lack of concreteness of operationalization of key principles has proved to be a major barrier in moving sociotechnical systems design from what is largely an art form toward scientific rigor (Hackman, 1981). Finally, it should be noted that although major system characteristics and principles have been identified, the theory lacks a consistent set of assumptions, partially because theory has been developed largely from practice rather than *vice versa*.

Major Interventions to Enhance Productivity: There is a large literature concerned with sociotechnical interventions. These have sometimes been termed "experiments" (Pasmore *et al.*, 1980), but that term is methodologically inaccurate. In fact, the vast majority of these studies are single-site case studies, with all the threats to validity inherent in this design (Cook and Campbell, 1979). A major weakness of all the sociotechnical design literature is the lack of studies in which confounding factors such as selection, history, and volunteerism have been controlled for by an appropriate design -- that is, a true experiment.

These problems notwithstanding, it is worthwhile to examine the intervention literature. The first efforts in sociotechnical design were attempts to apply World War II industrial production improvements to peacetime industries. Early studies in Europe by Trist and Bamforth (1951) and Rice (1958) have previously been described. In the U.S., interventions in this area were begun by corporations including General Foods, Proctor and Gamble, and TRW. More recently, Steers and Porter (1975) have tested the effects of semi-autonomous work teams in the automotive industry, and found the change to be effective.

Sociotechnical interventions have also been applied to "human-intensive" technologies as well as to those with large hardware components. Taylor (1980) discusses a sociotechnical intervention in a computer operations division of a larger R&D firm which was developed using the principle of minimum critical specification. He reports that design changes resulted in a better informed organization and a higher quality product. Bostrom and Heinen (1977a, 1977b) describe a sociotechnical redesign study in a large metropolitan newspaper which found that an "ongoing management phase" was necessary to insure continued congruence between organizational goals and needs. Finally, the Center for the Quality of Working Life (1978) outlined the flexibility and adaptability of sociotechnical design for service oriented settings.

Major reviews of these studies have been provided by several authors. However, they vary in the percent of studies showing improvements in productivity, from about 41% (Taylor, 1975; 1977a) to 93% (Srivastva *et al.*, 1975). The difference in sampling accounts for some of this discrepancy along with the varying rigor of research criteria (Pasmore *et al.*, 1980). One point is central to all the studies: the success of the intervention is partially dependent on the continued commitment of the organization to the sociotechnical design *process* -- a point we return to in our discussion of implementation (Chapter VII).

Model Development: The fourth part of the sociotechnical literature presents various conceptual and analytical models and examples of model application. Most of these models follow the early work of Foster (1967) and Emery (1963). The Foster model identifies several steps in the analysis of sociotechnical systems. They include scanning of the work unit and its environment; identification of unit operations and key process variances; analysis of the social system and worker perceptions of their roles and environmental analysis. Emery's model identifies worker needs (e.g., job status, task variety, optimum work cycle length, etc.) and group needs (e.g., the need for job rotation or physical proximity where jobs are interdependent or highly stressful).

In summary, the literature relating to sociotechnical design has expanded considerably. Recent studies emphasize the identification of intervention strategies to improve productivity, and impressive gains have been quoted. However, interdisciplinary differences in defining system characteristics and in operationalizing basic principles restrict our ability to generalize findings. The extrapolation of theory from practice further threatens the validity of model development. Future research should include controlled experimental comparisons of well defined concepts.

## Summary

This chapter has reviewed literature bearing on the creation of technology, as well as two different perspectives on how that technology is put into place in the organization. The important point is not that one or another perspective is *correct*, but rather that each view constitutes not only a vocabulary but a set of implicit assumptions about both technology and organizations. When one tries to synthesize findings from different research traditions, it is easy to forget the assumptions on which those findings are based. The comparisons between these different models in this chapter should serve as a suitable cautionary note in the exercise of research synthesis.

CHAPTER VII

# THE USER'S ROLE: IMPLEMENTATION ISSUES

In recent years a "new" stage or phase has been worked into most conceptualizations of the innovation process. Although there are few precise definitions of implementation, a substantial and highly varied literature has developed around this concept. The term describes a host of activities which take place between "adoption" (some point of organizational commitment to the innovation) and the permanent incorporation of the innovation into the organization's repertoire of practices. But there are few models which explore the internal dynamics of implementation as a process, and there are even fewer descriptive schemata for categorizing implementation events or milestones.

At least three bodies of "implementation" literature, while they all relate to the same general phenomena, are largely separate in conceptual terms, vocabulary, and levels of aggregation:

1) The *policy implementation* literature (e.g., Bardach, 1977; Pressman and Wildavsky, 1973; Sabatier and Mazmanian, 1980; van Meter and van Horn, 1975; Smith, 1973; Williams, 1975; 1980; Hargrove, 1976; Nelson and Yates, 1978) -- developed largely by political scientists, its concern is primarily with the creation of administrative structures and procedures to carry out legislative goals, and with the effects those structures have on society;

2) The *program implementation* literature (e.g., Gross, Giacquinta and Bernstein, 1971; Berman, 1980; Charters and Pellegrin, 1973; Fairweather, Sanders and Tornatzky, 1974; Fullen and Pomfret, 1977; Scheirer, 1981) -- developed largely by psychologists, its concern is for effective use of particular proven

human service techniques, typically in education or mental health;

3) The *management science implementation* literature (e.g., Huysmans, 1970; Schultz and Slevin, 1975; White, 1975; Wysocki, 1979, has a reasonably complete bibliography in this area) -- developed largely by industrial engineers and operations research specialists, its concern is for the effective deployment and use of decision aids (OR/MS models and techniques, management information systems, technology assessments, etc.) in organizational decision making.

The program implementation literature is related to "research utilization" analyses (Weiss, 1977; Caplan *et al.*, 1975; Human Interaction Research Institute, 1976), whose emphasis is on the ways in which research-based (usually social science) information is or is not used in the making of organizational decisions. Considerable attention has been given to the problem of the non-use by policy makers of the findings from evaluation research (e.g., Larsen, 1982). The research utilization literature is concerned less with organizational dynamics and more with attitudes and beliefs of organizational decision makers. It does, however, offer some useful observations on the ways in which new information interacts with organizational systems, and hence can illuminate implementation analysis.

The program and management science literatures tend to be normative in the sense of equating "success" with full implementation of the particular innovation under study. The assumption is that there is some optimal level of implementation (a level defined either by prior program development research or analysis of practice). The policy literature is generally less normative and more descriptive. It is also less likely to be shocked by failure, perhaps because the political scientists who have contributed most heavily to it are generally more comfortable with regarding conflict and compromise as a normal state of affairs, and have less teleological orientation to "outcomes" than do, say, engineers.

Given the complexity of public programs and the high levels of uncertainty involved in their operation, it is not surprising that implementation analysis has many of its origins in the public sector. Implementation difficulties have been most visible (often embarrassingly so) in the context of public service organizations. Although implementation variation may be more apparent as a problem in the public sector, it does not follow that it is a problem *only* in these organizations. However, except for the OR/MS literature, analysis of implementation as a "problem" in the private sector is uncommon (Scheirer, 1982). There is a substantial body of work on "resistance to change" (e.g., Coch and French, 1948; Zaltman, Duncan and Holbek, 1973), which does tend to cover some of the same ground.

The integration of implementation insights from these diverse perspectives (and others) into a coherent analysis of organizational innovation is a relatively recent development. Comparisons across the literatures, except at a general reference level, are rare. One useful exception which tries to make genuine comparisons between them is Yin's (1980a) study of implementation research approaches. Elmore (1978) distinguishes between views of implementation as "system management", "bureaucratic process", "organizational development", and "conflict/bargaining", and suggests that each of these "models" has distinctively different assumptions, goals, and implicit research methods for analyzing them.

As Chapter II noted, some of this diversity is probably accounted for by different foci or levels of analysis. Berman's (1978) distinction between *macro-implementation* (policy implementation at the Federal level) and *micro-implementation* (organizational incorporation of innovations) is based on the recognition that there is not necessarily one process of implementation, but rather a diverse set of activities loosely grouped under the same general head. This distinction is frequently mirrored within the organization itself, as certain parts set "policy" and other parts structure the actions necessary to embody that policy in behavior. The burden of the discussion in this review focuses on the more operational and intraorganizational aspects of implementation, since this is the level where the process is likely to involve the actual deployment of new technology.

The idea that implementation constitutes an important phenomenon (not merely noise, error variance, endogenous irrelevance, or individual perversity) has been slow to be incorporated into models of innovation. In the classical diffusion literature (e.g., Rogers and Shoemaker, 1971) the implicit assumption was that *adoption* -- a decision to use or not use an innovation -- was the end point in the innovation process. Once a decision to adopt a technology had been made, it was assumed that its deployment followed more or less automatically.

However, a variety of empirical studies (e.g., Eveland, Rogers and Klepper, 1977; Klonglan and Coward, 1970; Fairweather, Sanders and Tornatzky, 1974; Tornatzky *et al.*, 1980) have led to the conclusion that this assumption is not sustainable. Implementation is *not* a certainty; it often does not happen at all, and rarely does the process result in a simple "on/off" deployment of new technology as the traditional innovation literature suggested. These "revisionist" findings have resulted in a markedly increased level of empirical investigation of the phenomenon.

The term *implementation* is used to convey at least three different concepts:

1) As a generic, "umbrella" term to cover all post-adoption innovation-related activities (Zaltman, Duncan and Holbek, 1973);

2) In a relative sense, equivalent to "early stage" post-adoption activity (as opposed to "routinization", or later-stage implementation processes (Yin, 1979);

3) To focus attention on the decision events which can be regarded as "commitment points" with reference to adoption (Pressman and Wildavsky, 1973; Eveland, 1979).

The generic use of the term has the advantage of logical clarity. However, this use is unfortunately misleading in a literature review, since most studies of implementation are relatively short-term (one year or less), due to the expense of longer studies, and the difficulty involved in "tracing" implementation events. Therefore, although many authors whose work is reviewed herein have probably intended the term "implementation" to be understood in its generic sense, it is more accurate to interpret their findings as relevant largely to *early-stage* implementation. The degree to which such short-term analyses describe the full range of the process depends on the size, cost, and scope of the change and the nature of the organization. Moreover, the value of effects produced by an innovation is clearly dependent at least in part on *when* the effects are measured.

The processes involved in later stages have recently become a focus of research interest. These processes have been variously termed *routinization* (Yin, 1980a), *incorporation* (Lambright, 1980), *stabilization* (Pelz and Munson, 1980), *institutionalization* (Eveland, Rogers and Klepper, 1977), or *continuation* (Zaltman, Duncan and Holbek, 1973). These are all terms for the processes by which an innovation becomes part of the more or less permanent standard practice of an organization. It is worth noting that routinization is not necessarily equivalent to *permanence*, and does not necessarily imply any particular degree of interconnection with the rest of the organization (Eveland, 1983). The term simply indicates that the innovation has come to be an accepted part of the system.

It is generally agreed that part of the organizational innovation process involves changes in the innovation itself which arise in the course of putting it in place in the organization (see Figure 8). Where this process begins with a general idea which becomes different things in practice, the term *adaptation* is often used. Where a well-specified innovation receives minor changes, *modification* is sometimes found. Where a well-specified innovation undergoes major change, the term *reinvention* has some currency. Pelz and Munson (1980) describe these three levels as "borrowing", "adaptation", and "origination", and suggest that implementation dynamics may differ depending on the level involved.

The specific terminology is less important than the recognition of the phenomenon. In any case, what is being described is a process of "organizational evolution" (Majone and Wildavsky, 1978), a sequence of complex decisions not unlike the gradual shaping of policy decisions described by Mintzberg, Raisinghani and Theoret (1976). Clearly, such evolution affects the behavioral components of innovations more than the physical or hardware components. This fact explains why much research on implementation has been conducted in the public agency context. When the technology at hand is purely social and has no material components (or very limited ones), the issue of whether adaptation or reinvention is benign or threatening is of considerable interest (Calsyn, Tornatzky and Dittmar, 1977; Larsen and Agarwala-Rogers, 1977; Blakely, 1982).

Two research strategies have been followed in studying implementation. One approach has concentrated on the "dependent variable" of implementation itself, and on conceptualizing and measuring the degree of implementation or the fidelity of the process to particular models. A second group of researchers has been less concerned with the conceptual and methodological

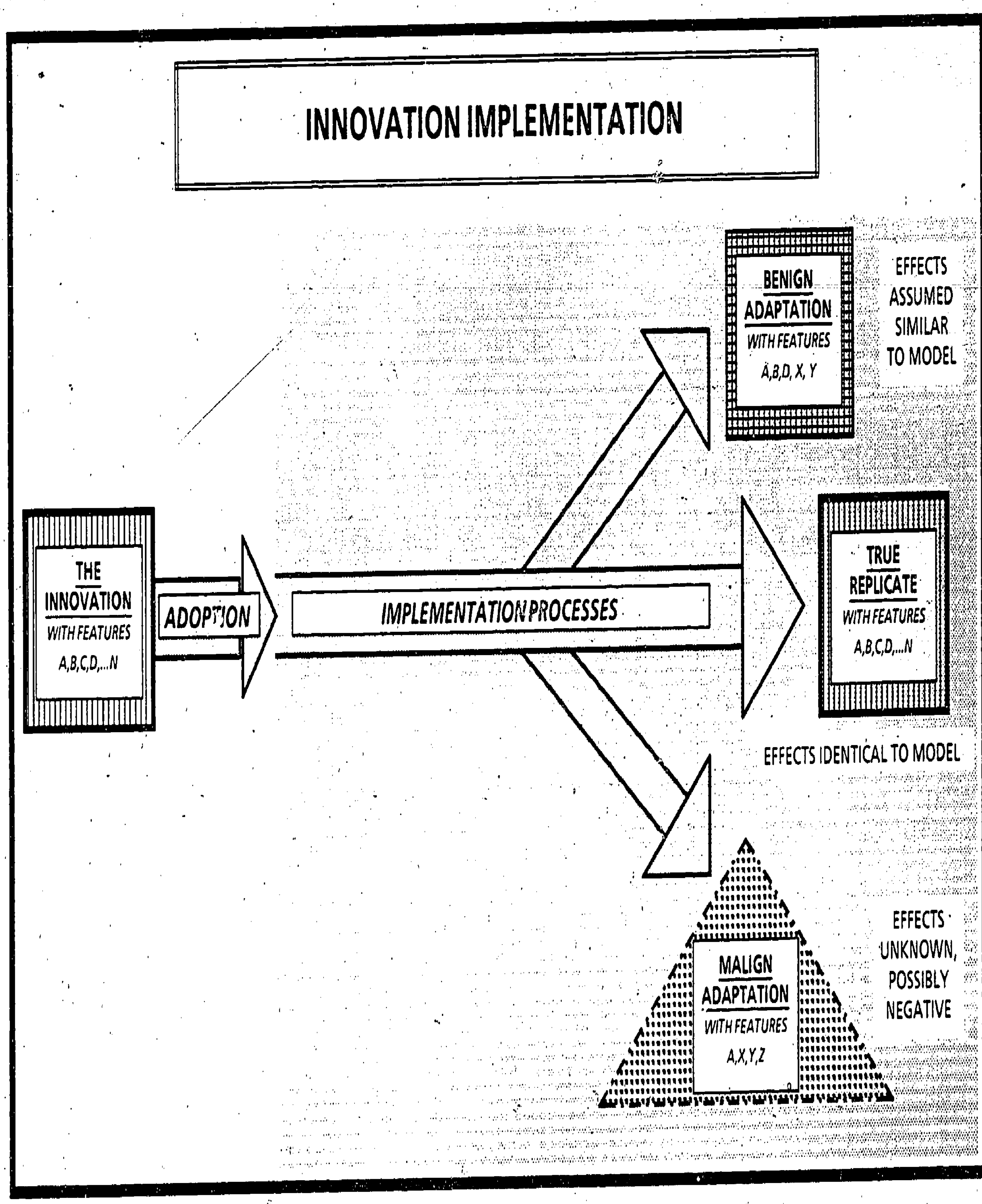

INNOVATION IMPLEMENTATION
THE INNOVATION
WITH FEATURES
A,B,C,D,...N
ADOPTION
IMPLEMENTATION PROCESSES
BENIGN ADAPTATION
WITH FEATURES
A,B,D, X, Y
EFFECTS ASSUMED SIMILAR TO MODEL
TRUE REPLICATE
WITH FEATURES
A,B,C,D,...N
EFFECTS IDENTICAL TO MODEL
MALIGN ADAPTATION
WITH FEATURES
A,X,Y,Z
EFFECTS UNKNOWN, POSSIBLY NEGATIVE

FIGURE 8

issues in measuring implementation and more concerned with identifying variables that affect implementation behavior. These variables have included indices of organizational structure, media of information exchange, and the like. In the remainder of this chapter, some ideas and findings relating to defining and measuring implementation are presented, and some variables which may influence the process are introduced.

## Measuring the Implementation Process

Unfortunately, there is little consensus on what specific organizational behaviors define the degree or extent of implementation. Various approaches differ on whether degree of implementation is to be conceptualized and measured as a *general* phenomenon or as a feature *relative* to a specific innovation or family of innovations. One technique is to try to define a set of specific activities (generally administrative actions) which all implementation sequences must incorporate at some point. Yin's (1979) definition of "passages" (soft to hard money; job descriptions; professionalization; organizational establishment; legislation; long-term contracts) and "cycles" (annual budgeting; new personnel; promotions; training; equipment turnover; widespread use) is an example of a very general approach which in his study was applied to a variety of innovations. Hage and Aiken (1970) employed a lergely similar technique.

Another approach is to define a set of more abstract categories of decisions, and define behavior relevant to particular innovations within the conceptual definitions of the categories. This approach is used in Eveland, Rogers and Klepper's (1977) framework defining five stages (agenda-setting, matching, redefining, structuring, and interconnecting), each characterized by a set of specific decisions which vary according to the innovation. In this study the conceptualization was applied to a family of innovations related to computer applications.

A third strategy is to define and measure degree of implementation in terms idiosyncratic to a particular technology. In this sense, for any given innovation to be fully deployed, a particular number of discrete steps or tasks will need to be completed. No assumptions are made about the ordering of the choices involved. Measurement involves checking off or rating accomplishment of each task, and counting up a composite score. This approach has been used by Fairweather, Sanders and Tornatzky (1974), Tornatzky *et al.*, (1980), and Hall and Loucks (1977).

However, determining in what stage of an innovation implementation process a particular organization or technology may be is not really equivalent to constructing a univariate dependent variable in the normal manner (Mohr, 1982). As Eveland (1982) notes, an indicator of stage by itself does not usefully discriminate between organizations as a dependent (or independent) variable should. Assuming the process continues, all organizations implementing the innovation will be expected to pass through the stage. Using a process marker for a dependent variable is rather like using "age" as a dependent variable, predicted by, say, height and weight. The analysis is feasible but very difficult to interpret.

Process markers *can* be used as independent or control variables for determining how much of a process has passed, to suggest what implementation behaviors might usefully be compared between organizations, and to identify points at which interventions might be worthwhile. While process indicators such as those proposed by Yin or by Eveland, Rogers and Klepper do not themselves make good dependent variables, they can thus be used as a basis for constructing a number of interesting variables, such as degree of implementation or fidelity scores.

## Adaptation and Fidelity

One of the most potentially useful variables characterizing implementation sequences is how the definition and nature of the innovation itself changes during the implementation process. Complex innovations usually comprise a number of relatively discrete features, some of which are more central to the basic idea than others. As noted in the earlier discussion of sociotechnical design, some of these features involve the nature of the technology itself and some involve the nature of the human behavior related to this technology. Different combinations of features may be implemented at different innovation sites. The relative number or degree to which core features which are implemented at any point can be used as an index of implementation or replication of a prototype technology (Hall and Loucks, 1977). The level of use (or degree of development sophistication), for example, can be crossed with various innovation dimensions such as content, objectives, and materials, to produce "innovation profiles" (Leithwood and Montgomery, 1980) for use in comparative research.

Degree of implementation is, in this approach, inherently a multivariate phenomenon, and single univariate dependent variables are inappropriate. The degree to which the concept can be represented as a single *index* rather than a set of distinct dimensions is a point currently in empirical debate. Selection of variables is, as always, a function of the research questions being pursued; there is no single mandatory implementation variable to be included in all cases.

One can look at the converse of the same phenomenon -- that is, the extent of adaptation, or *in*fidelity to a prototype model. Adaptation is the process; some "degree" measure is an indicator of its occurence. Whether adaptation is helpful or harmful is dependent on the results achieved by the technology as eventually deployed. One approach has been to try to identify whether the features altered are "core" or just superfluous elements. However, the evolving nature of most innovative technologies (due in fact to this adaptation) makes the identification of such immutable core features quite difficult, and presents researchers who wish to use this concept with serious measurement problems.

The exact degree of implementation for any specific innovation, and what features distinguish its core from its bells and whistles, is largely a judgment which depends on the perspective of the user of the term. Inventors, developers, disseminators, policy makers, consultants, users of an innovation, and others affected by its use may perceive the same "actual" extent of implementation in quite different ways. Those using this approach must, therefore, specify their criteria for measuring implementation as carefully and visibly as possible. In general, attention to measurement precision in implementation analysis has been rather less than careful in most cases (Scheirer, 1982).

Although the empirical literature concerned with adaptation is not large, a number of studies have dealt with adaptation in the course of looking at something else. For the most part, these studies have set out to study implementation of particular innovations, and discovered that this process did not result in the unequivocal appearance of the recognizable "innovation" in the organizations in question. The earliest explicit discussion of "adaptation" as a functional response, rather than as some form of pathological perversion, was Charters and Pellegrin's (1973) study of an educational innovation. Many subsequent studies have focused on education as well (Berman and McLaughlin, 1974, 1977; Havelock and Havelock, 1973; Rogers *et al.*, 1975; Hall and Loucks, 1978. The same process of adaptation has been noted in budgeting (Browning, 1968), urban modeling (Brewer, 1973), health programs (Hyman, 1973; Kaluzny, Gentry and Veney, 1974), computer systems (Eveland, Rogers and Klepper, 1977; Kraemer and Dutton, 1979), mental health programs (Larsen and Agarwala-Rogers, 1977) and the use of program evaluation (Calsyn, Tornatzky and Dittmar, 1977). Material technologies also vary greatly in their implementation, but to date we have only case descriptions of this phenomenon (Trist and Bamforth, 1951; Pasmore and Sherwood, 1978).

Fullan and Pomfret (1977) review sever ' studies in which the degree of implementation was measured explicitly. Examining this literature, it becomes clear that despite this extensive documentation of the existence of variation in degree of implementation, there is no systematic well-grounded terminology as yet developed to describe the factors which produce this variation. Recent exploratory work by Rogers, Magill and Rice (1979) has been specifically concerned with developing hypotheses concerning the factors which influence such reinvention, and some progress has been made towards developing a conceptual framework for these factors.

Some research has looked not only at variation in implementation but also the degree to which implementation fidelity determines effects. In one study, Hall and Loucks (1977) find that a measure of the degree of implementation of various educational practices was correlated with student achievement. Moreover, this index was a more important predictor of achievement than whether a school was a nominal adopter and had been assigned to an experimental condition (training intervention) or control treatment (no intervention). In a comprehensive review of program evaluation literature, Boruch and Gomez (1979) judge that a considerable percentage of negative evaluation findings can probably be accounted for by loss of fidelity in implementation, or, as they put it, the "contamination" of the independent variable (the innovative program). The implementation *process* -- or the lack thereof -- can influence the extent to which the innovation *effects* can be assessed (Tornatzky and Johnson, 1982).

In a less normative vein, Hall and Loucks (1978) argue that replications of an innovation can assume a whole host of "configurations" in various settings. Some of these configurations can be assumed to yield positive outcomes similar to those achieved by the prototype; others are likely to be aberrant versions. It is not infrequently the case that innovations which are presumably different (according to their developers) may be observationally indistinguishable after implementation (Barker, Bikson, and Kimbrough, 1981). It has also been suggested that variations which do not achieve full output in terms of their *developers'* criteria may yet produce substantial benefits in terms of their *own* criteria for organizations which use them (Pelz and Munson, 1980).

The crucial issue of measuring degree of implementation is therefore reduced to three related and equally important processes:

1) Identifying the "core aspects" which *define* an innovation;
2) Determining whether these core attributes are in fact implemented in the field;
3) Distinguishing empirically between those modifications which represent desirable "adaptations" and those which represent accidental or deliberate negative distortions of the technology.

The first is largely dependent upon *a priori* data-based judgments (e.g., understanding the generic technology of which a particular innovation is an example through interviews with innovation developers). The second involves difficult multivariate measurement problems. The third involves empirical assessment of the effects produced by various high probability mutations.

The underlying purpose of measuring degree of implementation is, of course, to understand better why innovations mutate and whether such mutations are generally functional, disfunctional, or not amenable to evaluation. But all of these issues pose major logistical and conceptual problems for researchers. For example, do self-reports yield "equivalent" implementation scores to those produced by observations? Who are the most useful informants for interviewing with regard to degree of implementation, particularly when few participants are involved with more than a narrow window of the whole process (March and Romelaer, 1979)? Whose criteria are being used for evaluating effects?

It should be noted that there is another literature bearing on the fidelity problem. This is the *single-innovation case study* in many industrial and governmental settings.* Usually related retrospectively from the point of view of the implementor, these studies frequently describe major reinventions or adaptations as though they were simple, logical responses to a situation -- regardless of how they may have changed the original idea. Brady's (1973) description of operational planning in HEW is a

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* As Yin (1981) notes, many studies which have ostensibly large numbers of respondents (e.g., individuals in organizations) are in fact studies of single organizations and/or single innovation experiences, and should not be confused for generalization purposes with real cross-organizational analyses, either quantitative or qualitative. As noted, the unit of *response* is not always equivalent to the unit of *analysis* or *inference*.

reasonable example; the OR/MS implementation literature is particularly full of such cases. In terms of outcomes, the nature of adaptation in such studies has tended to be positive, although not uniformly so.

## Factors Affecting Implementation

The generic method of implementation research is to determine where a particular organization is in the implementation process by looking at what decisions have and have not been made. But this measurement problem is only the first half of the process, and does not address the reasons *why* one might be interested in implementation. Whatever method is employed for measuring degree of implementation, most research in this area has concentrated on accounting for why the process takes one direction or another. There are considerably more data on the determinants of early-stage implementation than later-stage implementation, for the logistical reasons noted earlier -- few have had either the resources or the patience to study organizational phenomena for very long.

Fullen and Pomfret (1977), for example, note that broad-scale policies and incentives (e.g., Federal policy initiatives) have little impact on implementation, and that the global characteristics of the innovation per se (such as cost, size, and trialability) are not as important as might be expected in accounting for differences in implementation behavior. The important influences are: (1) the implementation *strategies* employed, including who is involved in decision making, information exchange, etc; and (2) characteristics of the implementing *organization* and their interaction with the evolution of the use of the innovation (that is, characteristics emphasizing the fit between the organization and the technology).

Intraorganizational Influences on Implementation

Several studies reinforce these points. In two experimental studies, (Fairweather, Sanders and Tornatzky, 1974; Tornatzky *et al.*, 1980) use of a mental health innovation was related statistically to participative decision making in organizations, and to intervention/consultation techniques which emphasized face-to-face interaction. Stevens and Tornatzky (1979) find implementation of a management innovation (program evaluation) to be enhanced by an experimental manipulation which increased the participation of staff in consultation sessions. Corbett and Guttinger (1977) find team, as opposed to unilateral, involvement in workshop training to increase the likelihood of implementation, although the definition/measurement of implementation is somewhat obscure in this case. Both Berman and McLaughlin (1978) and Yin (1979, 1980b) also note the correlation between a general factor of *local initiative* (in local-Federal relations) with the success of implementation. Kraemer and Dutton (1979) and Keen (1981) both note that the effects of perceptions of political interests may be critical to innovation behavior, which seems to be another way of making the same point.

Studies by Berman and McLaughlin (1978) and Yin, Heald and Vogel (1977) find that greater practitioner involvement in implementation (e.g., teacher participation during strategy sessions, early practitioner first-hand experience with innovative technologies, recognition by practitioners of the innovation's relative advantages, etc.) facilitated subsequent implementation. Also, both of these large-scale empirical studies revealed that the use of an innovation for a *core* application (one of crucial importance to the organization) and the *continuation* of top management support for the innovation were substantially associated with degree of later-stage implementation.

Gross, Giacquinta and Bernstein (1971) note that the extent of participation by teachers in implementing innovations was closely related to the durability of change. This phenomenon in a local government context has been termed "ownership" of the innovation, and seems very important in securing acceptance (Rogers, Magill and Rice, 1979). But as Charters and Pellegrin (1973) suggest, the more participation there is in an implementation process, the greater the likelihood that the innovation will be modified. As noted below, the effect of this may be either positive or negative in terms of outputs; while it almost always increases the satisfaction of participants with the process, and hence their *self-reports* of success, it may compromise the efficacy of the technology per se (Giacquinta, 1978). Adaptation in which organizational members become involved is generally viewed positively regardless of outcomes. People apparently like to become involved in the design of technologies they will have to live with (Bikson, Gutek, and Mankin, 1981; 1983). The trick would seem to be how to employ such participative approaches in a way that maintains the core beneficial features of the technology and produces only benign adaptations.

Berman and McLaughin's (1978) study concerning educational innovation compares the impact of a traditional policy lever (funding level), with other intraorganizational and strategy variables. The results clearly indicate that the latter were much more important in securing implementation. Moreover, Cooke and Malcolm (1981) suggest that the nature of the strategy chosen to govern implementation by the organization critically mediates the effects of external policy influences.

Macro Influences on Implementation

There have been few comparative assessments of the relative impacts on implementation of traditional broad-gauge *national* policy incentives (such as funding and regulation) versus more *organizationally* focused incentives (such as technical assistance). Williams and Elmore (1976) aptly point out that geographic spread and organizational layering of Federally-initiated programs often preclude effective central direction of implementation, but few empirical data are offered. It is important that there be an increase in studies tying together the macro-implementation (policy) and micro-implementation (organizational) perspectives.

In a similar vein, the importance of guidelines in innovation implementation has been pointed out (Rabinovitz, Pressman and Rein, 1976; McGowan, 1976) but virtually no empirical data are available. To emphasize the earlier point about the necessity for a longitudinal point of view, Kirst and Jung (1980) studied implementation over a ten year period, and found that increasingly specific and straightforward Federal guidelines gradually produced more complete implementation relative to the original legislative mandate, and more pervasive program effects. This latter point is echoed in Boruch and Gomez' (1977) review of the social program evaluation literature. They argue that negative or negligible outputs from such innovations are often the result of incomplete implementation of the innovation (the "independent variable") in the first place. Datta (1981) criticizes the Berman and McLaughlin studies on similar grounds, suggesting that criticisms of supposedly "national" programs is ill-founded when there is really no intensive national program to ensure implementation to begin with.

A common preoccupation of policy makers is the attenuation of effects of national programs at the local level. The usual response is a further twisting of the traditional policy levers of regulation, financial support, and oversight. But if in fact most of the phenomena that govern effective implementation are the results of *intra*organizational events, then some significant rethinking of Federal strategy would be implied. For example, an increase in the use of change agent mechanisms such as those used by the National Diffusion Network in the Department of Education (Emrick, 1977) might prove to have wide applications. As noted, there is very little cross-referencing between the policy implementation literature and the organizational implementation literature, and virtually no studies which directly compare macro versus micro approaches to implementation.

Innovation Outcomes and Implementation

Determing the "effectiveness" of innovation is, as Chapter II described, a multidimensional task. A distinction is often made between characteristics related to the *production efficiency* of the innovation, and those related to its *political viability*, the "bureaucratic self-interest" of decision makers and users. Studies by Berman (1980) and by Yin, Heald and Vogel (1977) suggest innovations seen as enhancing the latter set of purposes are more readily implemented. This distinction between "efficiency" and "self-interest" factors is also found in the literature specifically concerned with later-stage implementation. For example, self-interest concerns such as union influence, consideration of promotions, client demands, etc. are reported by Berman and McLaughlin (1978), Beyer and Stevens (1976), and Yin, Heald and Vogel (1977) to be of importance to later-stage implementation; they frequently outweigh considerations of efficiency, which tend to be defined at the level of the organization rather than at that of the person actually doing the implementing. This has implications for tracking the course of interlocking implementation decisions (Elmore, 1982)

The process of innovation, as noted earlier, tends to involve some parts of the overall organization much more than other parts. This implies that characteristics of the larger organization may not be very helpful in accounting for such local behavior. It is likely that local decision making criteria may be more influential in shaping the decision process than are more global, organization-wide, criteria. Of course, the conflict between these two factors is more assumed than empirically verified.

These distinctions are also clearly related to classic sociological conceptualizations such as the establishment of social legitimacy during organizational change (Perrow, 1970) and the conflict between efficiency and institutionalization criteria (Meyer and Rowan, 1977). These results echo and elaborate a provocative argument presented by Pincus (1974). Based on his review of the literature, Pincus identified "bureaucratic safety", "response to external pressure", and "approval of peer elites" as the factors most important to the implementation of educational (largely software) innovations. These factors are obviously subsumed in the "self-interest" category of incentives -- and are obviously more applicable to the professional and administrative levels of organizations than they are to the policy levels.

There have been very few studies which have independently measured specific innovation characteristics and associated them with implementation. Moreover, the characteristics measured have not generally reflected the mainstream of the "innovation characteristics" literature. For example, Berman and McLaughlin report that the nature of the innovations (educational methods) chosen for implementation determined project outcomes only to a limited extent, in that "ambitious" innovations were more likely to elicit staff commitment than routine projects. But the change process itself seemed to be more crucial to ultimate implementation than the innovation per se. Their overriding conclusion was that the use of certain change *strategies* (e.g., concrete and extended training, teacher participation in project decisions) as opposed to those found to be "ineffective" (e.g., outside consultation, "one-shot" training, packaged management approaches) was of much greater importance. Nonetheless, Yin, Heald and Vogel (1977) do find one innovation characteristic to have explanatory power: "Task-specific" (single application) innovations are associated with more clearcut implementation than are "task-diverse" (multiple application) innovations.

Finally, preparing a careful groundwork for later-stage implementation during earlier stages has been reported to be significantly related to later-stage success. For example, the importance of early and sustained planning (for resource supply, displacement of existing technology, personnel turnover, interorganizational relations, etc.) to the success of later-stage implementation has been generally observed (Ettlie, 1982). A number of authors (e.g., Sarason, 1972; Yates, 1978) also note that fundamental conflict concerning the *goals* of innovative projects can make implementation difficult and subsequent routinization impossible. Finally, a limited project *scope* (i.e., extent of innovation application) during the initiation phase was reported to be related to successful later-stage implementation by both Berman and McLaughlin (1978) and Yin, Heald and Vogel (1977). It is a truism of the planned change literature that change in small increments is generally more palatable to organization members than is a single large jump.

Undoing Implementation

The procession through implementation stages leads logically to the study of *termination*, or de-implementation of innovations (Bardach, 1977). This part of the process has been termed "exnovation" by Kimberly (1981). The effectiveness of any innovation is constrained by a given social and economic context. When that context changes, the innovation may no longer be useful in that setting (although it may remain useful in other settings). Determining the degree of "success" of any innovation is thus likely to be a function of *when* one looks at its effects, which are likely to change in value as criteria are changed by the passage of time.

For many reasons, and particularly in the case of public sector innovations, many innovations far outlive their usefulness. In fact, getting rid of outdated innovations is perhaps one of the most interesting processes one might study, in terms of relevance to public policy. Some of the effort devoted to improving the ability of innovators to fasten their innovations on organizations might usefully be devoted to finding ways to *un*fasten them when appropriate. However, this area has been largely ignored by innovation researchers, perhaps indicating what Rogers (1975) calls the "pro-innovation" bias of the field. Where it has been explored, termination is generally valued negatively, as in Rose's (1977) study of the "evaporation" of management by objectives. There is a need to integrate into innovation analysis the insights of analysts of organizational decline (e.g., Hirschman, 1970; Whetten, 1980). There is also a need for better indicators of the obsolescence of innovations. Much of the attention to this problem is currently confined to economic analyses of hardware life cycles. More attention to the problems of obsolete *behavior* (or social technologies) would be useful, although the program evaluation field has fulfilled this function to some degree.

## Summary

The thrust of all the work on implementation reviewed here is to extend significantly the time frame within which innovation must be studied. Deployment (and perhaps eventual disuse) of technology is a process that almost always involves years, not just weeks or months -- still less the single points at which innovation has frequently been measured in the past. Moreover, implementation phenomena represent the arena in which the success or failure of technology in meeting organizational purposes is ultimately determined. In Chapter IX the role of government policies and practices in innovation is reviewed; the reader is invited to consider the relative persistance of those government-influenced factors in the long and complex process of implementation just reviewed, and perhaps gain some sense of why such government interventions are often less than satisfactory in meeting their expectations.

# CHAPTER VIII

# THE SPREAD OF TECHNOLOGY

This chapter focuses on the processes by which technology is diffused among organizations, and on a series of specific mechanisms which have been created to enhance and promote this spread. The first part sets the general context for such programs, and subsequent sections review specific initiatives which have been employed. The general discussion draws on the earlier outline of the diffusion research tradition (Chapter IV) as well as other sources.

## General Perspectives on Marketing and Dissemination

*Marketing* of innovations is used in this review to describe processes of moving innovations from producer to user in the private sector, while *dissemination* is used here to describe the transmission of information about innovations where a public sector actor makes adoption decisions (particularly where development is Federal and use is made at the state or local agency level). Information dissemination strategies are in effect the public-sector analogue to market strategies. All comments in this section regarding the "uses" of technology should be viewed in light of the preceding treatment of implementation and related issues.

The distinction between marketing and dissemination is somewhat artificial. Marketing obviously involves transmission of information as well as hardware; dissemination frequently involves purchase decisions or expenditures of resources (although the resources so expended may well be more symbolic or in-kind than actual money transactions). Moreover, there is substantial interplay between private sector vendors of technology and public sector users, as well as between public sector technology developers and private users (Wilemon, 1979). However, since these two concepts have represented largely different research traditions and have attracted attention of rather different groups of investigators, the distinction is retained in this section.

Marketing activities or dissemination efforts are part of a broad group of activities which the National Academy of Engineering (1974) called "technology delivery systems". A technology delivery system encompasses a sequence of activities ranging from basic research to implementation of innovative products. The sequence usually involves many organizations, and often different groups within the same organization. Different levels of authority may be involved with innovation activities within each functional group.

The marketing component within such a system can be simply described as an information flow from innovation producers to innovation users. In the remainder of this section some of the evidence bearing on the relative efficiency of marketing and dissemination efforts is reviewed.

Evidence from the Private Sector

One of the most important general findings emerging from marketing/ innovation research is that the marketing function should not be separated from other activities in an innovation sequence. If information from product users relevant to marketing can be recycled into the R&D process, the chances for commercial success seem to be enhanced. Dean (1968) presents many examples of the importance of an extended view of marketing to private manufacturing firms. Project SAPPHO (Science Policy Research Unit, 1971) found downstream links to user organizations to be extremely important to the commercial success of innovations. Phase II of the SAPPHO study found that strong links to users minimized the users' subsequent efforts to adapt the innovation to their unique needs (for good or ill). It also suggested that greater levels and faster rates of diffusion among users resulted from higher awareness of the wants of the users. Mansfield and Wagner (1975) also concluded that greater integration between the R&D and marketing groups of a corporation enhance the chances for commercial success. Von Hippel's (1978) work on user-based innovation, Litvak and Maule's (1972) study of survival rates of new ventures in "high-technology" product areas, and Langrish and Gibbons' (1972) study of prize-winning technological innovations all support this conclusion.

It is not surprising that a high proportion of studies have concluded (on the basis of logic, practice wisdom, or actual data) that the effective integration of marketing and R&D is important. In a superficial way, the point is tautological. However, the many examples of ineffective integration, and the stark contrasts in success between innovations that have been developed with and without the benefits of marketing-based information, serve to stress the need for continued attention to these operational issues.

Given the consensus about the utility of integrating R&D and marketing, several authors have struggled with how this might be accomplished.

Robertson (1971) suggests that "the product life cycle" is one important determinant of a well-designed blueprint for coordinating R&D with marketing functions. Clarke (1974) reviews literature treating operational questions about effective integration, and concludes that marketing and R&D personnel should be brought together at various stages in a product's development. Souder (1977) explores different organizational coordinating mechanisms for integrating R&D and marketing, and concludes that the best method for a given organization is contingent on a combination of factors relating to technology, overall organization structure, and characteristics of personnel in marketing and R&D positions.

Special Problems of the Public Sector

When the focus shifts to the public sector, the importance of coordinating R&D and marketing (or dissemination) deserves further emphasis for at least two reasons. First, the coordination problem is freque[illegible] much larger, since different organizations (or agencies) may have primary responsibility for R&D and dissemination. The functions may be located in different, possibly competing, parts of the same agency. Targets may be layered, involving both industrial firms and households (as is the case, for example, with efforts to commercialize both solar energy and many management technologies such as word processing), and the budgetary authority controlling outlays for product development may be only loosely coupled to the resources available to R&D performers.

In addition, technology of interest to government agencies is often very difficult to evaluate. Many new t[illegible]ies that have received heavy government promotion have been serv[illegible]ng, but also occasionally budget-increasing or agency-disrupting. Frequently, complex hierarchies of authority exist in layers over the agency (Roessner, 1979). Finally, it is often the case that technologies being disseminated in the public sector are "social technologies", which are often weak in either operational specifics or clear evidence of outcomes.

In the public setting, therefore, dissemination of information often must go well beyond routine transmission of messages among professionals with common goals. Dissemination strategies need to consider the following points: (1) the purpose of the message; (2) the type of receiver; (3) the routineness of messages sent along the indicated pathway; (4) whether organizational boundaries are crossed; and (5) the complexity of the goals of the receiving unit.

The conclusions that can be drawn from the empirical literature on dissemination are fairly straightforward. There is considerable literature on what types of communication channels ought to be employed and at what phases during a dissemination effort. A common theme and conclusion throughout this literature is that face-to-face communication has a strong, positive effect on dissemination. Both Ryan and Gross's (1943) hybrid corn study and Coleman, Katz, and Menzel's (1966) medical innovation study highlight the importance of such personal contact.

These influential studies focus on individual rather than organizational behavior, but the findings have been consistently borne out in organizational settings. Fox and Lippett (1964), Fairweather, Sanders and Tornatzky (1974), Glaser *et al.* (1967), and Glaser and Ross (1971) all report empirical findings which point to innovation adoption being facilitated by interpersonal dissemination efforts. Included in this array of dissemination techniques are conferences, workshops, and site visits. Greenberg (1967) specifically points to the value of interpersonal contact in government-initiated technology transfer efforts. Bikson's (1980) review of knowledge utilization literature strongly supports the efficacy of interactive dissemination.

Several field studies concerned with dissemination of innovations to organizations have compared various dissemination methods and tactics. Havelock (1973) summarizes findings as of that date, most of which point to the need for a personal "linkage" activity between technology producers and users. A series of related studies in mental health settings (Larsen *et al.*, 1974; Larsen *et al.*, 1976; Roberts and Larsen, 1971) have found that potential users prefer, and make more effective use of, information given directly by people rather than media. In an experimental study, Fairweather, Sanders and Tornatzky (1974) find that workshops and demonstration programs are significantly superior to written media as dissemination tactics. In another experiment Fleischer (1978) finds that site visits by potential adopters marginally enhance the likelihood of adoption of mental health innovations in contrast to workshop-only dissemination. In addition, several well-controlled experiments (Conrath *et al.*, 1975; Chapanis, 1971) point out the utility of interpersonal communication in transmitting highly complex subject matter.

Despite these findings, there is limited understanding of the detailed processes involved in information dissemination. The general concept of uncertainty-reduction discussed elsewhere in this volume may explain part of the phenomenon. It will be recalled from the discussion of organizational contingency theory that more informal, less bureaucratic organizations may be more effective in dealing with nonuniform tasks. Social-psychological data (Bem, 1972; Festinger, 1954; Schachter, 1959) suggest that interpersonal interaction serves to "define social reality" in situations of stimulus ambiguity; innovation is usually a situation of stimulus ambiguity. This would explain both the findings concerning interpersonal dissemination and those regarding participative decision making and innovation. As a corollary, some studies (Rothman, 1974; Rogers and Shoemaker, 1971) indicate that change agents and dissemination strategies which are congruent with the norms and values of adopters and target systems are more likely to lead to adoption. In any event, the mechanics of such interactions need substantial further exploration. An integration of cognitive science, organizational theory, group dynamics, and innovation theory is called for, although probably some distance in the future.

## Technology Tran r Systems and Initiatives

It s' uld be noted that most governm  programs to promote the spread of technology are not characterized as "dissemination"; the term *technology transfer* is usually applied. The government agency is the provider of the technology (either directly or through subsidy of R&D), and other agencies or firms assume the role of clients served by such a technology transfer structure. This model of interaction is certainly the oldest approach used by the government to the dissemination of technology, but it is by no means the only one. Structurally, it is an example of Schon's (1971) "center-periphery" diffusion model, in that it involves a centralized screening and marketing of technologies for use by units of government or private firms. While the accomplishments of technology transfer have been substantial in many areas, a number of issues remain unresolved about the universal utility or effectiveness of these systems, such as:

1) Choosing the technology to be transferred;
2) Choosing the transfer mechanisms to be used;
3) Assessing the "success" of the process.

Before addressing these generic concerns, it would be useful to review past history and current practice in government technology transfer.

## History and Current Practice

The classic version of a technology transfer system is the agricultural extension program. This very large-scale operation dates back originally to the 1870's in parallel with the land-grant college system, and has been a focus of many analyses in recent years (e.g., Rogers, Eveland, and Bean, 1976; Hightower, 1972; Feller *et al.*, 1982). The agricultural extension system is perhaps the most "complete" of any of the existing technology transfer programs. It has incorporated features that are either absent or minimal in other agency efforts. Figure 9, adapted from Rogers, Eveland and Bean (1976), defines eight major aspects of this system and how they are or are not carried out in other parallel systems.

Until the middle 1960's there was little interest beyond the field of agriculture in technology transfer programs. Federal research was either conducted to benefit the Federal government directly or was communicated through professional channels, and there was no widespread consciousness of a need to share this research through marketing procedures. The greater competition for tax revenues which accompanied the expansion of Federal programs during the 1960's and 1970's led to a much greater consciousness on the part of Federal officials of a need to expand and demonstrate "utilization" of research. In this climate, interest in and commitment to "technology transfer" as a way of increasing research utilization became

## FIGURE 9
## MAIN ELEMENTS OF THE AGRICULTURAL EXTENSION SYSTEM COMPARED TO THOSE OF ITS "EXTENSIONS"

| Main Elements in the Agricultural Extension Model | Cooperative Extension Service (USDA) | Educational Extension Efforts (OE) | National Diffusion Network (OE) | Agricultural Extension in Developing Nations | Technology Utilization Program (NASA) | OSTS (U.S. Department of Commerce) |
|---|---|---|---|---|---|---|
| (1) A critical mass of new technology | Technology with a clear payoff, and connections with previous practice | Technology developed from theory | Technology developed from practice | Technology with payoff, but expensive and inaccessible | Yes, as a spinoff from space research | Not a well-defined mass of technology |
| (2) A research sub-system oriented to utilization | Yes, due to reward system for researchers | No | Yes, as R&D is conducted by D/D's | Somewhat | Yes, as a part of NASA's charter | No |
| (3) A high degree of user control over the research utilization system | Yes, through county planning councils | No | Yes, as R&D is conducted by D/Ds | No | No | No |
| (4) Structural linkages among the research utilization system's components | Yes | Yes, with help of ERIC | Yes, between D/D's and adopting schools | No, extension service relatively unconnected with researchers | No | No |
| (5) A high degree of client contact by the linking subsystem | Yes, agent:client ratio of 1:500 | Yes, in a pilot project | A reasonable client ratio | No, hopeless client ratios | No | No |
| (6) A "spannable" social distance across each interface between system components | Yes | Yes | Yes, as both D/D's and adopters are peers | No, wide social distance of agents from farmers | No | No |
| (7) Evolution as a complete system | Yes | No | No | No | No | No |
| (8) A high degree of control by the system over its environment | Yes, e.g., through the AFBF | No | No | No | No | No |

[From: Rogers, Eveland and Bean, 1976]

common in Federal agencies with any research support programs at all. Some of these programs represent spin-off utilization (usage of research originally developed for other purposes); some represent directed research created in response to user demands (Greenberg, 1967). There is an interplay of incentives for agencies to create such programs (Chakrabarti, 1973; Chakrabarti and Rubenstein, 1976).

Most emphasis in government technology transfer has been placed on hardware technology. Such technology is readily observable, identifiable, and portable. However, some of the more elaborate technology transfer systems outside of Agricultural Extension have involved "soft" technology of one sort or another. Most notable has been the National Diffusion Network in education (Emrick, 1977) which has a highly complicated and "interpersonally rich" transfer structure. Since it is likely more difficult to disseminate complex and uncertain social technologies, such developments are perhaps inevitable. Still unanswered is the question of whether complex social technologies can be "transferred" in any precise replicable form (Gottschalk *et al.*, 1981; Blakely, 1982).

Associated with the structural complexity of various transfer systems have been questions about what *modes* of communication should be used. Two general modes of technology transfer are currently in operation:

1) *Active* systems - Those systems where active transfer agents interact between researchers and clients often interpersonally or face-to-face (e.g., the county extension agent);

2) *Passive* systems - Those in which the access to the body of research is wholly the responsibility of the user, and an intermediary relates the two with a heavy reliance on formal or impersonal media.

Passive systems have obvious advantages. They are much cheaper to maintain and operate, without the high labor overhad of active systems. With the advent of sophisticated computer information processing, even relatively unsophisticated users can theoretically find their way through large data bases with some efficiency. These facts have not been lost on government program managers. Of the fifty technology transfer programs described in the most recent inventory (Federal Coordinating Council on Science, Engineering, and Technology, 1977), most can be categorized as largely passive in nature. Moreover, in a recent survey of Federal manufacturing technology transfer programs, Hetzner, Tornatzky and Klein (1983) found all but two to be essentially passive. The wisdom of that particular set of policy choices will be considered below.

<u>Choosing the Technology to be Transferred</u>

Assuming that government technology transfer programs are to be initiated, a basic question needs to be resolved: *which* technologies or research findings should be transferred? In the early days of the Agricultural Extension system, of course, such a question was less troublesome. The actual volume of research performed was considerably less, and the utility of emerging technologies probably had more readily apparent face validity to potential adopters. However, the very volume of government-supported research, the bewildering mix of basic and user-oriented results, and the limitations on resources available for transfer activities would suggest that some strategy is needed by information managers to choose which technologies should be emphasized. This has not usually been systematic.

One approach has been to consider all findings and technologies as equally worthy of transfer, and to attempt to disseminate all. Obviously, this strategy usually implies that a very passive, if usually rather large, transfer structure is created. For example, the approach taken by many research agencies has been merely to list completed projects, file final reports in the National Technical Information Service (NTIS), and enter information into computerized information retrieval systems. A heavy reliance is thus placed on the user community to pursue findings.

An alternative agency strategy has been to identify those research results and technologies which are "more equal" than others. Thus, agencies may establish screening structures to identify "exemplary" products, findings and technologies. The Joint Dissemination Review Panel, affiliated with the National Diffusion Network, is one example of such a function (Emrick, 1977). The assumption is that, once highlighted as exemplary, the given technology will be aggressively marketed or diss[illegible] a transfer structure. The agricultural extension system has [illegible] this flavor; university researchers, local extension agents, and individual farmers jointly (if loosely) set the agenda for the system.

Obviously, this issue is far from resolved either empirically or in terms of policy decisions. There would likely be different solutions for different agencies and different technical areas. For example, it might be quite appropriate for an agency such as the National Science Foundation to use a passive approach with its academic research audience rather than attempt to make discriminations of importance or quality. Such an approach, in turn, might be quite inappropriate with "social technologies" for unsophisticated users, such as local service agency administrators desperately looking for "proven" programs.

Choice of Transfer Mechanisms

The above comments notwithstanding, there are many issues remaining concerned with the communication processes and organizational structure of transfer mechanisms. For example, there may be situations in which passive transfer systems make economic sense or can provide some low-level visibility of technology, even though available evidence generally indicates that passive systems do not work very well when results are judged by volume of technology transferred through the system and eventually implemented. A number of studies reviewed in Rogers, Eveland and Bean (1976) of various technology sharing programs operated by NASA, the Department of Commerce, and others all come to essentially the same conclusion. Reviews of the performance of the Educational Resources Information Center and NTIS have likewise concluded that passive access does not lead to a high volume of activity.

In the last few years, there has been considerable interest in a variation of the active system which differs from the classic technology transfer approach in that it lacks the clearly defined "center" or "periphery" of Schon's (1971) model. That is, there is no single authoritative producer of information, and no clearly defined user. Each point in the system is presumed to have information that the others can use to some degree (Rogers and Leonard-Barton, 1980). These "network" models (sometimes called "peer match" approaches) have only recently begun to function, and relatively little is known about their effectiveness compared to traditional technology transfer modes (Bingham, 1981). The technology sharing systems formerly operated by Public Technology Inc. (PTI) under NSF sponsorship the "innovation networks", the International City Management Association Peer-Match programs, and other versions need systematic study, to determine how they differ from traditional practice, what their strengths and weaknesses might be, and the long-term effects of their activities (National Science Foundation, 1980a; Yin, 1980b).

Another structural innovation in technology transfer is *capacity-building* or *capacity sharing* (American Association for the Advancement of Science, 1981). Some would argue that this is a contradiction of technology transfer in the normal sense of the term. Rather, it is a system for increasing the capabilities of recipient jurisdictions to make educated judgments about technology rather than a program to "push" technology directly. As Roessner (1979) phrases it, such systems are aimed at "strengthening analytic and evalutive capabilities of state and local governments rather than the development and use of particular solutions". If this approach receives further support it will be in fact a major re-thinking of the entire technology transfer model. It deserves careful research attention in the future. Of particular interest would be "the degree to which agencies with a greater capacity to analyze problems really make better decisions about the role and use of science and technology" (National Science Foundation, 1980a). As Datta (1981) notes, the empirical evidence for either side of this debate is slim.

Evaluating the Success of Transfer Efforts

Another unanswered question concerning technology transfer programs has concerned their success or effect. Since few government programs have been in operation long enough to enable gathering meaningful longitudinal data, the evidence is scattered. However, even in well-established programs a variety of evaluation issues abound, mostly involving controversy about what criteria should be used to determine success (see Chapter II).

For example, it has been contended that in the agricultural extension system "success" has been more problematical than many would conclude. Hightower (1972) presents a severe critique of the effects of the system on the distribution of agricultural land, the quality of crop output, and the quality of American life in general. This is a a pointed example of how analysts who agree on the same general data can use it to derive quite different policy conclusions. There is also little agreement on the relative value of output measures (e.g., practices "adopted") versus process measures (e.g., farmers reached with information) for assessing the effectiveness of technology transfer systems. For example, Roessner's (1975) analysis used exclusively activity indicators. As we noted before, the choice of a dependent variable is a crucial value decision.

While most Federal technology transfer programs recognize that technical assistance as well as information is necessary, a more successful program is likely to have to allow for (1) the role of "knowledge vendors" as a link between public agencies and private technology suppliers; (2) the impact of the transfer process on existing organizational structure; (3) the "uneveness" of the implementation process within different parts of the organization; (4) the potential modification or reinnovation of the technology by users; and (5) the difference between design and implemenation failures. Further research into each of the areas should enhance the effectiveness of the technology transfer process.

## University/Non-University Interactions

University/non-university interactions represent one of the more useful areas in which to apply concepts of interorganizational relations and technology transfer as they relate to the innovation process (Baer, 1977; Shapero, 1979). The innovation process is often conceived as moving in a line from basic research, to applied research, to development, and to marketing and dissemination (Havelock, 1973), with different institutional performers involved in different stages of that longitudinal process. The stage-process model outlined earlier is compatible with this view. In this formulation, the university's role is seen as primarily the performer of basic research and it is widely assumed that this research provides a knowledge base which industry and government utilize (Battelle, 1973; IIT Research Institute, 1968; Sherwin and Isenson, 1967).

Not surprisingly, this model of a linear and unidirectional flow of information between universities and industry has been challenged more than once. As Mogee (1979:3) states:

> These models are admittedly oversimplified; in real life the progress of an innovation is never that straightforward. Sometimes stages are shortened, skipped, or overlapped.

In effect the university has not been considered as an active participant in the innovation process, but as part of the "environment" of the public or private user organizations. The "gatekeeper" literature, for example, examines how scientific and technical information enters and diffuses through user organizations (Allen, 1970; Keller and Holland, 1976), and how a relatively few people linked to a network of research (such as in universities) facilitate the acquisition and dissemination of needed information.

Part of the problem in defining the university's role in the innovation process is based on the lack of empirical research in this area. Analysis of university/non-university interactions has been generally limited to case studies of "successful" interactions and attempts to categorized existing collaborative efforts. For example, Brodsky, Kaufman, and Tooker (1979) define and describe sixteen types of activities ranging from corporate-funded university research to consultancies and continuing education programs; Baer (1976) develops a similar list. While the literature does identify hypothesized "barriers" to successful interactions, it does not clearly define measures of success, and generally fails to provide data about which mechanisms transfer what kinds of information best.

However, current developments are forcing government, industry and academia to look more closely at these collaborative efforts.* Government's concern is based on a perceived decline in U.S. productivity which has been related in part to insufficient R&D. Universities are concerned about diminishing financial support, decreases in enrollment, outdated university research facilities, and the increasing federal emphasis on accountability for support (Brown, 1980). For industry, inflation, taxes and the increase in government regulations have led them to look for ways to increase their science base without increasing in-house R&D expenditures.

Future attempts at providing more stable and productive university/non-university exchanges are in part dependent on a greater understanding of these transactions. In effect these interactions should be viewed as resource exchanges of money, personnel, facilities and knowledge.

Johnson and Tornatzky (1981) offer a preliminary analysis of university industry transactions within a general framework of interorganizational relations. They suggest three major factors which shape the degree

* Considerable interest has been focused on the cooperative university/industry research center model as one well adapted to current conditions (Eveland and Hetzner, 1982; Tornatzky *et al.*, 1982), but it is by no means the only such approach which is viable.

of interaction: (1) goal congruity and compatability; (2) boundary-spanning structures; and (3) organizational incentives.

Goal Congruity and Capability

When an organization interacts with another organization there are varying degrees of goal similarity and goal compatability. There is a considerable evidence in the literature that the degree of mismatch is related to the amount and success of interaction (Reid, 1969; Levine and White, 1961; Tornatzky and Lounsbury, 1979). Universities and industries may share the goal of increasing the knowledge base in a scientific field (albeit for different reasons). They may also have compatable if not identical interests, such as training scientists (universities) and hiring trained scientists and engineers (industry).

Other goals and objectives may be less similar or compatible. For example, industry is primarily interested in commercializing products and processes for profit and is thus by definition more interested (in the short run) on applications; universities, at least in recent decades, have emphasized basic research, discipline-bound science, and the norms of academic inquiry.

The time frame for task accomplishment is also significant. The course of basic science is typically not a time-bound activity for its practitioners; in contrast, the expenditure of scarce capital by industry on research projects has built-in time and resource limitations. The success or failure of university-industry transactions can perhaps be understood in terms of the operative goals and the objectives being sought. Research should examine the transaction structures and desired end states of both university and industry participants and consider the degree of congruity or compatability involved.

Boundary-Spanning Structures

"Interactions" between university and industry involve real people, things, and ideas. As such they must occur in a defined space, time, and setting. The units involved in such transactions are "boundary-spanning" units. Depending upon what is being exchanged, these structures could be part of the university, part of the industry firm, or could occupy some organizational space in between. For example, one common transaction typically involves the movement of trained students to industrial employers. The boundary-spanning units involved are placement services in the university and personnel units in industry. The result is a network of organizational sub-units with compatible functions. At issue is the extent to which these units are sufficiently tied together that they really *do* intersect and interact. Other types of boundary-spanning structures govern interactions such as joint research. Here the boundary-spanning structure might be a university-based research institute, an industrial lab, or some jointly-administered and geographically neutral setting in which university and industry scientists can interact.

One often neglected organizational design issue is the necessity to legitimate and structure the informal university-industry interactions that already exist and to define the implicit boundary-spanning structure involved. In most universities there is often a great deal of informal interaction with industry, usually in the form of consulting. But universities often do not provide structures for such activity to occur, and the normative status of such activity is often quite nebulous. One unanswered empirical and policy question is whether such interaction is facilitated by being openly supported and structured.

Firm size is another important consideration in the design of university-industry boundary-spanning units. There is considerable literature -- some anecdotal and some empirical -- that suggests that the small firm is heavily involved in innovation, productivity, and technological change (Gellman, 1977; Birch, 1979; Abernathy and Utterback, 1978). This may be due to the organizational structure of small firms, because of their ability to commercialize R&D more effectively, or their role relative to large firms. At any rate the planning of university-industry linkages that does not take into account the special role of the small firms is probably ill-informed. Unfortunately, when university or government move intentionally to create university-industry boundary-spanning structures there is a tendency to focus on large, highly visible firms as participants.

Equally important are the processes that nest within these boundary-spanning structures. The modes and style of communication among participants is probably at least as important as the structural setting. For example, empirical data (Tornatzky *et al.*, 1980) and practical experience suggest that information exchanged via person-to-person interaction is more readily assimilated. Data also suggest (Allen, 1977; Souder, 1977) that research activity is more productive amidst certain organizational processes than others. The designer of university-industry boundary-spanning units should consider findings such as these.

Finally, it should be noted that transaction structures assume some minimal degree of geographic propinquity. Universities that are rural and isolated may not be likely to develop viable boundary-spanning units, since the "span" is too wide in a practical sense. Similarly, industrial firms (particularly small companies) that are not adjacent to universities or do not have resources to support travel may be less likely to pick up innovative activities. There are some interesting empirical questions involved here, which might be answered using methodologies such as network analysis.

## Organizational Incentives and Rewards

Organizational goals and objectives operate at the micro as well as macro level through incentives (and disincentives) for individuals involved in university-industry interactions. In designing and implementing transaction structures, university administrators and industry executives need to ensure that individual rewards are built into participation. The actual operation of such incentives also needs further verification.

The reward system in academia is typically centered around salary, promotion and tenure decisions. The performance criteria for these rewards usually concern scholarly publication, training of students, performing research, etc. Data are needed on how these objectives are attained by faculty in university-industry collaborative settings, and what parallel incentives affect industry personnel. These issues bring to focus a possibly irreconcilable problem. Although personnel involved in boundary-spanning activities in any organization are "different" in the sense that the tasks that they perform are at variance with other organization members, they are still part of and drawn from the larger organization. They are thus subject to the norms and reward systems of two probably incompatible sub-groups of the parent organization.

The individual in this situation can get caught by conflicting role demands and reward systems. The boundary-spanning organization must devise ways of resolving these cultural discontinuities by "impedence matching" compatible norms and rewards (Van Rennes, 1982). In effect *intra*-organizational boundary-spanning is an issue in both university and industry organizations. "Boundary-spanners" may become co-opted by those outside (or inside) the organization with whom they work (Selznick, 1949).

This analysis suggests a number of areas for future research, including studies of the perceived incompatabilities between university and industrial goals, the relative success of different kinds of linkage mechanisms, the role of federal funding as a determinant of university-industry links, and the impact of intraorganizational structural characteristics on interorganizational relations. As noted above, the literature on university-industry interactions is more speculative and descriptive than empirical; this should be rectified.

## Special Initiatives Involving Small Business Firms

Chapter III suggested that the class of small business firms might have innovation dynamics rather different from those of larger firms. Partly for theoretical reasons and partly for reasons of political advantage, a number of government policy initiatives in innovation processes have been directed toward encouraging "small" business firms through set-asides, low cost loans, and programs of technical and managerial assistance. This is an excellent example of policy directed toward a large class of economic units. To understand the rationale for these interventions, it would be useful to understand better the advantages and disadvantages of small size, especially as they affect innovation.

Claims and counter claims have been made concerning the importance of small firms, the productivity of R&D projects conducted in small firms, the similarities or differences in the roles played by small firms and large firms in the innovation process, or the inherently high capacity of small firms to innovate. A major research tradition has been to track the productivity of such firms, and one index of productivity has been the relative contribution of small businesses to employment growth. A recent study (Birch, 1979) estimates that two-thirds of the gain in employment in the private sector of the U.S. economy during 1969-1976 occurred in firms with 1-20 employees. These findings and the underlying methodology have been questioned in recent work by Armington and Odle (1982), and the issue remains an important line of empirical research.

Another research approach has been to compare the role of R&D and invention in small firms with that of large firms in the same industry. Kamien and Schwartz (1975; 1982) review much of the literature in this area, and conclude that the sales/R&D ratio peaked among the group of medium sized firms, as did the production of inventions and innovations. These indices dropped off for large firms.

However, one problem with such studies is that "smallness" is measured in a purely *relative* sense, not in terms of some specific level of total employment in the firm. In absolute terms, thus, "smallness" tends to differ from one study to the next. In addition variables such as operations technologies employed, the repetitiveness of operations, and the specific organizational structure tend to be ignored. Frequently, smaller firms in some industries (particularly process industries like chemical and petroleum refining) are in fact quite large. As noted earlier, what smallness *means* in a social/organizational sense is often quite obscure.

Perhaps the most pervasive finding is that smaller firms have higher R&D productivity. They seem to produce more for their R&D budgets than do large firms (Mansfield, 1968), in terms of innovations, patents, and the like. However, these conclusions depend on the assumption that it is legitimate to use simple counts of patents or inventions as productivity indicators. These studies in practice assume that an innovation is the same to a large or small firm, despite the fact that some small high technology firms may be spin-offs from large firms and their innovations are thus not events independent of the experience of the larger firms. Without further data involving observation of causal relationships, such conclusions must be qualified.

Jewkes, Sawers, and Stillerman (1969) have studied 61 significant twentieth century inventions, and attempt to determine the origins for these inventions. They attribute only twelve to large R&D labs. Gellman (1977) analyzes firms with total employees of less than 1000 and finds that these firms were 24 times as productive (as measured by innovations per R&D dollar) as large firms with more than 10,000 employees during 1953-1973. In explaining these results, two dominant themes emerge, one focusing on the unusual role of R&D in the small firm, and the second on the advantageous organizational makeup of small firms.

First, no more than 10 percent (probably a much smaller proportion) of these firms engage in formal R&D activities (Freeman, 1974). A large proportion of the small firms that are engaged in R&D at any given time are *new* small firms, possible spinoffs from large corporations or from university research laboratories, and operate in small specialized markets that are uneconomic for large firms to pursue. As a number of writers have observed (Gold, 1967; Pavitt and Wald, 1971; Freeman, 1974; von Hippel, 1976), small firms and large firms frequently play complementary roles when they operate in the same broad market area. In other words, the role of

R&D in the small firm may be much more focused on exploiting a *particular* technological opportunity than fulfilling a general function, as it may be more likely to do in the large firm.

Not surprisingly, it has also been suggested that small firms have initial advantages over large firms in developing relatively radical, risky inventions up to the point of early commercialization (Abernathy and Utterback, 1978; Science Policy Research Unit, 1971). These arguments point to the organizational flexibility of small firms and determined inventors, including more rapid and thorough communication, more detailed relevant knowledge applicable to the product area, and greater ability to respond to new opportunities.

An interesting corollary of this argument is that small firms will tend to disappear after they have exploited their relative advantages in "technological trajectories" (Nelson and Winter, 1977) created by new product inventions and innovations around which they have been formed. *Technological trajectories* are conceptually clear lines of development work designed to improve products and processes in a number of different ways. Such firms tend to spend a high proportion of their budgets on applied R&D because they are exploiting potentially significant technical opportunities (Freeman, 1974). Ultimately these small firms will grow out of the small category, or disappear by merger or acquisition.

It appears, on the basis of fragmentary data, that small R&D based firms are highly involved in innovation, technological change, and productivity growth. However, why this is so remains somewhat obscure. It may be the case that in smaller organizations individual rewards and interests are tied more directly to the success of the whole organization, with less of a tendency for behavior to reflect "bureaucratic safety" criteria. The previous comments on the problems of using number of employees as a proxy for size are particularly relevant here; the number of employees per se does not contribute much conceptually to explanation and/or prediction. What appears needed are a set of well-operationalized and micro-level analyses of these issues.

Interestingly, it is in the area of small business innovation that there is the clearest relationship between government policy levers and intraorganizational variables. In fact, many Federal interventions in this area are explicitly intraorganizational in focus (e.g., NSF's Small Business Innovation Research Program, its variations in other agencies, and the Small Business Administration's assistance programs). If research can identify a certain type or size of organization as a seed bed of innovation, it may be in the national interest to promote such organizations. It is clear that various policy instruments can have a significant impact on the fecundity and mortality of these organizations. In particular, tax and assistance mechanisms (see Chapter IX) can be easily used to manipulate the supply of venture capital resources so critical to such firms (Bean, Schiffel and Mogee, 1975; Charles River Associates, 1977). By extension, these policy instruments can be employed to expand or contract the population of firms having such organizational characteristics.

## Commercialization Programs and Demonstration Projects

Over the past two decades, the Federal government has greatly increased its support of research and development on products which are ultimately to be marketed to private industry, state and local governments, and to the public in general. This direction is a significant departure from previous practice in which research and development activities were primarily to obtain products for the government's own use (e.g., the activities of the Department of Defense and the National Aeronautics and Space Administration). These R&D funding trends have yielded a variety of practices and programs generically labeled *commercialization initiatives*, designed to facilitate this inter-sector knowledge transfer. Commercialization efforts have, in general, been managed by government R&D planners and managers with little experience and few guidelines to deal with this process.

Commercialization of research and development, publicly funded or not, is accomplished largely by private sector actions. As large as Federal procurement is, it represents normally only a small percentage of the total commercial marketplace. By definition, the issue involves promoting interactions between organizations and actors in rather disparate sectors of the economy. A number of common themes run through the policy and research debate. One concern is the *respective role* of government and private sector in commercialization, one aspect of which is the essentially ideological question of whether government should support R&D on commercializable products or processes at all. A second area of concern is the *specific tools* that government managers need to employ to enhance the process.

There are relatively few strong empirical studies of commercialization phenomena generally. Arthur D. Little Inc. (1973) examine "barriers" to effective industrial innovation. and conclude:

> ...the dynamics of the market and feedback control through profit make private business the most effective innovator and resource allocator....We need to create open and mutually trustful communications between the public and private sector...so that private industry can play its full role as innovator.

How this is to be done is not specified.

A report of the Joint Economic Committee of the Congress (Gilpin, 1975) suggests that commercialization in the civilian industrial sector is in difficulty due to the divorce of the government's technology policy from socioeconomic realities. The basic premise of this analysis is that market demand is the primary determinant of successful commercialization, whereas many Federally-funded research and development programs use the "technology-push" concept. The report concludes that, outside of basic research, Federal research and development should be coupled to demonstrated demand. It also suggests that research and development funding should complement private funding rather than substitute for it, that government should avoid funding of direct commercial development, and that government should support R&D only in areas where industry, for various reasons, has tended to underinvest. As can be seen, these conclusions also tend more to restate the issues than provide specific operational guidelines.

A 1978 task force on demonstration projects as commercialization incentives in the Department of Energy observed that if DOE's objective is commercialization, it should be heavily staffed with entrepreneurs rather than technocrats, R&D managers, and their economic advisors. An analysis of DOE's roster of several hundred R&D executives, on the other hand, revealed that only eleven had significant commercial experience. As a corollary, the task force observed, most DOE contracts were "overmanaged," which had implications for the net cost of the contracts and for the ultimate degree of commercialization achieved. More work needs to be done on this apparent disparity between the experiential background of Federal R&D managers and the norms and practices of the private sector.

These studies on commercialization are of course only illustrative, although there are certain consistencies. Most agree that market demand

and the relationship between public and private sector participants are key elements. Many of the authors argue for the need for more empirical data for changes in procurement policy and patent policy, and for the alleviation of many problems faced by small firms. All of these issues are discussed elsewhere in this review.

Issues involving demonstration projects in particular are closely related to those involving commercialization in general. Since demonstration projects have been used as a major vehicle in Federal commercialization efforts and have obvious visibility, they merit some special concern. The attractiveness of demonstration projects is congruent with interest on the part of Federal policy makers in "getting S&T products off the shelf" (House and Jones, 1977). Unfortunately, the results of many demonstration programs have been disappointing in the long run.

Demonstration projects can be viewed as a special kind of information dissemination or technology transfer. They are scaled-up proofs of concept or field trials, typically demonstrating hardware or social technologies that have not been employed at significant levels of operation outside the Federal establishment. Demonstrations are assumed to reduce risks for potential users as well as to provide information, since they actually "show and tell" a new technology. It may of course be the case that an *in vivo* demonstration may enhance rather than reduce a user's perceptions of the impossible complexity or incompatibility of a new technology, but that should be as legitimate a function of demonstration as technology promotion.

There is growing awareness in government circles that demonstration projects do not work as well as once assumed. This conclusion is supported in a number of evaluative reports and publications (House and Jones, 1977;

Jacoby and Linden, 1976; Bean and Roessner, 1978; Abernathy and Chakravarthy, 1979). The reasons for this lack of success are reviewed by Glennan *et al.* (1978) in their study of demonstration projects, which concluded that success was enhanced by the following factors:

1) A high degree of reproducibility of the innovation demonstration;

2) A well-developed technology base;

3) A well developed institutional environment or "home" for the technology;

4) Little need for cooperative action among the institutional entities involved;

5) A high level of need for the innovation by users;

6) A low degree of time pressure and a high degree of operational flexibility.

A seemingly simpler view of the cause of success or failure is provided by Abernathy and Chakravarthy (1979) in their review of ten demonstration projects. They stress the importance of stimulating demand for new technologies, and note that efforts to push new technologies via development and demonstration are ineffective unless coupled with demand-creating activities. Demand could be stimulated by establishing new regulatory requirements requiring modifications in product design or process technology, or through provision of financial incentives such as government purchases, price subsidies, or tax breaks.

There is considerable overlap between Abernathy and Chakravarthy's framework and Glennan's "conditions for success". When innovations are developed in the private sector, there is usually a strong awareness of market considerations and potential demand. Technology "push" by suppliers will not continue very long unless there is an expectation that commercial success will be achieved. Thus, from the point of view of

Glennan's six conditions for success, it is obvious that conditions (3) through (6) are fulfilled "naturally" in the private sector.

The isolation of technology-pushing organizations from the markets for their innovations is probably the fundamental cause of difficulty in achieving success in demonstrating them. The recommendation of the above-noted task force to staff Federal agencies more densely with entrepreneurs instead of technocrats to increase the incidence of success from demonstration projects probably would help. Others recommend even more fundamental changes in demonstration programs. For example, Glennan *et al.* (1978:36) recommend that demonstration projects should "simulate the workings of the normal market...". In all fairness, however, Federally sponsored demonstration projects usually operate in areas where private sector activity has been weak. In these special situations, the political system may choose to "overrule", or at least substitute for, the market.

Because the demonstration project has been a politically popular tool to implement national policy in both technical and non-technical areas, it will continue to be used, as much for its evident visibility and signal of political concern (symbolic and concrete) as for its presumed effectiveness in promoting technological change and lasting innovation. The policy relevance of further research in this area seems obvious, if only to provide some empirical guidance to a commonly-used policy instrument.

## Summary

This chapter has reviewed some of the different conceptual and administrative perspectives on how technology gets communicated to its potential users. Some illustrative types of organizational arrangements -- large and small firms, public and quasi-public agencies, university/nonuniversity cooperative systems -- are briefly summarized, and many possible variations in technology transfer approaches are indicated. Like many of the other areas covered in this review, the distribution function is disaggregated both in theory and in practice. To the extent that this critical set of events in the life cycles of organizational technology can be integrated more fully into the mainstream of research reviewed here, the purpose of this chapter will have been fulfilled.

# PART IV

# GOVERNMENT POLICY AND INNOVATION

# CHAPTER IX

## GOVERNMENT POLICY AND INNOVATION

Thus far, discussion has focused largely on the internal dynamics of organizations trying to innovate. But, as noted, organizations (and sectors) affect each other in crucial ways. This chapter describes some of the approaches that have been taken by government to structure those interactions -- both the efforts of the government to affect innovation in its own agencies, and government attempts to affect innovation in other public agencies and private organizations, either in terms of products or processes. Some of these interventions operate at what is usually called the "policy level". That is, they are general actions intended to apply to a large class of organizations (or to the whole population) more or less in the same way (although not necessarily with identical effects). Some are "programmatic" interventions, intended to affect particular smaller groups of firms or individual organizations. In general, they represent more specific varieties of policy mechanisms than those described in the preceding chapter.

Somewhat different reasoning underlies the government role in innovation processes in public versus private agencies. The rationale for the government role relative to its own agencies, or to other units of government such as states and local governments, is usually developed in terms of the efficiency of the governing process as a whole. It is assumed that new, more "effective" programs or practices will result in more social benefits via better or cheaper government services. This is particularly complicated where intergovernmental divisions of responsibility for funding and operations are involved.

In an analogous manner, government's rationale for influencing innovation in the private sector is that some actions are simply beyond the scope of any single private economic unit. Although benefits might accrue to all, no single company could realize enough economic gains to offset the costs of innovative actions. For example, increasing the supply of basic scientific manpower demands a considerable increase in educational spending. However, no single company could, or would need to, command more than a small percentage of the output in new trained personnel. Similar arguments can be made in the case of the generation and promotion of advanced manufacturing technology, particularly given that the government is the primary user of many products to which such technology is applied (Hetzner, Tornatzky and Klein, 1983). The pros and cons of a government role in public and private innovation have been frequently debated (National Science Foundation, 1980a), but the prevailing consensus is that government does have some role in fostering at least some kinds of innovation in the interests of national productivity.

Previous discussions have summarized various processes of commercialization, demonstration, technology transfer, and other devices that have been extensively employed by government. The following sections summarize what is known regarding the other traditional general "policy levers" of regulation, taxes, and patents, and the newer and less well structured levers of personnel policy, acquisition and assistance, and mandating of technology.

It should be noted that these government policies and practices form part of the milieu for each single organization involved in innovation. They constitute some of the background or exogenous variables that presumably influence organizational decision making. It is also important to realize that these various government influences do not comprise an orchestrated whole. They are typically the result of a composite of several agencies' activities and the residue of several administrations' political mandates. Rarely if ever are such policy choices considered systematically as discrete alternatives, and direct comparison between policies exists virtually entirely in the mind of the analyst. Thus, the rationality of the relationship between "policy" and organizational response is likely to be apparent only in retrospect.

## Regulation

Two groups of regulations that affect private firms can be distinguished: (1) environmental, health, and safety (EHS) regulations, and (2) economic regulation of firms in the energy, transportation, and communications sectors. Both groups of regulations have come under increasingly intensive scrutiny in recent years. It is noteworthy that the current administration has slowed the introduction of new regulations and has began to study cancelling certain existing regulations. However, these changes are for the most part not based on an assessment of their effects on innovation, although such effects may be expected. In the large bodies of critical, evaluative, and historical literatures about regulation, innovation has received very little empirical attention.

What literature exists is concerned primarily with innovation (usually in process technology) to meet specific EHS requirements, rather than the impact of EHS regulations on the more general innovativeness of firms in developing new products or processes. For example, there has long been a controversy regarding the effect on innovation of two different compliance strategies -- setting standards vs. dictating the actual compliance technology to be used by affected firms. The former approach defines targets or desired end-states of compliance; the latter approach specifies the technological means by which compliance is to be achieved. This issue has now been seemingly resolved in favor of standard-setting because it permits flexibility and thus may result in more innovative and cheaper approaches. Regulatory areas now covered by the direct standards approach are: (1) air and water pollution; (2) drug regulation; (3) workplace safety and consumer product safety; (4) registration of pesticides; and (5) identification of toxic substances (MacAvoy, 1977).

In the case of air, water, and workplace safety regulations, older firms may experience serious technical problems in meeting standards designed for fairly modern plant and equipment, or may find they can meet the standards only with expenditures on pollution abatement equipment which are frequently rather large. Relatively large amounts of additional capital may be diverted from production to compliance. When technical problems arise which were not allowed for in the original planning, firms may spend more than they can recover. In response, firms may ask the regulatory agency to lower standards, or may spend increasing amounts of funds on legal delaying actions, lobbying, and public relations designed to discredit the regulatory agency and its standard-setting processes.

The capital costs of compliance, or the costs of delaying tactics, divert resources that could be used for activities related to innovation. But the tradeoff is not direct; firms are often able to pass on some of the added costs of regulation to their customers or to find slack resources. Data Resources Inc. (1978) estimate that each dollar spent on pollution abatement equipment reduced spending on productive plant and equipment by 33 to 40 percent. In general, techniques are much better developed for estimating the *costs* of regulation (which are localized in a given firm) than for estimating the *benefits* which are likely to be much more spread out over the population and over time.

Since standard setting is inevitably a political process (either in legislative bodies or in the workings of regulatory agencies) there is always uncertainty about the future course of regulatory activity. This uncertainty, in turn, may impede innovation processes. For example, compliance is not always achieved by add-on equipment, and may require fundamental changes in process technology. Industries are reluctant to focus on innovations in process technology if there is a possibility that the new technology might conflict with future standards (Eads, 1972).

Much of the analysis of innovation and regulation has involved firms engaged in the production of potentially hazardous substances, since they face a particularly uncertain situation. Examples include pharmaceuticals (Grabowski, 1976; Jadlow, 1970; Jondrow, 1972; Lasagna, Wardell and Hanson, 1978; Peltzman, 1974; Schwartzman, 1976); industrial chemicals (Eads, 1978; Greenberg, Hill and Newburger, 1977; Hill, 1975; Iverstine, 1978); and automobiles (Grad, 1974; Heywood, Allen and Masterson, 1976). There is a strong social interest in the products of these industries, and existing standards are often based on weak scientific evidence. Thus, these standards change frequently as new knowledge about harmful effects is accumulated. Changes in standards have become a function of growth in scientific knowledge concerning the phenomenon, or technology used to measure its effects. Firms are sometimes even held responsible for the consequences of past behaviors which are now viewed as aversive given new knowledge or measurement techniques; while this may make legal sense, it does add to the uncertainty in predicting the consequences of decisions about technology.

Studies of pharmaceuticals have been the most comprehensive. Negative connections between innovation and the establishment of standards have been demonstrated more frequently than not. However, these findings are not likely to be generalizable to other industries. Only preliminary results can be claimed from the studies of industrial chemicals and automobiles. For example, in the automobile industry it has proved difficult to separate the effect of fuel economy standards from those of emission standards. There is some evidence to suggest that regulations have forced innovations in core product technology onto an industry that had long competed largely on the basis of non-technological product features such as styling, non-functional accessories, and the like.

Providing economic penalties for polluting manufacturing operations is frequently mentioned as the most efficient method of achieving EHS goals of air water quality (Selig, 1973). This approach sets financial penalties toxic discharges and allows each firm to determine whether the penalties are sufficiently severe to induce it to clean up its operations. The fees are, in essence, the costs of not complying. The impact of the economic incentives approach on innovation is expected to be less harsh than under direct standard setting. Firms developing and adopting innovative process technologies do not run the danger of encountering tougher standards that negate the gains made through innovation. It is even possible that R&D programs will generate process innovations that lower total unit costs.

The empirical findings concerning the effects of the *regulatory lag* (the typical delay by regulatory commissions) are somewhat conflicting and contradictory. Commission flexibility in reacting to changes in available technologies and associated unit costs or market shares appears, however, to be an important variable. Greater flexibility appears to be associated with the encouragement of innovation, and vice versa.

The ability of regulated firms to pass on costs to their customers seems to have uncertain technological effects. There is weak empirical evidence that it discouraged cost-cutting process innovations and encouraged service innovations in the 1950's and 1960's (Noll, 1971). But persistent inflation during the 1970's may have invalidated those observations. In regulated areas where firms are protected from actual or threatened competition, the ability to pass on costs may lead to managerial laxity, reducing the incentive to innovate (Leibenstein, 1969).

When regulatory commissions permit or encourage rates which in effect subsidize particular market regions or service areas, technological impacts seem to depend on the degree of competition and the attitude of the relevant regulatory commission. Market regions and service areas with rates that are below unit costs need not discourage process innovations directed at cost savings that would contribute to system-wide profits. However, rates below unit costs would likely discourage innovations by unregulated competitors, actual or potential, especially if regulatory commissions are committed to preserving the market shares of existing firms (Wilcox, 1971; Shepherd, 1971).

Market regions where rates are above unit costs may encourage service innovations under competitive conditions (as a form of non-price competition) if the regulatory commission is flexible (Barber, 1964; Sloss, 1978; MacAvoy and Sloss, 1967; Friedlaender, 1969; Eads, 1978). If the commission is inflexible and committed to preserving the current market shares of firms, then process innovations may be discouraged, and service innovations will be discouraged (Noll, 1975).

Finally, in those regulated industries where profit is constrained by the value of the firms in total assets or total revenue, the rate of innovation may be retarded if the allowed rate of return on invested capital exceeds significantly the cost of raising capital (Wilcox, 1971). But this does not appear to have been a widespread occurrence in the last decade. Also, innovation may be biased towards substituting capital for labor, if allowed profit is constrained by the value of the firms' total assets (Averch and Johnson, 1962; Smith, 1974). Shepherd (1971) offers an example of this effect in satellite communications.

It should be noted that some forms of economic regulation may also have an impact on innovation to the extent that they intersect with research and development functions of the firm. For example, Horwitz and Kolodny (1978) find that recent financial reporting requirements seem to have had a negative impact on R&D spending in small firms. Other such disaggregated effects need to be assessed in future studies.

Thus, existing literature suggests that the effects of regulation on innovative activity are mixed and heterogenous. While some may argue that this indicates a failing of the literature, it is more likely an accurate reflection of reality. The effects of regulation are likely to be industry and technology specific, and also, to vary as a function of the nature and practices of the involved regulatory agency. This is one area of innovation processes in which broad-brush generalizations are not likely to be seen.

## Tax Policy

Tax policy has an obvious relationship to the amount of slack resources available to a firm. Such resources may be used in innovation either for *capital investment* in new technology generated by the firm or by others, or for *investment in R&D*, the direct generation of such technology. Tax policies can affect either variety of spending. The most direct effect of taxation is probably on firm decisions about how much is spent on R&D or about the distribution of R&D by categories. A portfolio of research and development projects is assumed to be ranked in some order of priority, based on expected financial gain and other investment possibilities. Tax concessions for R&D would presumably tend to induce a firm to include more projects in its portfolio, to intensify its efforts on existing projects, and possibly to include a greater number of high risk projects. The premise is that there is a direct relationship between committments of extra resources to R&D and discernable gains in innovation (Collins, 1981).

These issues can be examined empirically, at least in principle. Special tax programs enacted in past years seem to have some positive impact on innovation (or at least on R&D spending). One of the earliest of these (Section 174 of the Internal Revenue Service Code, enacted in 1954) allowed firms to treat that part of their R&D expenses that were not plant and equipment as current expenses in order to reduce their immediate tax burden (Economic Report of the President, 1978; Kendrick, 1977). While the growth in private R&D was impressive during the next 15 years, it is virtually impossible to determine retrospectively how much of this growth was due to these tax concessions. It should be noted that this 1954 change in the U.S. tax code has probably been the change most directly targeted toward promoting innovation. If the effects of this specific a tax program on innovation are unclear, then determining the impact other of less specific adjustments in the tax code is likely to be even more difficult.

Other changes in the tax code during the last three decades should also have influenced innovation in the private sector. These include changes in the corporate and private income tax schedules and changes in the capital gains tax rate. There also are a variety of special purpose tax codes that might have an effect on innovation if they were changed, including several focused on small business firms and their sources of capital. For example, small firms can treat capital losses as ordinary income losses for tax purposes, which is less damaging to their short run cash flow. This could make them more likely to take chances with "innovative" capital resources. Further, regulated investment companies, including venture capital firms and small business investment companies, get special tax breaks. For example, the income of regulated venture capital firms is not taxed when paid out as dividends.

Since most of these rules are intended to serve purposes broader than promoting innovation and since innovation is affected by a variety of factors aside from tax codes, designing empirical studies to uncover the direct effects of tax changes on technological innovation is conceptually and methodologically difficult. The lack of a control group in effect forces researchers to use time-series data (before and after the change) as a quasi-experimental proxy for control and experimental groups. This approach creates the additional difficulty of requiring adjustments for the complex array of other external and internal factors influencing innovation over time. Given the many threats to validity of such a design (Cook and Campbell, 1979) it is not surprising then that effectively *no* empirical research has been conducted from which one might clearly infer the direct impact of the tax code on innovation.

Some empirical studies have investigated the link between increased investment spending (assumed to be related to tax rates) and increased innovative activity in the capital goods sector (Kaplan, 1976). Other studies have examined the connections between the level of investment and changes in sales, the investment tax credit, liberalized use of accelerated depreciation, and other special tax incentives (Break, 1974; Fromm, 1971; Klein, 1974; Visscher, 1976). The strongest connection seems to be between sales and investment, which has led to suggestions that Federal policy should be concerned with maintaining aggregate demand and stable prices (Jorgenson, 1971; Okun and Perry, 1978; von Furstenberg and Malkiel, 1977). Recently, there has also been a recognition that tax policies regarding capital gains and depreciation have negative effects on corporate income under severe inflation. The Financial Accounting Standards Board has been very active in seeking remedies for problems of this type, and changes in the tax treatment of capital values may soon follow.

Despite the lack of empirical research, or direct links between changes in tax code and innovation, the area is still of obvious conceptual importance and policy significance. Changing the tax code is one of the few direct mechanisms by which private sector activities can be redirected without constructing a Federal bureacratic intervention, as does regulatory or subsidy activity. Moreover, it is an activity with great visibility and therefore great political-symbolic importance (Edelman, 1964). It is not surprising that a large array of changes designed to stimulate innovation in the tax code have been either proposed or enacted. Such proposals fall generally into four categories: (1) special tax benefits for R&D expenditures (the investment tax credit); (2) larger allowable deductions for support of research in universities; (3) lower tax rates for business income derived from successful innovations; and (4) expanded opportunities to use business losses from technology-based enterprises as taxable income offsets, either against successful enterprises under the same ownership or against future income from the same enterprise.

Analytically, one must attempt to determine if these policies would result in increased innovation, and if the benefits of increased innovation offset the loss of tax revenues and increase R&D funds (Kaplan, 1976; Kendrick, 1977; Mansfield, 1977; Slitor, 1966; Wolfman, 1965). These are aggregate questions, however, which may have relatively little connection with the ultimate innovative behavior of firms. As current changes in the tax codes evolve, there will be opportunities for real-time studies to deal with these questions at both the aggregate and disaggregated levels.

## Patent Policy

The primary issues in the area of patent policy and technological innovation can be subsumed under three general questions:

1) Does the granting of exclusive rights to inventors promote utilization of government-sponsored technological R&D better than acquisition of title by government?

2) Do patents in general act as incentives or impediments to technological innovation?

3) Does the currently available patent data support the contention that the U.S. is "losing its genius" for technological innovation when compared to other developed nations?

The first question concerns the circumstances in which Federally-funded R&D activity leads to a patentable product or process. Since 1963, Federal policies have involved either (1) a *title policy*, where the government acquires title to the invention and the contractor/inventor retains a royalty-free, nonexclusive license; or (2) a *license policy*, where the contractor/inventor retains title and the government acquires a royalty-free, nonexclusive license. The Bayh-Dole Bill, which took effect on July 1, 1981, introduced additional changes, primarily favoring small business in obtaining patent rights from Federally-funded research.

The largest and most comprehensive effort to provide data concerning the effects of patent policy on Federally-supported innovation was undertaken by Harbridge House (1968). The study investigates the effects of patent policy on (1) commercial utilization of government-sponsored inventions; (2) business competition in commercial markets; and (3) participation of contractors in government research and development programs. The report concludes that permitting inventors to retain exclusive rights (license policy) promotes utilization better than title policy in at least the following circumstances:

1) Where the inventions as developed under government contracts are not directly applicable to commercial uses and the inventing contractor has commercial experience in the field of the invention, which occurs most frequently with DOD, NASA and AEC inventions;

2) Where the invention is commercially oriented but requires substantial private development to perfect it, or applies to a small market, or is in a field occupied by patent sensitive firms and its market potential is not alone sufficient to bring about utilization (Harbridge House, 1968:7).

Patent policy was revised by Presidential Memorandum in 1971 to enlarge the authority of agency heads to waive title to contractors, and to authorize the grant of an exclusive license under a government-owned patent. The Commission on Government Procurement (1972) recommended the prompt and uniform implementation of this revised policy.

Concerning the issue of whether patent policies function as incentives for government-sponsored R&D, the Harbridge House report concludes that educational and non-profit research institutions require some measure of exclusive rights to motivate them to invest in the work necessary to commercialize their inventions. The effect of patent policies for industrial firms was contingent on the firm's relationship with the government. Firms placed differing weights on the need for exclusive rights in using government inventions. At one extreme were firms who rely heavily on patent rights to establish their proprietary position in commercial markets and would hesitate to invest in an invention in which they could not obtain exclusive rights. At the other extreme, some firms were so completely in the government market that they attached little or no importance to patent rights for commercial purposes.

Finally, an important difference was observed between the research-oriented firms doing business with DOD, NASA and AEC, and the product-oriented firms aligned with the Department of Agriculture and the Tennessee Valley Authority. The former were much more aggressive in their search for useful innovations in the work they performed; the latter tended to rely on government laboratories for innovations in their fields.

Kitti (1979) observes that since many inventors use the protection of both patents and state trade secret laws, the separation of the effects of these two modes of protection is difficult to make empirically. This has resulted in an abundance of theoretical modelling and a paucity of empirical research. Kitti summarizes the research on patents-as-incentives as supporting the argument that longer patent life is likely to lead to both higher levels of innovation and earlier introduction of innovations. However, the magnitude of this effect is not overwhelming.

Patent policy can also function as an *impediment* to innovation. Kitti (1979) cites a number of studies indicating that a major barrier produced by patent policies was the high frequency of challenged patents declared invalid by the courts (approximately 50%). Excessive litigation is a threat to any patent system, and is a particular problem for small firms with limited resources for legal assistance. Other impediments mentioned were the perceived shortness of patent life and government regulations that consumed patent life by requiring non-developmental activity (e.g., safety testing) to occur after patents were granted.

A popular current theme is the decline of U.S. technological innovation relative to other developed nations. However, the empirical data on this matter are equivocal. For example, the ratio of U.S. patents licensed abroad to foreign patents licensed in the U.S. declined 47 percent between 1966 and 1975, with a corresponding 91 percent increase in foreign-origin patents. The share of U.S. patents granted to foreign residents more than doubled in 15 years, reaching a level of more than 35 percent in 1975. Since 1970, Japanese patenting has increased more than 100 percent in almost every major industrial category. However, Schiffel and Kitti (1978) reanalyze patent *application* data and draw quite different conclusions. They examine each country's filings both as a percentage of total foreign patent applications filed in the U.S., and as a percentage of that country's national applications. U.S. applications in the eight countries are also analyzed. They find that: (1) annual U.S. patent applications in the eight countries remained relatively stable for 1965-1974, even in Japan; and (2) the data "reinforce the notion that rising levels of exports or generally greater economic interdependence explains a good deal of the rise in foreign patent filings" (Schiffel and Kitti, 1978:334).

In summary, while the jury is still out on the patent balance issue, patenting still plays an important role in innovation-related research as both an important independent variable and as an often useful indicator of innovative activity.

## Developing Scientific and Technical Personnel

Conventional wisdom dictates that an advanced industrial society requires the best science and technology personnel available. A recent report captures this view:

> Behind achievements and performance lie the availability and effective use of sufficient numbers of well-trained scientists, engineers, and teachers of science and engineering at all educational levels (National Science Foundation, 1980b).

Two generic issues cut across this general perspective: (1) the question of the *supply* of technical personel, and (2) the issue of *movement and flow*. The manpower issue will also be discussed on two levels: (1) the aggregate supply and flow of well-trained scientists and engineers on a general societal level; and (2) the supply and flow of R&D personnel within and between discrete organizations.

### Supply Issues

The adequate supply of knowledgeable manpower is an obvious, yet often overlooked, underlying variable of major importance in innovation. Studies often conclude that technical innovators are usually highly productive PhD scientists or engineers (Pelz and Andrews, 1966). Several researchers have advanced the notion of manpower supply as *human capital* -- a type of investment in people (Becker, 1964). Nelson and Phelps (1966) suggest that the technological progressiveness of a society directly depends on an educated populace, and as an example cite the remarkable progress in U.S. agriculture as a function of the improved education of farmers. In a comparison of the U.S., Japan, and newly industrializing countries, Hayami and Ruttan (1971) conclude that aggregate investment in human capital (public education expenditures) is a major contributing factor in a country's capacity to accommodate the transfer of agricultural technologies and to increase the use of local technologies.

If one considers the supply of technical manpower as human capital it is also important to realize that this capital stock is not homogeneous. The mixture of necessary technical skills is always changing as a result of the uneven advances across technologies. As a result a conceptualization of human capital must also consider concepts such as *depreciation* (obsolescence) and *renewal* (replacement of resources and updating of skills). For example, Bell *et al.* (1976) propose a framework for assessing the educational system of a modern industrial society that allows for the obsolescence of professional skills and the necessity for long range planning for continuing education. Updating is critical in a highly technological age in which breakthroughs create new science and engineering challenges. In one empirical study Roney (1966) finds that at least one engineer in 15 eventually becomes out of date within his/her current job assignment and over one-half do not keep up with their general profession. Bell *et al.* (1976) see active roles for both employers and universities in providing continued education through on- and off-campus courses, conferences, journals, and other means. The role of government agencies in such efforts would be pivotal.

Though the need for professional updating is readily acknowledged, questions arise about which methods are effective, which methods would engineers and scientists utilize, and how much updating is necessary. Kaufman (1974) suggests that one-fifth to one-third of an engineer's working time be devoted to updating activity depending on area of specialization and job responsibility. Margulies and Raia (1972) questioned 290 scientists and engineers about methods they use for maintaining competence in their field. As perceived by these respondents, the most valuable sources of updating were "on the job problem-solving" and "collegial interaction". Little importance was placed on formal coursework. Given these findings, work environment would seem to have an influence on remaining professionally competent and current in one's field. Margulies and Raia in fact observe that settings featuring openness of communication, team effort in problem-solving activities, and autonomy of individual scientists and engineers were most likely to enhance skills maintainance.

In addition to concerns about the skill repertoire in this pool of human capital, there is also concern about the number of people represented. Much controversy concerns the issue of current and projected supply of scientists and engineers. Various government agencies and science and engineering organizations routinely collect statistics on college enrollments, degrees granted, and employment to monitor for possible shortages. The consensus of these surveys is that except for spot shortages in some subspecialties basic science fields have adequate supplies of manpower.

However, some types of engineers, computer scientists, and other specialized technologists are in short supply, and that trend is expected to continue into the next decade. Such supply mismatches may put some public and not-for-profit organizations under pressure to shift resources and priorities radically.

Deficiencies in the aggregate manpower supply lead to questions similar to those raised about skills updating. What institutional preparation and incentives are there for individuals to receive training in highly technical areas of study? What is the influence of early school training on career choices (Gordon, 1980)? Are secondary school teachers qualified to teach science courses and are school facilities adequately equipped for science education (Weiss, 1978)? Are high schools exposing students to enough science curriculum (Welch, 1979; Terleckyj, 1977)? At the university level there are concerns about the relaxation of degree requirements, reduction of Federal funding of research projects and fellowships, shortages of teachers in certain subspecialties, and lack of Federal support to replace obsolete instrumentation.

Not only does technological change creates uncertainties as to what science and technology skills will be in demand in the future, but this uncertainty is exacerbated by Federal policies and attitudes toward research and education. Johansson (1978), in a study of one university which was heavily committed to federally funded research, examines the short run consequences of decreased funding during 1968 to 1970. Natural scientists were found to be more affected than social scientists; and full-time researchers were more adversely affected than faculty members. The end result was that the scientists crossed over from research to full-time teaching, or from basic research to applied, changed from one subfield to another, or changed jobs. The short term effects may have significant long term consequences such as an impairment the ability of universities to train new researchers.

## Manpower Flows

Interest in manpower flows, or "the movement of people across organizational boundaries" (Ettlie, 1980:1086), arose as a result of studies suggesting that technology transfer and innovation processes are heavily dependent upon the infusion of new personnel into organizations (Grusky, 1960; Jervis, 1975; Ettlie and Vellenga, 1979). Such studies have given a dynamic quality to scientific personnel issues and have forced researchers and policy makers to look beyond simple aggregate supply data. For example, researchers have found evidence that scientific mobility may either hinder (Gilfillan, 1935; Blau, 1973) or stimulate (Carlson, 1962; Rubenstein and Ettlie, 1979) innovation. To account for these contrasting outcomes, Price (1977) and Ettlie (1980) propose that the positive effect of mobility on innovation is subject to the laws of diminishing returns. That is, the infiltration of new scientists into an organization results in increases in technological innovativeness up to some point at which the disruptive impacts of personnel turnover become evident.

Manpower flows may have a unique institution-building role in innovation. For example, spin-off firms form when one or more researchers leave an employer to start a new firm. Such firms may gain entry into new markets if they can find a competitive edge over other less innovative firms in the industry (Goodman and Abernathy, 1978). Biggadike (1976) finds a close relationship between the presence of personnel with scientific skills and the undertaking of significant technological innovation as a corporate strategy, and that the addition of a new employee with unique technical skills could mean a radical change in corporate strategic planning.

Several studies suggest that manpower flows lead more often to radical rather than incremental innovations (Ettlie and Vellenga, 1979; Rubenstein and Ettlie, 1979; Morison, 1966). In a study of 18 textile machinery innovations, Rothwell *et al.* (1974) conclude that the transfer of individuals to compensate for deficient in-house technical resources would be the "most efficient method of transferring technology". To qualify this view, it should be noted that merely increasing skilled manpower in itself is insufficient to affect the innovativeness of an organization. In order to maximize the effect of an infusion of technical personnel, managers must recognize the need to establish interpersonal ties among scientific personnel (Blau, 1973; Holland, Stead and Leibrock, 1976) and to foster individual commitment to job *vs.* organization (Hall and Schneider, 1972), just to name a few.

Government can play a significant role in influencing manpower flows within and between states and regions. Tax allowances for moving expenses and differential property taxation can cushion the effects of relocation and significantly affect migration. Conversely, disparities in social benefits between regions are likely to affect mobility in the inverse fashion. It is necessary to factor manpower flow effects into any general strategy for affecting innovation through Federal policy.

## Effects of Government Transaction Devices

Those Federal activities that involve monetary transactions between government and the private sector, or between different units or levels of government (such as Federal assistance to states or local governments), are particularly important for innovation. These transactions involve either *acquisition* (purchase via contracting devices) or *assistance* (transfer of funds in the form of one type of grant or another).

A variety of such financial transactions may have an impact on technological change. Acquisition often involves the direct purchase for government use of research and development and the subsidizing of technological development, while assistance in turn may be particularly important in the maintenance of an R&D infrastructure (such as the supply of scientific manpower), or in providing incentives and structures for the transfer or dissemination of technologies.

This area of policy activity has not attracted much empirical research, and much of the analytical work is comprised of government reports, often with little supporting data. The most comprehensive analysis of this nature was in the report of the Commission on Government Procurement (1972) which was established by statute and included members of the Congress, the executive branch and other non-governmental appointees. As noted in a follow-up performed by the General Accounting Office (1979), the Procurement Commission concentrated much of its efforts on the *process* of buying research or other goods or services, rather than on the results achieved by alternative mechanisms. For example, one of the recommendations of the Commission was that an alternative transaction mechanism be created, to be in effect part grant and part contract. This *cooperative agreement* mechanism was authorized in the Grant and Cooperative Agreement Act of 1977 (P.L. 95-224), although its actual implementation by executive agencies has varied widely.

Accountability *vs.* Innovativeness

Whenever public funds are expended by government there are always questions of accountability. Government typically responds to this need for accountability by developing rules, guidelines, regulations, and various devices to "protect" the public investment. However, this approach may be particularly innappropriate when the thing being procured involves research and development. Often the government is involved in the purchase of something that heretofore does not exist, and may be investing in a process that will likely not be repeated again. The result is that systems designed to insure accountability may be at odds with the processes involved in creating innovation and fostering technological development.

A variety of approaches have been proposed to deal with this general problem. For example, fairly complex contracting procedures have been developed for the acquisition of major defense systems. These guidelines provide for a sequential series of decision points, designed to ensure that bidders for a contract will not be unduly constrained in their technological tasks at each stage of the decision process, but some rational control is maintained by Federal program managers. The applicability of such procedures to non-defense areas of government activities is in some dispute.

The issue of accountability vs. innovativeness is not exclusively confined to contractual relationships. Equally unclear is what the structure of the assistance relationship should be when the activity involves basic research conducted in academic or other not-for-profit institutions under a grant. As Staats (1979:18) describes the issue:

> The fundamental dilemma here is how to achieve adequate accountability for public funds without imposing excessive controls, direction, and administrative burden on reseach grantees, which would inhibit freedom of intellectual inquiry and efficient performance of research.

Although legally grants are relatively unencumbered in terms of the degree of control exercised by the grantor, there are still issues of accountability involved. At the very least, it must be determined whether the researcher did perform the research at all or squandered the money. At the extreme, what evidence of a public benefit is there from a grant award? A variety of administrative and accounting practices have been employed by government to address acountability concerns; it is still empirically unclear how these practices affect the research process and/or innovation.

Transaction Devices and the Transfer/Dissemination of Technology

Not only are transaction devices implied in the development of innovations, but they are often a potentially powerful tool used by government to insure dissemination and use of research findings. It is useful to consider at what stage in the innovation process should government expenditures be used to maximize technology transfer. Earlier we discussed the differences between transfer strategies involving centralized diffusion and those involving capacity-sharing. These two strategic alternatives have different types of transactions or grant mechanisms associated with them. The institution-building approach would be more compatible with "no strings" block grants; the directed, centralized dissemination approach with highly structured mechanisms, including contracts and cooperative agreements.

Unfortunately, empirical data on the comparative effectiveness of various transaction mechanisms in facilitating innovation are singularly lacking in the innovation process literature. The relative effectiveness of large scale block grants, targeted special purpose grants, or contracts in improving the functioning and technological sophistication of local agencies in areas such as education and law enforcement is particularly debatable. Recent choices by the current administration have suggested a turn towards the block grant formula and a reliance on local initiative and decision making. Ideological inclinations aside, there are very limited data to support this move (Datta, 1981), and there are, in fact, contrary data (Kirst and Jung, 1980) to suggest that highly structured, centrally-directed assistance mechanisms may be quite effective in influencing change and innovation in target systems. At any rate, there are a variety of questions for subsequent research. In fact, given that assistance mechanisms may be changed radically over the next few years, we may be in the midst of a natural experiment worthy of some data collection.

Transactions and the Science and Technology Infrastructure

Many grant or contract mechanisms involve devices and funds designed to have an impact on the scientific infrastructure itself. For example, defense contracts have a certain percentage of funds earmarked for "independent research and development", which is in effect "blue-sky" money for the contract winner and which can be employed to pursue research directions largely at the firm's discretion. In a similar manner, funds for overhead are a substantial part of virtually all grant awards. The assumption behind giving credit for overhead expenditures is that such money is a legitimate and necessary expense for research institutions in maintaining research capabilities, lab facilities, computer centers, and the like. However, it is also possible for institutions to use overhead dollars in a variety of different ways, some of which may be related only peripherally to research capabilities.

Virtually no studies examine the empirical relationship between these various approaches to infrastructure development and research productivity or innovation. All of these various devices are based on largely untested premises and accounting approaches adopted with little theoretical or practical assessment. However, there is probably enough spontaneous variation in the actual implementation of these various devices that some interesting comparative studies could be conducted.

## Mandated Technology -- The Case of Management Decision Aids

There are occasions when government involvement with technological innovation takes the form of mandating or encouraging the use of certain *specific* techniques by some population of organizations. The processes and effects involved in this approach have been relatively little studied. In hard technology areas, this technique has been used (as noted earlier) in regulations to ensure environmental quality control -- in particular, air and water pollution control devices. The approach has been much more widely applied by the government -- although not always recognized as such -- in conjunction with social technologies.

Particularly prominent among government-mandated or promoted social technologies have been several "decision aids" or management technologies employed in both public and private organizations. These include program evaluation techniques (Abt, 1976; Sechrest and Yeaton, 1981), PPBS, ZBB, computer modeling, environmental impact analysis, and technology assessment. The effectiveness of these aids is determined by the nature of the decision being made, the organizational setting, the feasibility of implementing them (Berg *et al.*, 1976; Brewer, 1973), and the inherent match (or nonmatch) between criteria and situation (Cochran, 1980). The Planning, Programming and Budgeting System (PPBS), for example, was widely pushed in the 1960's as a way to provide a structured arrangement for feeding the information obtained from other management technologies into the decision making process (Weiss, 1972).

It should also be noted that the use of formal decision aids and methods has not been restricted to public service programs or to non-material technologies. Wherever "effects" are not adequately evaluated by market mechanisms and where an obvious public interest is involved, such techniques are likely to be employed. Examples are large scale experimental evaluations of clinical treatments or surgical procedures. Results of these studies have considerably altered the practice of private sector practitioners. In fact, the Federal government, through the regulatory process, has mandated the use of some evaluation systems in industry during the development of particular products, to assess their impact on public health and safety. Mandatory testing of new drugs is an example.

Management technologies represent interesting innovations in their own right, and can also be seen as important intervening factors in the process of innovation in other areas. Thus they may be both dependent and intervening variables, both innovation *outcome* and innovation *process*. Such management technologies play a crucial part in decisions throughout the innovation process. In circumstances involving highly complex innovations with multiple and ambiguous effects, formal processes of evaluation provide a way of "keeping score" in the absence of market cues (Edwards, Guttentag and Snapper, 1975). Such tools are used by the developer during the prototype stage to assess the worth of the original innovation. This information in turn, serves as a decision aid to potential adopters during the dissemination process. During implementation, evaluation is used to decide how to adapt and whether to expand or continue the technology, and whether to incorporate the innovation as standard practice.

Unfortunately, relatively little empirical work has been done concerning the impact of decision aids and the use of knowledge derived from them in decision making. Patton *et al.*'s (1977) study of the impact of Federal health evaluation research pinpoints the importance of the "personal factor" of highly motivated individuals in the utilization process. Caplan (1977) surveyed Federal policy-level decision makers to analyze their utilization of social science research findings. They conclude that the factors which reduce utilization involve value and ideological differences between decision makers and social scientists. On the other hand, Weiss and Bucuvalas (1977) find that research which challenges the status quo provides an "alternative cognitive map", and is characterized as *facilitating* the future development of innovative programs and policies. Other work in this area is summarized by Weiss (1977), but the field is quite dissaggregated.

Management decision technology also plays an important decision making role in private sector innovation, though the development of operational frameworks generalizable to more than one firm or industry has yet to occur. Models for project selection, project termination, and other critical decision points must carefully incorporate information about external and internal uncertainties, information often not uniformly obtainable or even reliable. Researchers have attempted to pinpoint critical factors considered in R&D decisions (Bruno, 1973; Rubenstein *et al.*, 1974) and subsequently to incorporate these factors into normative frameworks (Baker, 1974; Schwartz and Vertinsky, 1977). But progress in conceptual refinement of R&D decision making has not been attended by equal progress in research on the actual use and impact of such frameworks on the innovation process.

As has been noted, decision aids and management technologies can be viewed as innovations per se, and their dissemination, adoption and implementation of such techniques can be studied in a manner analogous to other technologies. The use of OR/MS techniques is, as noted earlier, a major strand in the implementation perspective (Bean *et al.*, 19?5; Bean and Radnor, 1980). In these studies the dependent variable is typically a surrogate -- that is, some measure of the methodological quality or sophistication of the process being deployed, rather than a direct assessment of the contribution of the management technology to productivity. For example, Bernstein and Freeman (1975) examine the use of evaluation research methods in a sample of 152 studies. The key variables predicting "evaluation quality" (defined as the use of the best methodology available) included the nature of the award (grant vs. contract), duration of the project, its theoretical underpinning, type of organization, project outcome, project director's academic discipline, and organizational arrangements between the research team and the evaluated program. Stevens and Tornatzky (1980) studied the adoption and implementation of program evaluation methodologies as an innovative practice in drug abuse programs.

Management decision technology, viewed as both an intervening variable and an innovation, can be seen as an attempt to reduce organizational uncertainty regarding the characteristics of an innovation or its optimum usage or effects. Clearly it is a subject for future research. One area needing work is the impact of evaluative research, as an innovation, on organizational structure and technologies. In addition, only a few studies such as Stevens and Tornatzky (1980) have focused on decision aids as the innovation per se. The use of such non-material technologies in both public and private sectors pose particular problems of implementation, and can fruitfully contribute to that literature (as, in the case of management science techniques, they have in the past). In any event, it is clear that the use of certain social technologies is rather more complex than usually allowed for by government policy makers.

## Summary

This chapter has reviewed a wide variety of mechanisms intended to increase the overall deployment of technology in the U.S. through Federal interventions. The general impression is one of diversity and indeed minimal coordination. On the other hand, considering the lack of empirical evidence bearing on the relative effectiveness of such transactions, it is perhaps better to "let a hundred flowers bloom" than to rush to premature consensus. The field remains open to conceptual and empirical development.

# PART V

# SUMMARY: LESSONS LEARNED AND UNLEARNED

## SUMMARY: LESSONS LEARNED AND UNLEARNED

This review has moved widely and rapidly through a large and diverse body of literature, with relatively little attempt at synthesis. This final part briefly summarizes what seem to be the most important conclusions to be drawn from the review. Some conclusions are specific to particular bodies of knowledge; some cut across fields and disciplines.

As noted at the beginning, an understanding of technological change must focus on the organizations where technology is used. Moreover, a working definition of technology should include both its material/physical aspects and the social/behavioral implications involved in the use of such physical tools by people. Innovation -- technology new to a given organization -- is bounded in its effectiveness by both technical and social dimensions. Starting from this base, the following points stand out:

### Part I: Definitions and Approaches

- Innovation is usually a lengthy process (often spanning years) that involves relatively consistent steps or stages characterized by discrete decisions and behaviors.

- There are two major points of view from which stages of innovation processes are commonly defined: the point of view of the *producer* of the technology, and that of its *user*. The former encompasses activities ranging from basic research/idea generation to marketing and dissemination; the latter encompasses activities ranging from awareness of technological opportunities to eventual implementation and routinization.

- The innovation process involves many social units ranging from individuals to groups to organizations to industries to societies, and any mode of analysis tied exclusively to a single discipline or one which focuses on only a single social unit will be incomplete.

- Characteristics of technologies as perceived by users seem to be related to their adoption and implementation. There is some debate, however, as to the extent to which these characteristics are inherent in the technologies or a function of the setting in which the technologies are deployed.

- "Knowledge-based social technologies" involve replicable procedures of known efficacy rather than material artifacts. They should, however, be analyzed in the same terms as material technologies.

- The usual indices of innovation -- adoption and implementation -- are not ends in themselves, but rather means to ends such as productivity, profit, or effectiveness.

## Part II: Organizational and Contextual Component

- Organizations and organization members usually experience high degrees of uncertainty about how technologies are defined and used, and this uncertainty affects the organizational context within which technology is applied. Organizations which can cope with a higher degree of uncertainty are more efficient in accomodating to innovation than those which are highly structured, linear, and "rational".

- Characteristics of organizational structure such as complexity, formalization, and centralization seem to be related to innovation, but the mechanics of those relationships are unclear and there is high variability in the magnitude of the effects.

- Organizational size seems to be an important factor in technological innovation, but size has seldom been adequately conceptualized or measured and may reflect the effects of a number of other variables.

- Innovation often involves exchanges of knowledge and resources between organizations, and the manner in which these boundary-spanning relationships are transacted is affected by the norms and procedures of the interacting organizations and the rewards for the interaction.

- Organizational contexts or environments can be described in many different terms, both economic and social; they significantly affect organizations' capacities for innovation through constraints on resources and information required for making effective organizational decisions.

- There are more similarities than differences between public and private sector organizations at the level of their innovation behavior, despite apparent major differences in their economic milieu and incentive structure.

- A number of characteristics appear to differentiate individuals who are "innovative" from those who are not, but these findings are probably barely generalizable either to the organizational level or to complex innovations.

- Certain social/organizational roles played by individuals (e.g., "product champion" or "entrepreneur") appear to be particularly important in the innovation process, but it is unclear whether people exercising these roles are born, developed, or the results of serendipity and circumstance.

- The relative importance to innovation of individual behavior, group dynamics, organizational context, and economic/societal factors, and how these influence and condition each other, remains a major question for future research.

## Part III: The Sequence of Innovation Activities

- Since innovation is a set of activities which takes place within organizations, it is helpful to look at what is known about organizational dynamics. Public policies succeed or fail at the level of the organization acting in response to them, such as a production facility, R&D department, or school.

- The organization, placement, management, and interconnection of the R&D function is particularly important to innovation, but the relationships are highly contingent and do not lend themselves to simple prescriptions.

- The choices involved in designing complex technological systems (such as production facilities) involve many tradeoffs among technical, social, and economic components; such designs are never permanent, but must be constantly adjusted as these components change.

- Implementation -- deploying innovations from concept to practice -- is the part of the innovation process where success or failure of the effort is critically determined. It is very unclear, however, to what degree implementation can be influenced by macro-level policies.

- A crucial implementation research question is the degree to which innovations get changed or adapted from their prototypes as they are put into practice, and the circumstances under which such changes *reduce* or *enhance* the effectiveness of the technology. This involves identifying the crucial elements of technologies and developing ways to determine whether they have in fact been deployed.

- Successful implementation seems to be related to interpersonal interaction, participation in decision making, a perception of control and on the part of those affected by the implementation, and decentralized and non-bureaucratic strategies for introducing change.

- Product R&D that is tied to the firm's marketing functions and strategy is more likely to yield commercially successful innovations.

- Effective dissemination of innovations is strongly enhanced by face-to-face interactive communication.

- Systems of technology transfer which place the major responsibility on the user to identify needs and possible technical solutions do not transfer much technology; however, strong "technology-push" systems run the risk of transferring inappropriate or unusable solutions which have a low rate of effective implementation.

- The more a technology transfer system encourages direct communication between source and user in the choice of the knowledge to be transferred, the greater will be its success as seen by both sides.

- While university/industry research interactions and knowledge transfer promise much in the way of technological innovation, there are significant incompatibilities between industry and the academy in goals and rewards and a limited understanding of what structures and processes best facilitate such cooperation.

- Evidence attesting to the innovativeness and growth potential of small high-technology based firms is suggestive if ambiguous. The operational meaning of "smallness" and the definition of what specific factors are responsible for such success remain to be established.

- Commercialization and demonstration projects operated by government have had a checkered pattern of effects, primarily because of neglect of market forces in project selection and staffing.

Part IV: Government Policies

- The effects of regulation on innovation are likely to be industry and technology specific and to vary as a function of the nature and practices of the regulatory agencies and the political climate in which regulation is decided. Few broad generalizations are feasible.

- At an undifferentiated level, tax and patent policies can affect decisions about resources available for R&D and for implementation of new technology, but the effects of specific choices about such policies are difficult if not impossible to determine even in retrospect.

- Government policies intended to affect the technological infrastructure through use of different transaction devices (grants, contracts, procurements, mandating of technology, etc.) are based largely on legal and accounting criteria, and have little demonstrated relationship to innovation outcomes.

- Movement of technical personnel is a major vehicle for technology transfer, and the aggregate supply of technically trained individuals is associated with aggregate innovation, but the mix of public and private initiatives which can most effectively influence such supply and movement remains largely unknown.

# LIST OF REFERENCES CITED

LIST OF REFERENCES CITED

Abernathy, W.J. (1978) The Productivity Dilemma: Rc `ock to Innovation in the Automobile Industry. Baltimore: Johns Hopkins University Press.

Abernathy, W.J. and Chakravarthy, B. (1979) "Government Intervention and Innovation in Industry: A Policy Framework." Working Paper, Graduate School of Business, Harvard University,

Abernathy, W.J. and Utterback, J.M. (1978 ) "Patterns of Industrial Innovation." Technology Review. 80:40-47

Abt, C.C. (Ed.) (1976) The Evaluation of Social Programs. Beverly Hills, CA: Sage Publications, Inc.

Aiken, M. and Hage, J. (1968) "Organizational Interdependence and Intra-Organizational Structure." American Sociological Review. 33:912-930

Aiken, M. and Hage, J. (1971) "The Organic Organization and Innovation." Sociology. 563-82

Aldrich, H.E. (1971) "Organizational Boundaries and Inter-organizational Conflict." Human Relations. 24:279-293

Allen, T.J. (1970) "Communication Networks in R&D." R&D Management. 1:14-21

Allen, T.J. (1977) Managing the Flow of Technology. Cambridge, MA: MIT Press.

Allen, T.J. and Cohen, S.I. (1969) "Information Flow in Research and Development Laboratories." Administrative Science Quarterly. 14:12-19

American Association for the Advancement of Science. (1981) Partnerships for the 1980's: An Overview of Intergovernmental Science and Technology. Washington, DC: AAAS Publication No. 81-R-2.

Argyris, C. (1965) Organization and Innovation. Homewood, IL: R.D. Irwin.

Armington, C. and Odle, M. (1982) "Small Business -- How Many Jobs?" The Brookings Review. 1(2):14-17

Averch, H. and Johnson, L.L. (1962) "Behavior of the Firm Under Regulatory Constraint." American Economic Review. 52:1052-69

Baer, W.S. (1977) "Universities and Other R&D Performers." In B.L.R. Smith and J.J. Karlesky, (Eds.), The State of Academic Science. Volume II: Background Papers.

Baer, W.S. (1976) University-Industry Interactions in Civil Sector R&D. Santa Monica, CA: The Rand Corporation.

Baker, N.R. (1974) "R&D Project Selection Models: An Assessment." IEEE Transactions on Engineering Management. EM-21(4):165-171

Baker, N.R. (1977) An Assessment of Modeling Capability Related to the Process of Organized Technological Innovation within the Firm. Cincinnati, OH: Final Report, Grant No. PRA-7517332, National Science Foundation, University of Cincinnati.

Baker, N.R. and Freeland, J.R. (1972) "Structuring Information Flow to Enhance Innovation." Management Science. 19:105-116

Baker, N.R., Siegman, J. and Rubenstein, A.H. (1967) "The Effects of Perceived Needs and Means on the Generation of Ideas for Industrial R&D Projects." IEEE Transactions on Engineering Management. EM-14:156-163

Baker, N.R. and Pound, W.H. (1964) "R&D Project Selection: Where We Stand." IEEE Transactions on Engineering Management. EM-11: 124-134

Baldridge, J.V. and Burnham, R.A. (1975) "Organizational Innovation -- Individual, Organizational, and Environmental Impacts." Administrative Science Quarterly. 20:165-176

Barber, R.J. (1964) "Technological Change in American Transportation: The Role of Government Action." Virginia Law Review. 50:824-895

Bardach, E. (1977) The Implementation Game. Cambridge, MA: MIT Press.

Barker, P., Bikson, T.K. and Kimbrough, J.M. (1980) Diversity in the Classroom. Santa Monica, CA: Rand Corporation. Publication No. R-2170/5-NIE

Barnard, C.I. (1938) The Functions of the Executive. Cambridge, MA: Harvard University Press.

Barrett, J.H. (1970) Individual Goals and Organizational Objectives -- A Study of Integration Mechanisms. Ann Arbor, MI: CRUSK/ISR.

Bartley, S.H. and Chute, E. (1947) Fatigue and Impairment in Man. New York: McGraw-Hill Book Co.

Bass, B.M. (1952) "Ultimate Criteria of Organizational Worth." Personnel Psychology. 5:157-173

Battelle-Columbus Laboratories. (1973) Interactions of Science and Technology in the Innovative Process: Some Case Studies. Columbus, OH: Technical Report, Contract No. NSF-C667, National Science Foundation.

Bean, A.S. and Mogee, M.E. (1976) "The Role of the Purchasing Agent in Industrial Innovation." Industrial Marketing Management. 5:221-229

Bean, A.S. and Radnor, M. (1980) "The Role of Intermediaries in the Implementation of Management Science." TIMS Studies in Management Sciences. 13:121-137

Bean, A.S., Neal, R.D., Radnor, M. and Tansik, D.A. (1975) "Structural and Behavioral Correlates of Implementation in U.S. Business Organizations." In R.L. Schultz and D.P. Slevin (Eds.), Implementing Operations Research/Management Science. New York: American Elsevier Publishing Co.

Bean, A.S. and Roessner, J.D. (1979) "Assessing the Government Role in the Commercialization of Federally Funded R&D." Proceedings of the American Chemical Society Symposium on Commercialization of Federally Funded R&D, Miami.

Bean, A.S., Schiffel, D.D. and Mogee, M.E. (1975) "The Venture Capital Market and Technological Innovation." Research Policy. 4:380-408

Becker, M.H. (1970) "Sociometric Location and Innovativeness: Reformulation and Extension of the Diffusion Model." American Sociological Review. 35:267-82

Becker, S.W. and Gordon, G. (1966) "An Entrepreneureal Theory of Formal Organizations." Administrative Science Quarterly. 11:315-344

Bell, D. (1973) The Coming of Post-Industrial Society. New York: Basic Books Inc.

Bell, D., Bikson, T.K., Rich, P.J. and Wuchitech, J.M. (1976) The Role of Education in Facilitating Adaptation to Technological Change: An Analytical Framework and Review of the Literature. Santa Monica, CA: Rand Corporation, R-1821-NSF.

Bem, D.J. (1972) "Self-Perception Theory." In L. Berkowitz (Ed.), Advances in Experimental Social Psychology. Vol. 6. New York: Academic Press Inc.

Beniger, J. (1979) "Stratification in Information and Commodity Networks: Toward a Statistics of 'Exchange Dominance'." Proceedings of the Business and Economic Statistics Section, American Statistical Association. Vol. 14

Benson, J.K. (1975) "The Interorganizational Network as a Political Economy." Administrative Science Quarterly. 20:229-249

Benson, J.K. (1977) "Organizations: A Dialectical View." Administrative Science Quarterly. 22:1-21

Berg, M. *et al.* (1976) Factors Affecting Utilization of Technology Assessment Studies in Policy Making. Ann Arbor, MI: University of Michigan, Final Report to the National Science Foundation, Document No. PB-290138/AS.

Berman, P. (1978) "The Study of Macro- and Micro-Implementation." Public Policy. 26(2):157-184

Berman, P. (1980) "Thinking about Programmed and Adaptive Implementation: Matching Strategies to Situations." In D. Mann and H. Ingram (Eds.), Why Policies Succeed or Fail. Beverly Hills, CA: Sage Publications.

Berman, P. and McLaughlin, M.W. (1974) Federal Programs Supporting Educational Change: A Model of Educational Change. Santa Monica, CA: Rand Corporation. R-1589/1-HEW.

Berman, P. and McLaughlin, M.W. (1977) Federal Programs Supporting Educational Change: Factors Affecting Implementation and Continuation. Santa Monica, CA: Rand Corporation. R-1589/7-HEW.

Berman, P. and McLaughlin, M.W. (1978) Federal Programs Supporting Educational Change: Implementing and Sustaining Innovations. Santa Monica, CA: Rand Corporation. R-1589/8-HEW.

Bernstein, I.N. and Freeman, H.E. (1975) Academic and Entrepreneurial Research. New York: Russell Sage Foundation.

Beyer, J.M. and Stevens, J.M. (1976) "The Routinization of Change: Implementation of Policy in Federal Organizations." Paper Presented to the American Sociological Association, New York.

Biggadike, E.R. (1976) Corporate Diversification: Entry, Strategy and Performance. Cambridge, MA: Harvard University Press.

Bigoness, W.J. and Perreault, W.D. (1981) "A Conceptual Paradigm and Approach for the Study of Innovators." Academy of Management Journal. 24(1):68-82

Bikson, T.K. (1980) Getting It Together: Gerontological Research and the Real World. Santa Monica, CA: Rand Corporation. Publication No. P-6447.

Bikson, T.K., Gutek, B.A. and Mankin, D.A. (1981) Implementation of Information Technology in Office Settings: Review of Relevant Literature. Santa Monica, CA: Rand Corporation. Publication No. P-6697

Bingham, R.D. (1976) The Adoption of Innovation by Local Government. Lexington, MA: Lexington Books.

Bingham, R.D. (1981) Professional Associations and Municipal Innovation. Madison: University of Wisconsin Press.

Bingham, R.D., Freeman, P.K. and Felbinger, C.L. (1982) Toward an Understanding of Innovation Adoption: An Empirical Application of the Theoretical Contributions of Downs and Mohr. Milwaukee, WI: Report to the National Science Foundation, University of Wisconsin-Milwaukee.

Bion, W.R. (1961) Experiences in Groups, and Other Papers. New York: Basic Books.

Birch, D. (1979) "The Job Generation Process." Cambridge, MA: Unpublished manuscript. MIT Program on Neighborhood and Regional Change.

Blakely, C. (1982) "Organizational Innovations: What Have We Learned?" Presented to the American Psychological Association, Washington, DC.

Blau, P.M. (1973) The Organization of Academic Work. New York: Wiley-Interscience.

Blau, P.M. and Scott, W.R. (1962) Formal Organizations. San Francisco, CA: Chandler.

Blois, K.J. and Cowell, D.W. (1979) "Marketing Research for New Product Ideas Arising from R&D Departments." R&D Management. 9(2):61-64

Borgatta, E.F. and Jackson, D.J. (1980) Aggregate Data: Analysis and Interpretation. Beverly Hills, CA: Sage Publications.

Boruch, R.F. and Gomez, H. (1977) "Sensitivity, Bias, and Theory in Impact Evaluations." Professional Psychology. 8:411-434

Boruch, R.F. and Gomez, H. (1979) "Measuring Impact: Power Theory in Social Program Evaluation." In Datta, L.E. and Perloff, R. (Eds.), Improving Evaluations. Beverly Hills. CA: Sage Publications. 139-170

Boruch, R.F., McSweeny, A. J. and Soderstrom, E.J. (1977) Randomized Field Experiments for Program Development and Evaluation: An Illustrative Bibliography (revised). Evanston, IL: Northwestern University, Psychology Department, Unpublished Paper.

Bostrom, R.P. and Heinen, S. (1977a) "MIS Problems and Failures, Part I: A Sociotechnical Perspective." MIS Quarterly. September:17-32

Bostrom, R.P. and Heinen, S. (1977b) "MIS Problems and Failures, Part II: The Application of Sociotechnical Theory (Part II)." MIS Quarterly. December:11-28

Bourgeois, L.J. (1981) "On the Measurement of Organizational Slack." Academy of Management Review. 6:29-40

Boylan, M.G. (1977) "The Sources of Technological Innovations." In B. Gold (Ed.), Research, Technological Change, and Economic Analysis. Lexington, MA: Lexington Books.

Bozeman, B. (1981) "Dimensions of 'Publicness': An Approach to Public Organization Theory." Unpublished Paper, Syracuse University.

Brady, R.H. (1973) "MBO Goes to Work in the Public Sector." Harvard Business Review. 51(2):65-74

Break, G.F. (1974) "The Incidence and Economic Effects of Taxation." In The Economics of Public Finance. Washington D.C.: The Brookings Institution. 119-240

Brewer, G.D. (1973) Politicians, Bureaucrats, and the Consultant. New York: Basic Books.

Bright, J.R. (1958) Automation and Management. Boston, MA: Harvard University, Graduate School of Business Administration.

Brodsky, N., Kaufman, H.G. and Tooker, J.D. (1979) University-Industry Cooperation: A Preliminary Analysis of Existing Mechanisms and their Relationship to the Innovation Process. New York: NYU Center for Science and Technology Policy.

Brooks, H. (1982) "Social and Technological Innovation." In S.B. Lundstedt and E.W. Colglazier (Eds.), Managing Innovation. New York: Pergamon Press.

Brown, B.W. and Saks, D.H. (1975) "The Production and Distribution of Cognitive Skills within Schools." Journal of Political Economy. 83:571-593

Brown, G.E. (1980) "University-Industry Links: Government as Blacksmith." Paper Presented to AAAS Symposium on Government-Industry-University Relations, San Francisco, CA.

Brown, L.A. (1978) "The Innovation Diffusion Process in a Public Policy Context." In Radnor, M., Feller, I. and Rogers, E.M. (Eds.), The Diffusion of Innovations: An Assessment. Evanston, IL: Final Report, Northwestern University, Grant Number PRA-7680388, National Science Foundation.

Browning, R.P. (1968) "Innovative and Non-. vative Decision Processes in Government Budgeting." In R.T. Golembiewski (Ed.), Public Budgeting and Finance. Itasca, IL: F.E. Peacock Publishers. 128-145

Bruno, A.V. (1973) "New Product Decision Making in High Technology Firms." Research Management. 16:28-31

Buffa, E.S. (1977) Modern Production Management. New York: John Wiley and Sons. 5th Edition.

Burns, T. and Stalker, G.M. (1961) The Management of Innovation. London: Tavistock Publications.

Burstein, L. (1978) "The Role of Levels of Analysis in the Specification of Educational Effects." Unpublished manuscript, Educational Finance and Productivity Center, University of Chicago.

Burstein, L., Linn, R.L. and Capell, F.J. (1978) "Analyzing Multilevel Data in the Presence of Heterogeneous Within-class Regressions." Journal of Educational Statistics. 3(4): 347-383

Calsyn, R., Tornatzky, L.G., and Dittmar, S. (1977) "Incomplete Adoption of an Innovation: The Case of Goal Attainment Scaling." Evaluation. 128-130

Cameron, K.S. (1981 ) "The Enigma of Organizational Effectiveness." New Directions for Program Evaluation. 11:1-13

Campbell, D.T. and Stanley, J.C. (1966) Experimental and Quasi-Experimental Designs for Research. Chicago, IL: Rand McNally and Co.

Caplan, N. (1977) "A Minimal Set of Conditions Necessary for the Utilization of Social Science Knowledge in Policy Formulation at the National Level." In C.H. Weiss (Ed.), Using Social Research in Public Policymaking. Lexington, MA: Lexington Books. 183-198

Caplan, N., Morrison, A., and Stambaugh, R.J. (1975) "The Use of Social Science Knowledge in Policy Decisions at the National Level." Ann Arbor, MI: Institute for Social Research.

Carlson, R.O. (1962) Executive Succession and Organizational Change. Chicago, IL: Midwest Administration Center, University of Chicago.

Carlson, R.O. (1965) Change Processes in the Public Schools. Eugene, OR: Center for the Advanced Study of Educational Administration, University of Oregon.

Carter, C.F. and Williams, B.R. (1959) Science in Industry. London: Oxford University Press.

Cartwright, D. (1973) "Determinants of Scientific Progress -- The Case of Research on the Risky Shift." American Psychologist. 28:222-231

Center for the Quality of Working Life, Institute of Industrial Relations, UCLA. (1978) Sociotechnical Analysis of Nursing Services on a Medical Ward in a 250 Bed Community Hospital. Paper Prepared by Participants annd Staff of a Residential Course on Organization Effectiveness.

Chakrabarti, A.K. (1973) "Some Concepts of Technology Transfer: Adoption of Innovations in Organizational Context." R&D Management. 3:111-130

Chakrabarti, A.K. (1974) "The Role of Champion in Product Innovation." California Management Review. 17(2):58-62

Chakrabarti, A.K. and Rubenstein, A.H. (1976) "Interorganizational Transfer of Technology: A Study of the Adoption of NASA Innovations." IEEE Transactions on Engineering Management. EM-23: 20-34

Chandler, A.D. (1977) The Visible Hand. Cambridge, MA: Harvard University Press.

Chapanis, A. (1971) "Prelude to 2001: Explorations in Human Communication." American Psychologist. 26: 949-961

Charles River Associates. (1977) An Analysis of Venture Capital Market Imperfections. Final Report, Experimental Technology Incentives Program, National Bureau of Standards, U.S. Department of Commerce.

Charters, W.W. and Pellegrin, R.J. (1973) "Barriers to the Innovation Process: Four Case Studies of Differentiated Staffing." Educational Administration Quarterly. 9:3-14

Cherns, A.B. (1976) "The Principles of Organizational Design." Human Relations. 29:783-792

Cherns, A.B. and Wacker, G. (1976) Analyzing Social Systems: The Socio-technical Approach. Los Angeles, CA: UCLA Center for the Quality of Working Life.

Churchman, C.W. (1979) The Systems Approach and its Enemies. New York: Basic Books.

Clark, B.R. (1965) "Interorganizational Patterns in Education." Administrative Science Quarterly. 10:224-237

Clarke, T.E. (1974) "Decision-making in Technologically-based Organizations: A Literature Survey of Present Practice." IEEE Transactions on Engineering Management. EM-21

Cobb, R.W. and Elder, C.E. (1972) Participation in American Politics. Boston, MA: Allyn and Bacon.

Coch, L. and French, J.R. (1948) "Overcoming Resistance to Change." Human Relations. 1:512-533

Cochran, N. (1980) "Society as Emergent and More than Rational: An Essay on the Inappropriateness of Program Evaluation." Policy Sciences. 12:113-129

Cohen, M.D., March, J.G. and Olsen, J.P. (1972) "A Garbage-Can Model of Organizational Choice." Administrative Science Quarterly. 17:1-25

Cole, R.E. (1979) Work, Mobility, and Participation: A Comparative Study of American and Japanese Industry. Berkeley, CA: University of California Press.

Coleman, J.S. (1958) "Relational Analysis: The Study of Social Organizations with Survey Methods." Human Organization. 17:26-36

Coleman, J.S., Katz, E. and Menzel, H. (1966) Medical Innovation: A Diffusion Study. New York: Bobbs-Merrill.

Collins, E.L. (1981) Tax Policy and Innovation: A Synthesis of Evidence. Washington, DC: National Science Foundation, PRA Research Report 82-1.

Collins, R. (1981) "On the Microfoundations of Macrosociology." American Journal of Sociology. 86(5):984-1014

Comfort, L.K. (1981) "Goals and Means: The Problem of Specification in the Development of Effective Public Policy." Administration and Society. 13(1):77-108

Comrey, A.L., Backer, T.E. and Glaser, E.M. (1973) A Source Book for Mental Health Measures. Los Angeles: Human Interaction Research Institute.

Commission on Government Procurement. (1972) Report of the Commission on Government Procurement. Vol. 2, Part B. Washington, D.C.: Government Printing Office.

Conrath, D.W., Buckingham, P., Dunn, E.V. and Swanson, J.N. (1975) An Experimental Evaluation of Alternative Communication Systems as Used for Medical Diagnosis. Behavioral Science. 20(5):296-305

Cook, T.D., Appleton, H., Conner, R.F., Shaffer, A., Tamkin, G. and Weber, S.J. (1975) "Sesame Street" Revisited. New York: Russell Sage Foundation.

Cook, T.D. and Campbell, D.T. (1979) Quasi-Experimentation: Design and Analysis for Field Setting. Chicago, IL: Rand McNally.

Cooke, R.A. and Malcolm, B. (1981 ) "Choosing and Implementing Resource Recovery Systems." National Center for Resource Recovery Bulletin. 11(2):35-39

Cooke, R.A. and Rousseau, D.M. (1981) "Problems of Complex Systems: A Model of System Problem Solving Applied to Schools." Educational Administration Quarterly. 17(3):15-41

Cooper, R. and Foster, M. (1971) "Sociotechnical Systems." American Psychologist. 26:467-474

Corbett, W.T. and Guttinger, H.I. (1977) "The Assumptions, Strategies, and Results of a Linkage Model for Dissemination." Paper presented at American Educational Research Association, New York.

Coughenour, C.M. (1965) "The Problem of Reliability of Adoption Data in Survey Research." Rural Sociology. 30:184-203

Counte, M.A. and Kimberly, J.R. (1974) "Organizational Innovation in a Professionally Dominated System." Journal of Health and Social Behavior. 15(3)

Crenson, M.A. (1971) The Un-Politics of Air Pollution. Baltimore, MD: Johns Hopkins University Press.

Cummings, T. (1983) "Transorganizational Development." Los Angeles, CA: University of Southern California, School of Business Administration. Working Paper.

Cummings, T. and Srivastava, S. (1977) The Management of Work. Kent, OH: Kent State University Press.

Cyert, R.M. and March, J.G. (1963) A Behavioral Theory of the Firm. Englewood Cliffs, NJ: Prentice-Hall.

Czikszentmihalyi, M. (1975) Beyond Boredom and Anxiety. San Francisco, CA: Jossey-Bass.

Daft, R.L. and Becker, S.W. (1978) The Innovative Organization. New York: Elsevier.

Data Resources, Inc. (1978) Macroeconomic Impacts of Federal Pollution Control Laws: 1978 Assessment. Washington, DC: Council on Environmental Quality.

Datta, L.E. (1981) "Damn the Experts and Full Speed Ahead." Evaluation Review. 5(1):5-32

David, P. (1974) Technical Change, Innovation and Economic Growth. Cambridge, Eng.: Cambridge University Press.

Davis, L.E. and Cherns, A.B. (Eds.) (1975) The Quality of Working Life. Vols. I and II. New York: Free Press.

Davis, L.E. and Taylor, J.C. (Eds.) (1972) Design of Jobs. London: Penguin Books, Inc.

Davis, L.E. and Taylor, J.C. (1976) "Technology, Organization, and Job Structure." In R. Dubin (Ed.), Handbook of Work, Organization and Society. Chicago, IL: Rand McNally.

Davis, L.E. and Trist, E. (1972) "Improving the Quality of Working Life: Experience of the Sociotechnical Approach." In U.S. Department of Health, Education and Welfare, Work in America. Cambridge, MA: MIT Press.

Dean, B.V. (1968) Evaluating, Selecting, and Controlling R&D Projects. New York: American Management Association. AMA Research Study.

Denison, E.F. (1962) The Sources of Economic Growth in the U.S. and the Alternatives Before Us. New York: Committee for Economic Development, Supplementary Paper No. 13.

Doctors, S. (1969) Role of Federal Agencies in Technology Transfer. Cambridge, MA: MIT Press.

Downey, H.K., Hellriegel, D. and Slocum, J.W., Jr. (1975) "Environmental Uncertainty: The Construct and its Application." Administrative Science Quarterly. 20:613-629

Downs, A. (1967) Inside Bureaucracy. Boston, MA: Little, Brown and Co.

Downs, G.W. (1978) "Complexity and Innovation Research." In Radnor, M., Feller, I., and Rogers, E.M. (Eds.). The Diffusion of Innovations: An Assessment. Evanston, IL: Northwestern University, Final Report to National Science Foundation, Grant No. PRA-7680388.

Downs, G.W. and Mohr, L.B. (1976) "Conceptual Issues in the Study of Innovation." Administrative Science Quarterly. 21:700-714

Duchesneau, T.D., Cohn, S.F., and Dutton, J.E. (1979) A Study of Innovation in Manufacturing: Determinants, Processes, and Methodological Issues. Volume I. Orono, ME: Report to the National Science Foundation, Grant No. RDA-7423652, University of Maine.

Duchesneau, T.D. and Dutton, J.E. (1977) "Innovation in the Footwear Industry: Characteristics of Decision Making and the Determinants of Adoption." Paper prepared for Joint ORSA/TIMS meeting, Atlanta, November 7-9.

Duetsch, L.L. (1973) "Research Performance in the Ethical Drug Industry." Marquette Business Review. 17(3):129-143

Duncan, R.B. (1972) "Characteristics of Organizational Environments and Perceived Environmental Uncertainty." Administrative Science Quarterly. 313-327

Durkheim, E. (1933) The Division of Labor in Society. New York: Free Press.

Eads, G.C. (1978) "Chemicals as a Regulated Industry." Paper presented at the American Chemical Society Symposium on the Effects of Government Regulation on Innovation in the Chemical Industry, Miami, FL.

Eads, G.C. (1972) The Local Service Airline Experiment. Washington, D.C.: The Brookings Institution.

Economic Report of the President. (1978) Washington, DC: Government Printing Office.

Edelman, M. (1964) The Symbolic Uses of Politics. Urbana, IL: University of Chicago Press.

Edwards, W. Guttentag, M. and Snapper, K. (1975) "A Decision-Theoretic Approach to Evaluation Research." In M. Guttentag and E. Struening, Handbook of Evaluation Research. Beverly Hills: Sage Publications. 139-181

Elmore, R.F. (1978) "Organizational Models of Social Program Implementation." Public Policy. 26(2):185-228

Elmore, R.F. (1982) Backward Mapping: Implementation Research and Policy Decisions." In W. Williams (Ed.), Studying Implementation: Methodological and Administrative Issues. Chatham, NJ: Chatham House Publishers. 18-35

Emery, F.E. (1963) "Some Hypotheses about the Way in which Tasks May Be More Effectively Put Together to Make Jobs." Tavistock Doc. T-176.

Emery, F.E. and Thorsrud, E. (1969) Form and Content in Industrial Democracy. London: Tavistock.

Emery, F.E. and Trist, E.L. (1965) "The Causal Texture of Organizational Environments." Human Relations. 18:21-32

Emrick, J.A. (1977) Evaluation of the National Diffusion Network. Volume I. Menlo Park, CA: Stanford Research Institute.

Endler, N.S. (1973) "The Person Versus the Situation -- A Pseudo Issue? A Response to Alker." Journal of Personality. 41:287-303

Endler, N.S. and Magnusson, D. (Eds.) (1976) Interactional Psychology and Personality. New York: Halsted Press.

Erbring, L. and Young, A.A. (1979) "Individual and Social Structure." Social Methods and Research. 7(4):396-430

Ettlie, J.E. (1980) "Manpower Flows and the Innovation Process." Management Science. 26:1086-1095

Ettlie, J.E. (1982) Organizational Context and Innovation. Chicago, IL: DePaul University, Department of Mannagement. Report to the National Science Foundation, Division of Industrial Science and Technological Innovation, Grant No. PRA-7914354.

Ettlie, J.E. (1983) "Organizational Policy and Innovation Amomg Suppliers to the Food Processing Sector." Academy of Management Journal. 26(1):27-44

Ettlie, J.E. and Vellenga, D.B. (1979) "The Adoption Time Period for Some Transportation Innovations." Management Science. 25:429-443

Etzioni, A. (1960) "Two Approaches to Organizational Analysis: A Critique and a Suggestion." Administrative Science Quarterly. 5:257-78

Etzioni, A. (1975) A Comparative Analysis of Complex Organizations. New York: Free Press.

Evan, W.M. (1966) "The Organization-Set: Toward a Theory of Interorganizational Relations." In J.D. Thompson (Ed.), Approaches to Organizational Design. Pittsburgh, PA: University of Pittsburgh Press. 173-192

Eveland, J.D. (1979) "Issues in Using the Concept of 'Adoption' of Innovations." Journal of Technology Transfer. 4 (1):1-14

Eveland, J.D. (1982) "Innovation as Specification: Issues and Implications." Innovation Processes Research Section, National Science Foundation, Internal Working Paper.

Eveland, J.D. (1983) "Social Dimensions of Changing Office Technology." Journal of Clinical Computing. Forthcoming.

Eveland, J.D. and Hetzner, W.A. (Eds.) (1982) Development of University--Industry Cooperative Research Centers: Historical Profiles. Washington, DC: National Science Foundation.

Eveland, J.D., Rogers, E.M., and Klepper, C.M. (1977) The Innovation Process in Public Organizations: Some Elements of a Preliminary Model. Ann Arbor, MI: Report to the National Science Foundation, University of Michigan, Grant No. RDA 75-17952.

Eveland, J.D. and Strasser, S.M. (1979) "Classifying Criteria of Organizational Effectiveness: An Empirical Analysis." Paper presented to the Academy of Management, Atlanta, GA.

Fairweather, G.W., Sanders, D.H., Maynard, H. and Cressler, D. (1969) Community Life for the Mentally Ill. Chicago: Aldine Publishing Co.

Fairweather, G.W. and Tornatzky, L.G. (1977) Experimental Methods for Social Policy Research. Oxford: Pergamon Press Inc.

Fairweather, G.W., Sanders, D.H. and Tornatzky, L.G. (1974) Creating Change in Mental Health Organizations. New York: Pergamon Press.

Farace, R.V. and Mabee, T. (1980) "Communication Network Analysis Methods." In Multivariate Techniques in Human Communication Research. New York: Academic Press. 365-391

Federal Coordinating Council for Science, Engineering and Technology. (1977) Directory of Federal Technology Transfer. Washington, DC: Government Printing Office.

Feldstein, M. (1978) "The Impact of Inflation on Capital Formation." Testimony before the Joint Economic Committee Hearing, "Investment in the Current Recovery." July 11.

Feller, I. (1978) "The Applicability of Economic Analysis to the Adoption of Innovations by Public Sector Organizations." In Radnor, M., Feller, I. and Rogers, E.M. (Eds.), The Diffusion of Innovations: An Assessment. Evanston, IL: Final Report, Northwestern University, Grant Number PRA-7680388, National Science Foundation.

Feller, I. (1981) "Public-Sector Innovation as 'Conspicuous Production'." Policy Analysis. 7(1):1-20

Feller, I., Johnston, I., Kaltreider, L., Madden, P., Moore, D., Rusinko, C., and Sims, L. (1982) The Transfer of Agricultural, Food and Related Technologies. University Park, PA: Institute for Policy Research and Evaluation, Pennsylvania State University. Report to the Department of Agriculture, Contract No. 53-32R6-1-55.

Feller. I., Menzel, D.C., and Engel, A.J. (1974) Diffusion of Technology in State Mission-Oriented Agencies. University Park, PA: Penn State University, Center for the Study of Science Policy, Report to the National Science Foundation, Grant No. DA-39596.

Feller. I. and Menzel, D.C. (1976) Diffusion of Innovations in Municipal Governments. University Park, PA: Penn State University, Center for the Study of Science Policy, Report to the National Science Foundation, Grant No. DA 44350.

Festinger, L. (1954) "A Theory of Social Comparison Processes." Human Relations. 7:117-140

Festinger, L. and Katz, D. (1966) Research Methods in the Behavioral Sciences. New York: Holt, Rinehart and Winston.

Fiedler, F.E. (1967) A Theory of Leadership Effectiveness. New York: McGraw-Hill Book Co.

Firebaugh, G. (1978) "A Rule for Inferring Individual-Level Relationships from Aggregate Data." American Sociological Review. 43:557-572

Fitts, P.M. and Jones, R.E. (1947) Psychological Aspects of Instrument Display. U.S. Air Force Air Material Command, Report No. TSEA-694-12A.

Fliegel, F.C. and Kivlin, J.E. (1966) "Attributes of Innovation as Factors in Diffusion." American Journal of Sociology. 72:235-248

Fleischer, M. (1978) Effects of Site Visits on Innovation Adoption. Unpublished dissertation, Department of Psychology, Michigan State University.

Foster, M. (1967) Analytical Model for Sociotechnical Systems. London: Tavistock Press. Document No. 7.

Fox, R.S. and Lippitt, R. (1964) "The Innovation of Classroom Mental Health Practices." In M.B. Miles (Ed.), Innovation in Education. New York: Bureau of Publications, Teachers College, Columbia University.

Freeman, J. and Hannan, M.T. (1975) "Growth and Decline Processes in Organizations." American Sociological Review. 40:215-228

Freeman, C. (1974) The Economics of Industrial Innovation. Baltimore, MD: Penguin Books, Inc.

Friedlaender, A.F. (1969) The Dilemma of Freight Transport Regulation. Washington, DC: The Brookings Institution.

Fromm, G. (Ed.) (1971) Tax Incentives and Capital Spending. Washington, DC: The Brookings Institution.

Ful[illegible] Pomfret, A. (1977) "Research on Curriculum Instruction and [illegible]ntation." Review of Educational Research. 47 (2):335-397

[illegible].N. and Gaertner, G.H. (1982) "Merit Pay Outcomes as a Function of Management Strategy." Paper presented to the Midwest Political Science Association, Milwaukee, WI.

Garfinkel, H. (1967) "Good Organizational Reasons for Bad Clinic Records." In H. Garfinkel, Studies in Ethnomethodology. Englewood Cliffs NJ: Prentice-Hall.

Garvey, W.D., Lin, N. and Nelson, C.E. (1970) "Communication in the Physical and the Social Sciences." Science. 170:1166-1173

Gee, E.A. (1976) Managing Innovation. New York: John Wiley and Sons, Inc.

Gellman Research Associates, Inc. (1977) "Indicators of International Trends in Technological Innovation." In Science Indicators 1976. Washington, DC: National Science Board.

General Accounting Office. (1979) Report to the Congress, Recommendations of the Commission on Government Procurement: A Final Assessment. Washington, DC: General Accounting Office Publication PSAD-79-80.

Georgopoulos, B.S. (Ed.) (1972) Organization Research On Health Institutions. Ann Arbor, MI: Institute for Social Research.

Georgopoulos, B.S. and Cooke, R.A. (1979) "A Conceptual-Theoretical Framework for the Organizational Study of Hospital Emergency Services." Ann Arbor, MI: Working Paper, Institute for Social Research, University of Michigan.

Gerstenfeld, A. and Berger, P. (1980) "An Analysis of Utilization Differences for Scientific and Technical Information." Management Science. 26 (2):165-179

Ghorpade, J. (Ed.) (1971) Assessment of Organizational Effectiveness: Issues, Analysis, and Readings. Pacific Palisades, CA: Goodyear Publishing Co.

Giacquinta, J.B. (1978) "Educational Innovation in Schools: Some Distressing Conclusions about Implementation." Paper presented to the American Educational Research Association, Toronto, Canada.

Gilfillan, S.C. (1935) The Sociology of Invention. Cambridge, MA: MIT Press.

Gilpin, R. (1975) Technology, Economic Growth and International Competitiveness. Report to the Joint Economic Committee of the Congress of the United States, Washington, DC: Government Printing Office.

Glaser, B.G. and Strauss, A.L. (1967) The Discovery of Grounded Theory: Strategies for Qualitative Research. Chicago: Aldine Publishing Co.

Glaser, E.M., Coffey, H.S., Marks, J.B. and Sarason, I.B. (1967) Utilization of Applicable Research and Demonstration Results. Los Angeles, CA: Human Interaction Research Institute.

Glaser, E.M. and Ross, H.L. (1971) Increasing the Utilization of Applied Research Results. Los Angeles, CA: Final Report, Human Interaction Research Institute, Grant No. 5 R12-MH-09250-02, National Institute of Mental Health.

Glass, G.V. (1978) "Integrating Findings: The Meta-Analysis of Research." In L.S. Shulman (Ed.), Review of Research in Education (Vol. 5). Itasca, IL: F.E. Peacock Publishers, Inc.

Glennan, T.K., Hederman, W.F., Johnson, L.J. and Rettig, R.A. (1978) The Role of Demonstrations in Federal R&D Policy. Washington, DC: Government Printing Office.

Gold, B. (1967) "The Decision Framework in Generating Major Technological Innovations: Some Unfashionable Hypotheses." In B. Gold (Ed.), Analyse et prevision. Paris, France.

Gold, B. (1978) "Some Shortcomings of Research on the Diffusion of Industrial Technology." In Radnor, M., Feller, I. and Rogers, E.M. (Eds.), The Diffusion of Innovations: An Assessment. Evanston, IL: Final Report, Northwestern University, Grant Number PRA-7680388, National Science Foundation.

Gold, B., Peirce, W.S. and Rosegger, G. (1970) "Diffusion of Major Technological Innovations in U.S. Iron and Steel Manufacturing." Journal of Industrial Economics. 18:218-241

Goldberger, A.S. and Duncan, O.D. (Eds.) (1973) Structural Equation Models in the Social Sciences. New York: Seminar Press.

Goodman, R.A. and Abernathy, W.J. (1978) "The Contribution of 'New Boy' Phenomena to Increasing Innovation and Improvement in New Technology." R&D Management. 9:33-41

Goodman, P. and Pennings, J. (1977) New Perspectives on Organizational Effectiveness. San Francisco: Jossey-Bass.

Gordon, G. *et al*. (1974) "Organizational Structure, Environmental Diversity, and Hospital Adoption of Medical Innovations." In Kaluzny, A., Innovation in Health Care Organizations. Chapel Hill, NC: University of North Carolina Press.

Gordon, M.S. (1980) "Lost Talent: The Problems of the Secondary Schools." Washington, DC: Commissioned Paper, National Research Council.

Gottschalk, R. *et al*. (1981) "Multisite Implementation and Replication of Research Results: Is the Modified R&D Model Viable?" Paper presented to the Annual Meeting of the Evaluation Research Society, Austin, TX.

Gough, H.G. and Heilbrum, A.B. (1965) The Adjective Checklist Manual. Palo Alto, CA: Consulting Psychologists Press Inc.

Grabowski, H.G. (1976) Drug Regulation and Innovation. Washington, DC: American Enterprise Institute.

Grad, F.P. *et al*. (1974) The Automobile and the Regulation of its Impact on the Environment. Technical Report, NSF/RA/X-74-023, 1974, University of Oklahoma, Grant No. ERP-7101870, National Science Foundation. (Published: University of Oklahoma Press).

Granovetter, M.S. (1973) "The Strength of Weak Ties." American Journal of Sociology. 78:1360-1380

Gray, V. (1973) "Innovation in the States: A Diffusion Study." American Political Science Review. 67:1174-1185

Greenberg, D.S. (1967) "Civilian Technology: NASA Study Finds Little 'Spin-off'." Science. 157:1016-1018

Greenberg, E., Hill, C.T. and Newburger, D.J. (1977) The Influence of Regulation on Process Innovation: A Case Study of Ammonia Production. Final Report, Washington University, Grant No. PRA-7523266, National Science Foundation.

Greene, D. and David, J.L. (1981) "A Research Design for Generalizing from Multiple Case Studies." Palo Alto, CA: Working Paper, Bay Area Research Group.

Griffith, B.C. and Mullins, N.C. (1972) "Coherent Social Groups in Scientific Change." Science. 177:959-964

Griliches, Z. (1973) Research Expenditures and Growth Accounting. In B.R. Williams (Ed.), Science and Technology in Economic Growth. 59-95

Gross, N.G., Giacquinta, J.B. and Bernstein, M. (1971) Implementing Organizational Innovations. New York: Basic Books.

Gruber, W.H. and Marquis, D.G. (1969) Factors in the Transfer of Technology. Cambridge, MA: MIT Press.

Grusky, O. (1960) "Administrative Succession in Formal Organizations." Social Forces. 39:104-115

Guetzkow, H. (1965) "Communications in Organizations." In J.G. March (Ed.), Handbook of Organizations. Chicago, IL: Rand McNally.

Gulick, L. and Urwick, L. (Eds.) (1937) Papers on the Science of Administration. New York: Institute of Public Administration, Columbia University.

Hackman, J.R. (1981) "Sociotechnical Systems Theory: A Commentary." In A.H. Van de Ven and W. Joyce, Perspectives on Organization Design and Behavior. New York: Wiley-Interscience.

Hackman, J.R. and Oldham, G.R. (1974) The Job Diagnostic Survey. New Haven, CT: Department of Administrative Sciences, Yale University, Technical Report No. 4.

Hackman, J.R. and Suttle, J.L. (Eds.) (1977) Improving Life at Work. Santa Monica, CA: Goodyear Publishing.

Hage, J. (1980) Theories of Organizations. New York: John Wiley and Sons.

Hage, J. and Aiken, M. (1970) Social Change in Complex Organizations. New York: Random House.

Hage, J. and Dewar, R. (1973) "Elite Values Versus Organizational Structure in Predicting Innovation." Administrative Science Quarterly. 18

Hall, G.E. and Loucks, S.F. (1977) "A Developmental Model for Determining Whether the Treatment is Actually Implemented." American Educational Research Journal. 14(3):263-276

Hall, G.E. and Loucks, S.F. (1978) "Innovation Configurations: Analyzing the Adaptation of Innovations." Paper presented to the American Educational Research Association, Toronto, Canada.

Hall, R.H. (1972) Organizations: Structure and Process. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Hall, R.H., Clark, J.P., Giordano, P.C., Johnson, P.V. and van Roekel, M. (1977) "Patterns of Interorganizational Relationships." Administrative Science Quarterly. 22(3):457-474

Hall, D.T. and Schneider, B. (1972) "Correlates of Organizational Identification as a Function of Career Pattern and Organizational Type." Administrative Science Quarterly. 17:340-350

Hamblin, R.L. (1973) A Mathematical Theory of Social Change. New York: Wiley Interscience.

Hannan, M.T. (1971) Aggregation and Disaggregation in Sociology. Lexington, MA: Lexington Books.

Hannan, M.T. and Freeman, J. (1977) "The Population Ecology of Organizations." American Journal of Sociology. 82(5):929-964

Hannan, M.T., Freeman, J. and Meyer, J.W. (1976) "Specification of Models of Organizational Effectiveness." American Journal of Sociology. 41:136-143

Harbridge House, Inc. (1968) Government Patent Policy Study. Vols. I-IV. Final Report to the Federal Council for Science and Technology Committee on Government Patent Policy, Washington, DC: Government Printing Office.

Hargrove, E.C. (1976) "Implementation." Policy Studies Journal. 5(1):9-15

Harvey, E. (1968) "Technology and the Structure of Organizations." American Sociological Review. 33:247-259

Hatry, H.P. (1977) How Effective are Your Community Services? Washington, DC: Urban Institute.

Havelock, R.G. (1973) Planning for Innovation through Dissemination and Utilization of Knowledge. Ann Arbor, MI: Center for Research on Utilization of Scientific Knowledge, University of Michigan.

Havelock, R.G. and Havelock, M.C. (1973) Educational Innovation in the United States. Ann Arbor, MI: Center for Research on Utilization of Scientific Knowledge, Institute for Social Research, University of Michigan.

Hayami, Y. and Ruttan, V.W. (1971) Agricultural Development: An International Perspective. Baltimore, MD: Johns Hopkins University Press.

Hayes, R.H. and Abernathy, W.J. (1980) "Managing our Way to Economic Decline." Harvard Business Review. 58 (July-August):67-77

Hayward, G., Allen, D.H. and Masterson, J. (1976) "Characteristics and Diffusion of Technological Innovations." R&D Management. 7(1):15-24

Hetzner, W.A. (1980) "The Linkage between Science and Technology Policy and Innovation Processes." Paper presented to the ORSA/TIMS Joint National Meeting, Colorado Springs, CO.

Hetzner, W.A., Tornatzky, L.G. and Klein, K.J. (1983) "Manufacturing Technology in the 1980's: A Survey of Federal Programs and Practices." Management Science. In press.

Heydebrand, W.V. (1973) "Autonomy, Complexity, and Non-Bureaucratic Coordination in Professional Organizations." In W.V. Heydebrand (Ed.), Comparative Organizations: The Results of Empirical Research. Englewood Cliffs, NJ: Prentice-Hall, Inc. 158-189

Hickson, D.J., Pugh, D.S. and Pheysey, D.C. (1969) "Operations Technology and Organization Structure: An Empirical Reappraisal." Administrative Science Quarterly. 14:378-397

Hightower, J. (1972) Hard Tomatoes, Hard Times: The Failure of America's Land Grant College Complex. Washington, DC: Agribusiness Accountability Project.

Hill, C.T. (1975) A State of the Art Review of the Effects of Regulation on Technological Innovation in the Chemical and Allied Products Industries. 3 vols. Final Report, Washington University, Grant No. RDA-7420086, National Science Foundation.

Hill, G.W. (1982) Adoption Agent Attributes and their Relation to Academic Innovation. East Lansing, MI: Michigan State University, Unpublished Dissertation.

Hirschman, A.O. (1970) Exit, Voice, and Loyalty. Cambridge, MA: Harvard University Press.

Holland, W.E., Stead, B.A., and Leibrock, R.C. (1976) "Information Channel/Source Selection as a Correlate of Technical Uncertainty in a Research and Development Organization." IEEE Transactions on Engineering Management. EM-23:163-167

Hollander, S. (1965) The Sources of Increased Efficiency: A Study of DuPont Rayon Plants. Cambridge, MA: Harvard University Press.

Horwitz, B. and Kolodny, R. (1980) The Economic Effects of Uniformity in the Financial Reporting of R&D Expenditures. College Park, MD: College of Business, University of Maryland, Report to the National Science Foundation, Grant No. PRA-7821782.

House, P. and Jones, D. (1977) Getting it off the Shelf: A Methodology for Implementing Federal Research. Boulder, CO: Westview Press.

Hull, F. and Hage, J. (1981) "A Systems Approach to Innovation and Productivity." College Park, MD: University of Maryland, Center for the Study of Innovation, Working Paper A-1.

Human Interaction Research Institute. (1976) Putting Knowledge to Use: A Distillation of the Literature Regarding Knowledge and Change. Washington, DC: National Institute of Mental Health.

Huysmans, J.H. (1970) The Implementation of Operations Research. New York: Wiley-Interscience.

Hyman, H.H. (ed.) (1973) The Politics of Health Care. New York: Praeger.

IIT Research Institute. (1968) Technology in Retrospect and Critical Events in Science. Final Report, Contract No. C535, National Science Foundation.

Inse[illegible] . and Moos, R.H. (1974) "Psychological Environments." American Psychologist. 29:179-188

Iverstine, J.C. (1978) The Impact of Environmental Protection Regulations on Research and Development in the Industrial Chemical Industry. Final Report, Southeastern Louisiana University, Grant No. PRA-7621321, National Science Foundation.

Jacobs, D. (1974) "Dependency and Vulnerability: An Exchange Approach to the Control of Organizations." Administrative Science Quarterly. 19:45-59

Jacoby, H.D. and Linden, L.H. (1976) Government Support for the Commercialization of Energy Technologies. Cambridge, MA: MIT Energy Laboratory, MIT-EL 76-009.

Jadlow, J.M. (1970) The Economic Effects of the 1962 Drug Amendments. Unpublished Doctoral Dissertation, University of Virginia.

Janis, I. and Mann, L. (1977) Decision Making. New York: Free Press.

Jervis, P. (1975) "Innovation and Technology Transfer -- The Roles and Characteristics of Individuals." IEEE Transactions on Engineering Management. EM-22:19-27

Jewkes, J., Sawers, D. and Stillerman, R. (1969) The Sources of Invention. 2nd ed. New York: W.W. Norton and Co., Inc.

Johansson, M.A. (1978) Fluctuations in Federal Funds for University Research and the Roles and Careers of Academic Scientists. Final Report to the U.S. Department of Labor, Grant No. 91-34-69-50 and No. 91-34-70-63.

Johnson, B.M, Taylor, J.C., Smith, D.R., and Cline, T.R. (1983) Innovation in Word Processing. Stanford CA: Stanford University, Institute for Communication Research.

Johnson, E.C. and Tornatzky, L.G. (1981) "Academia and Industrial Innovation." In G. Gold (Ed.), New Directions for Experiential Learning: Business and Higher Education -- Toward New Alliances. San Francisco, CA: Jossey-Bass.

Johnston, R. and Gibbons, M. (1975) "Characteristics of Information Usage in Technological Innovation." IEEE Transactions on Engineering Management. EM-22:27-34

Jondrow, J.M. (1972) A Measure of the Monetary Benefits and Costs of the Regulation of Prescription Drug Effectiveness. Unpublished Doctoral Dissertation, University of Wisconsin.

Jorgenson, D.W. (1971) "Econometric Studies of Investment Behavior: A Survey." Journal of Economic Literature. 9: 1111-1147

Kaluzny, A.D., Gentry, J.T., and Veney, J.E. (Eds.) (1974) Innovation in Health Care Organizations. Chapel Hill, NC: University of North Carolina Press.

Kamien, M.I. and Schwartz, N.L. (1974) "Risky R&D with Rivalry." Annals of Economic and Social Measurement. 3:267-277

Kamien, M.I. and Schwartz, N.L. (1975) "Market Structure and Innovation: A Survey." Journal of Economic Literature. 13:1-37

Kamien, M.I. and Schwartz, N.L. (1982) Market Structure and Innovation. Cambridge: Cambridge University Press.

Kaplan, R.S. (1976) Tax Policies for R&D and Technological Innovation. Chapter 1: "Tax Policies of U.S. and Foreign Nations in Support of R&D and Innovation." Pittsburgh, PA: Final Report, Carnegie-Mellon University, Grant Number RDA-7421227, National Science Foundation.

Katz, D. and Kahn, R.L. (1978) The Social Psychology of Organizations. New York: John Wiley and Sons. Second Edition.

Katz, E. (1962) "Notes on the Unit of Adoption in Diffusion Research." Sociological Inquiry. 32(2):3-9

Kaufman, H.G. (1974) Obsolescence and Professional Career Development. New York: American Management Association.

Kaufman, H.G. (1976) Are Government Organizations Immortal? Washington, DC: The Brookings Institution.

Keen, P.G.W. (1981) "Information Systems and Organizational Change." Communications of the ACM. 24(1):24-33

Keller, R.T. (1978) "Communication and Innovation in Research and Development Organizations: An Overview of the Literatures." Paper presented to the National ORSA/TIMS Meeting, New York.

Keller, R.T. and Holland, W.E. (1978) Technical Information Flows and Innovation Processes. Houston, TX: Final Report, University of Houston, Grant No. PRA-7618441, National Science Foundation.

Kelly, P. and Kranzberg, M. (Eds.) (1978) Technological Innovation: A Critical Review of Current Knowledge. (4 vols.). San Francisco, CA: San Francisco University Press.

Kendrick, J.W. (1961) Productivity Trends in the U.S. Princeton, NJ: Princeton University Press.

Kendrick, J.W. (1977) "Policies to Promote R&D and Productivity Growth." In Preliminary Papers for a Colloquium on the Relationships between R&D and Economic Growth/Productivity. Washington, DC: National Science Foundation. E1-25

Kimberly, J.R. (1976a) "Issues in the Design of Longitudinal Organizational Research." Sociological Methods and Research. 4: 321-347.

Kimberly, J.R. (1976b) "Organizational Size and the Structuralist Perspective." Administrative Science Quarterly. 21:571-597

Kimberly, J.R. (1981) "Managerial Innovation." In P.C. Nystrom and W.H. Starbuck (Eds.), Handbook of Organizational Design. London: Oxford University Press. 84-104

Kimberly, J.R. and Evanisko, M.J. (1981) "Organizational Innovation: The Influence of Individual, Organizational, and Contextual Factors on Hospital Adoption of Technological and Administrative Innovations." Academy of Management Journal. 24:689-713

Kimberly, J.R. and Miles, R.H. (Eds). (1980) The Organizational Life Cycle. San Francisco: Jossey-Bass Inc.

Kirst, M. and Jung, R. (1980) The Utility of a Longitudinal Approach in Assessing Implementation: A Thirteen Year View of Title I. ESEA Draft Report, Stanford, CA: Institute for Research on Educational Finance and Governance.

Kitti, C. (1979) "Patent Invalidity Studies: A Survey." Idea. 20(1):55-76

Klein, B.H. (1977) Dynamic Economics. Cambridge, MA: Harvard University Press.

Klein, L.R. (1974) "Issues in Econometric Studies of Investment Behavior." In the Colloquium: On econometric studies of investment. Journal of Economic Literature. 12 (March):43-49

Klonglan, G.E. and Coward, W.E. (1970) "The Concept of Symbolic Adoption: A Suggested Interpretation." Rural Sociology. 35:77-83

Klonglan, G.E., Warren, R.D., Winklepleck, J.M. and Paulsen, S.K. (1976) "Interorganizational Measurement in the Social Services Sector: Differences by Hierarchical Level." Administrative Science Quarterly. 21:675-687

Koontz, H. and O'Donnell, C. (1955) Principles of Management; An Analysis of Managerial Functions. New York: McGraw-Hill.

Koontz, H. and O'Donnell, C. (1976) Management: A Systems and Contingency Analysis of Managerial Functions. New York: McGraw-Hill.

Kraemer, K.L. and Dutton, W.H. (1979) "The Interests Served by Technological Reform: The Case of Computing." Administration and Society. 11(1):80-106

Kraemer, K.L. and King, J.L. (1979) "New Findings on the Transfer of Computing Applications among Cities." Journal of Technology Transfer. 4:99-110

Kuhn, T.S. (1962) The Structure of Scientific Revolutions. Chicago, IL: University of Chicago Press.

Lambright, W.H. (1980) Technology Transfer to Cities. Boulder, CO: Westview Press.

Lambright, W.H., Teich, A. and Carroll, J.D. (1977) Adoption and Utilization of Urban Technology: A Decision Making Study. Syracuse, NY: Syracuse Research Corp., Report to the National Science Foundation, Grant No. RDA75-19704.

Langrish, J. and Gibbons, M. (1972) Wealth from Knowledge. New York: John Wiley and Sons.

Larsen, J.K. (1982) Information Utilization and Non-Utilization. Palo Alto, CA: American Institutes for Research.

Larsen, J.K. and Agarwala-Rogers, R. (1977) "Reinvention of Innovative Ideas: Modified? Adapted? or None of the Above?." Evaluation. 136-140

Larsen, J.K., Arutunian, C.A. and Finley, C.J. (1974) Diffusion of Innovations among Community Mental Health Centers. Palo Alto, CA: American Institutes for Research.

Larsen, J.K., Norris, E. and Droll, J. (1976) Consultation and its Outcome: Community Mental Health Centers. Palo Alto, CA: American Institutes for Research.

Lasagna, L., Wardell, W.M. and Hanson, R.W. (1978) Technological Innovation and Government Regulation of Pharmaceuticals in the United States and Great Britain. Rochester, NY: Final Report, The University of Rochester, Grant No. PRA-7519066, National Science Foundation.

Lawrence, P.R. and Lorsch, J.W. (1967) Organization and Environment. Cambridge, MA: Harvard University Press.

Lawrence, P.R. and Lorsch, J.W. (1969) Developing Organizations: Diagnosis and Action. Reading, MA: Addison-Wesley.

Leadley, S.M. (1969) "An Integrative Model: Comparative Relations among Organizations." Paper presented to Rural Sociology Conference.

Leibenstein, H. (1969) "Organizational or Frictional Equilibria, X-Efficiency, and the Rate of Innovation." Quarterly Journal of Economics. 83:600-623

Leithwood, K.A. and Montgomery, D.J. (1980) "Evaluating Program Implementation." Evaluation Review. 4:193-214

Leontief, W. (1982) "Academic Economics." Letter to Editor, Science. 217:104

Levine, S. and White, P.E. (1961) "Exchange as a Conceptual Framework for the Study of Interorganizational Relationships." Administrative Science Quarterly. 5:583-601

Levine, S. and White, P.E. (1963) "The Community of Health Organizations." In H.E. Freeman *et al*. (Eds.), Handbook of Medical Sociology. Englewood Cliffs, NJ: Prentice-Hall. 339-343

Lewin, K. (1947) "Frontiers in Group Dynamics." Human Relations. 1:5-41

Likert, R. (1961) New Patterns of Management. New York: McGraw-Hill.

Lindblom, C.E. (1959) "The Science of Muddling Through." Public Administration Review. 19:79-88

Little, A.D. and Co. (1973) Barriers to Innovation in Industry: Opportunities for Public Policy Changes. Report to the National Science Foundation.

Litvak, I.A. and Maule, C.J. (1972) "Managing the Entrepreneurial Enterprise." Business Quarterly. 37(2):42-50

Litwak, E. (1961) "Models of Bureaucracy which Permit Conflict." American Journal of Sociology. 67:177-184

Locke. E.A. and Schweiger, D.M. (1979) "Participation in Decision Making: One More Look." Research in Organizational Behavior. 1:265-339

Lundstedt, S.B. and Colglazier, E.W. (Eds.) (1982) Managing Innovation. New York: Pergamon Press.

Lynch, B.P. (1974) "An Empirical Assessment of Perrow's Technology Construct." Administrative Science Quarterly. 19:338-357

MacAvoy, P.W. (Ed.). (1977) OSHA Safety Regulation: Report of the Presidential Task Force. Washington, DC: American Enterprise Institute for Public Policy Research.

MacAvoy, P.W. and Sloss, J. (Eds.). (1967) Regulation of Transport Innovation: The ICC and Unit Coal Trains to the East Coast. New York: Random House, Inc.

Majone, G. and Wildavsky, A.B. (1978) "Implementation as Evolution." In Freeman, H.E. (Ed.), Policy Studies Review Annual. Volume II. Beverly Hills, CA: Sage Publications 103-117

Malek, F.W. (1978) Washington's Hidden Tragedy. New York: Free Press.

Mansfield, E. (1968) Industrial Research and Technological Innovation: An Econometric Analysis. New York: W.W. Norton and Co., for the Cowles Foundation for Research in Economics at Yale University.

Mansfield, E. (1977) "Research and Development, Productivity Change, and Public Policy." In Preliminary Papers for a Colloquium on the Relationships between R&D and Economic Growth/Productivity. Washington, DC: National Science Foundation. A:1-19.

Mansfield, E. and Wagner, S. (1975) "Organizational and Strategic Factors Associated with Probabilities of Success in Industrial R&D." The Journal of Business. 48(2):179-198

Mansfield, E. *et al.* (1971) Research and Innovation in the Modern Corporation. New York: W.W. Norton.

March, J.G. and Romelaer, P. (1979) In March, J.G. and Olsen, J.P., Ambiguity and Choice in Organizations. Bergen, Norway: Universitetsforlaget.

March, J.G. and Simon, H.A. (1958) Organizations. New York: John Wiley and Sons.

March, J.G. (Ed.) (1965) Handbook of Organizations. Chicago, IL: Rand McNally.

Margulies, N. and Raia, A.P. (1972) Organization Development. New York: McGraw Hill.

Marquis, D.G. and Allen, T.J. (1967) "Communication Patterns in Applied Technology." American Psychologist. 21:1052-1060

Marrett, C.B. (1971) "On the Specification of Interorganizational Dimensions." Sociology and Social Research. 56:83-99

Marrow, A.J., Bowers, D.G. and Seashore, S.E. (1967) Management by Participation. New York: Harper and Row Publishers, Inc.

Martino, J.P., Chen, K.L. and Lenz, R.C., Jr. (1978) Predicting the Diffusion Rate of Industrial Innovations. Dayton, OH: Final Report, University of Dayton Research Institute, Grant Number PRA-7617188, National Science Foundation.

Massie, J. (1965) "Management Theory." In J.G. March (Ed.), Handbook of Organizations. Chicago, IL: Rand McNally and Co. 387-422

McGowan, E.F. (1976) "Rational Fantasies." Policy Sciences. 7:439-454

McKelvey, B. (1975) "Guidelines for the Empirical Classification of Organizations." Administrative Science Quarterly. 20:509-525

Mechanic, D. (1962 ) "Sources of Power of Lower Participants in Complex Organizations." Administrative Science Quarterly. 7:349-364

Meyer, M.W. (Ed.) (1979) Environments and Organizations. San Francisco, CA: Jossey-Bass.

Meyer, J.W. and Rowan, B. (1977) "Institutionalized Organizations: Formal Structure as Myth and Ceremony." American Journal of Sociology. 83:340-363

Miles, M.B. (1979) "Qualitative Data as an Attractive Nuisance: The Problem of Analysis." Administrative Science Quarterly. 24:590-601

Miller, W.N. (1952) "Interinstitutional Conflict as a Major Impediment to Delinquency Prevention." Human Organization. 17:20-23

Miller, J.G. (1965a) "Living Systems: Basic Concepts." Behavioral Science. 10:193-237

Miller, J.G. (1965b) "Living Systems: Structure and Process." Behavioral Science. 10:337-379

Miller, J.G. (1965c) "Living Systems: Cross-Level Hypotheses." Behavioral Science. 10:380-411

Miller, J.G. (1972) "Living Systems: The Organization." Behavioral Science. 17:1-182

Mintzberg, H.D. (1979) The Structuring of Organizations. Englewood Cliffs, NJ: Prentice-Hall.

Mintzberg, H., Raisinghani, D., and Theoret, A. (1976) "The Structure of 'Unstructured' Decision Processes." Administrative Science Quarterly. 21:246-275

Mischel, W. (1973) "Toward a Cognitive Social Learning Reconceptualization of Personality." Psychological Review. 80:252-283

Moch, M.K. (1976) "Structure and Organizational Resource Allocation." Administrative Science Quarterly. 21:661-674

Mogee, M.F. (1979) The Relationship of Federal Support of Basic Research in Universities to Industrial Innovation and Productivity. Washington, DC: Congressional Research Service, Library of Congress.

Mohr, L.B. (1969) The Determinants of Innovation in Drganizations." American Political Science Review. 63(1):111-126

Mohr, L.B. (1971) "Organizational Technology and Organizational Structure." Administrative Science Quarterly. 16:444-477

Mohr, L.B. (1973) "The Concept of Organizational Goal." American Political Science Review. 67:470-481

Mohr, L.B. (1976) "Organizations, Decisions, and Courts." Law and Society. Summer:621-642

Mohr, L.B. (1982) Explaining Organizational Behavior: The Limits and Possibilities of Theory and Research. San Francisco, CA: Jossey-Bass.

Mooney, J.D. and Reilly, A.C. (1939) Principles of Organization. New York: Harper Brothers

Moore, B.V. (1920) Personnel Selection of Graduate Engineers: The Differentiation of Apprentice Engineers for Training as Salesmen, Designers, and Executives of Production. Pittsburgh, PA: Doctoral Dissertation, Bureau of Personnel Research, Division of Applied Psychology, Carnegie Institute of Technology.

Moos, R.H. (1975) The Human Context: Environmental Determinants of Behavior. New York: John Wiley and Sons.

Morley, S.A. and Smith, G.W. (1974) "Managerial Discretion and the Choice of Technology by Multinational Firms in Brazil." Houston, TX: Program of Development Studies, Rice University, Paper No. 56.

Morgan, C.T., Cook, J.S., Chapanis, A. and Lund, M.W. (Eds.). (1963) Human Engineering Guide to Equipment Design. New York: McGraw-Hill.

Morison, E.E. (1966) Men, Machines, and Modern Times. Cambridge, MA: MIT PRESS.

Mott, P.E. (1972) The Characteristics of Effective Organizations. New York: Harper and Row.

Myers, S. and Marquis, D.G. (1969) Successful Industrial Innovations; A Study of Factors Underlying Innovation in Selected Firms. Washington, DC: National Science Foundation. Government Printing Office. NSF 69-17.

Naroll, R. (1965) "Galton's Problem: The Logic of Cross-Cultural Analysis." Social Research. 32:428-451

National Academy of Engineering. (1974) Technology Transfer and Utilization: Recommendations for Redirecting the Emphasis and Correcting the Imbalance. Washington DC: Academy Report No. PB-232 123

National Science Foundation. (1980a) Second Annual Science and Technology Report. Washington, DC: Government Printing Office.

National Science Foundation. (1980b) Science and Engineering: Education for the 1980's and Beyond. Washington, DC: Government Printing Office.

Nay, J. and Kay, P. (1982) Government Oversight and Evaluability Assessment. Lexington, MA: Lexington Books

Nelson, R.R., Peck, M.J. and Kalachek, E.D. (1967) Technology, Economic Growth, and Public Policy. Washington, DC: The Brookings Institution.

Nelson, R.R. and Phelps, E.S. (1966) "Investment in Humans, Technological Diffusion, and Economic Growth." American Economic Review. 56:69-75

Nelson, R.R. and Winter, S.G. (1974) "Neoclassical vs. Evolutionary Theories of Economic Growth." Economic Journal. 84

Nelson, R.R. and Winter, S.G. (1977 ) "In Search of a Useful Theory of Innovation." Research Policy. 6:36-76

Nelson, R.R. and Yates, D. (Eds.). (1978) Innovation and Implementation in Public Organizations. Lexington, MA: Lexington Books.

Niskanen, W. (1971) Bureaucracy and Representative Government. Chicago, IL: Aldine and Atherton.

Noll, R.G. (1971) Reforming Regulation. Washington, DC: The Brookings Institution.

Noll, R.G. (1975) Government Policies and Technological Innovation. (5 vols). Pasadena, CA: Final Report, California Institute of Technology, Grant Number RDA-7307241, National Science Foundation.

Okun, A.M. and Perry, G.L. (Eds.) (1978) "Innovative Policies to Slow Inflation." Washington, DC: Brookings Papers on Economic Activity. Special Issue. The Brookings Institution.

Ouchi, W. (1977) "The Transmission of Control Through Organizational Hierarchy." Academy of Management Journal. 21:248-263

Ouchi, W. (1980) "Markets, Bureaucracies, and Clans." Administrative Science Quarterly. 25:129-142

Parsons, T. (1961) "An Outline of the Social System." In T. Parsons, Theories of Society. Volume I. New York: Free Press. 38-41

Pasmore, W.A. *et al*. (1980) Sociotechnical Approaches to Organization Change in USAREUR. Cleveland, OH: Case Western Reserve University, Final Report, Contract No. MDA 903-79-R-0145.

Pasmore, W.A. and Sherwood, J.J. (Eds.). (1978) Sociotechnical Systems: A Sourcebook. La Jolla, CA: University Associates.

Patton, M.Q. (1980) Qualitative Evaluation Methods. Beverly Hills, CA: Sage Publications.

Patton, M.Q., Grimes, P.J., Guthrie, K.M., Brennan, N.J., French, B.D. and Blyth, D.A. (1977) "In Search of Impact: An Analysis of the Utilization of Federal Health Evaluation Research." In C.H. Weiss (Ed.), Using Social Research in Public Policy Making. Lexington, MA: Lexington Books.

Pavitt, K. and Wald, S. (1971) The Conditions for Success in Technological Innovation. Paris, France: Organization for Economic Cooperation and Development.

Pearson, K. (1897) "On a Form of Spurious Correlation which May Arise when Indices are Used in the Measurement of Organs." Proceedings of the Royal Society of London. 60:489-497

Peltzman, S. (1974) Regulation of Pharmaceutical Innovation: The 1962 Amendments. Washington, DC: The American Enterprise Institute for Public Policy Research.

Pelz, D.C. (1982) Use of Information in Innovating Processes by Local Governments. Ann Arbor, MI: University of Michigan, Report to the National Science Foundation, Grant No. ISI-79-20575.

Pelz, D.C. and Andrews, F.M. (1966) Scientists in Organizations: Productive Climates for Research and Development. New York: John Wiley and Sons, Inc.

Pelz, D.C. and Munson, D. (1980) "The Innovating Process: A Conceptual Framework." Ann Arbor, MI: Working Paper, Center for Research on Utilization of Scientific Knowledge, University of Michigan.

Pennings, J.M. (1975) "The Relevance of the Structural-Contingency Model for Organizational Effectiveness." Administrative Science Quarterly. 20:393-410

Perrow, C.B. (1967 ) "A Framework for the Comparative Analysis of Organizations." American Sociological Review. 32:194-208

Perrow, C.B. (1968) "Organizational Goals." In International Encyclopedia of the Social Sciences, Revised Edition. New York: MacMillan.

Perrow, C.B. (1970) Organizational Analysis: A Sociological View. Belmont, CA: Wadsworth Publishing Co., Inc.

Perrow, C.B. (1979) Complex Organizations: A Critical Essay. Glenview, IL: Scott, Foresman and Co.

Perrow, C.B. (1982) "The Organizational Context of Human Factor Working Paper, Committee on Human Factors, National Res Council.

Pfeffer, J. and Salancik, G.R. (1978) The External Control of Organizations. New York: Harper and Row.

Pfeffer, J., Salancik, G.R. and Leblebici, H. (1976 ) "The Effect of Uncertainty on the Use of Social Influence in Organizational Decision Making." Administrative Science Quarterly. 21:227-245

Pickle, H. and Friedlander, F. (1967) "Seven Societal Criteria of Organizational Success." Personnel Psychology. 20:165-178

Pincus, J. (1974) "Incentives for Innovation in the Public Schools." Review of Educational Research. 44:113-144

Pressman, J.L. and Wildavsky, A.B. (1973) Implementation. Berkeley, CA: University of California Press.

Price, J.L. (1972) "The Study of Organizational Effectiveness." Sociological Quarterly. 13:3-15

Price, J.L. (1977) A Study of Organizational Turnover. Ames, IA: Iowa State University Press.

Prien, E.P. (1966) "Dynamic Character of Criteria: Organization Change." Journal of Applied Psychology. 50:501-504

Provan, K.G., Beyer, J.M. and Kruytbosch, C. (1980) "Environmental Linkages and Power in Resource-Dependence Relations between Organizations." Administrative Science Quarterly. 25:200-225

Quinn, R.E. and Rohrbaugh, J. (1981) "A Competing Values Theory of Organizational Effectiveness." Public Productivity Review. 5(2):122-140

Rabinovitz, F., Pressman, J. and Rein, M. (1976) "Guidelines: A Plethora of Forms, Authors and Functions." Policy Sciences. 7(4):399-416

Radnor, M., Ettlie, J.E. and Dutton, J. (1978) "The R&D Management Literature and Innovation Diffusion Research." In Radnor, M., Feller, I. and Rogers, E.M. (Eds.), The Diffusion of Innovations: An Assessment. Evanston, IL: Final Report, Northwestern University, Grant Number PRA-7680388, National Science Foundation.

Radnor, M., Feller, I. and Rogers, E.M. (Eds.). (1978) The Diffusion of Innovations: An Assessment. Evanston, IL: Final Report, Northwestern University, Grant Number PRA-7680388, National Science Foundation.

Randolph, W.A. (1979) "Technology and the Design of Organization Units." In R.H. Miles and W.A. Randolph, The Organization Game. Santa Monica, CA: Goodyear Publishing Co. 87-101

Reid, W.J. (1964) "Interagency Coordination in Delinquency Prevention and Control." Social Service Review. 38:418-429

Reid, W.J. (1969) "Interorganizational Coordination in Social Welfare: A Theoretical Approach to Analysis and Intervention." In R.M. Kramer and H. Specht (Eds.), Readings in Community Organization Practice. Englewood Cliffs, NJ: Prentice-Hall.

Rice, A.K. (1958) Productivity and Social Organization: The Ahmedabad Experiment. London: Tavistock Publications Ltd.

Riecken, H.W. and Boruch, R.F. (Eds.) (1974) Social Experimentation: A Method for Planning and Evaluating Social Intervention. New York: Academic Press, Inc.

Roberts, A.O. and Larsen, J.K. (1971) Effective Use of Mental Health Research Information. Palo Alto, CA: Final Report, American Institutes for Research, Grant No. 1 R01 MH 15445, Nat al Institute of Mental Health.

Roberts, E.B. (1969) "Entrepreneurship and Technology." In W.A. Gruber and D.G. Marquis (Eds.), Factors in the Transfer of Technology. Cambridge, MA: MIT Press.

Roberts, K.H., Hulin, C.L. and Rousseau, O.M. (1978) Developing an Interdisciplinary Science of Organizations. San Francisco, CA: Jossey-Bass.

Robertson, T.S. (1971) Innovative Behavior and Communication. New York: Holt, Rinehart and Winston, Inc.

Robinson, W.S. (1950) "Ecological Correlations and the Behavior of Individuals." American Sociological Review. 15:351-357

Roessner, J.D. (1979) "Federal Technology Policy: Innovation and Problem Solving in State and Local Governments." Policy Analysis. 5:181-200

Roessner, J.D. (1975 ) Federal Technology Transfer: An Analysis of Current Program Characteristics and Practices. Washington, DC: Committee on Domestic Technology Transfer, Federal Council for Science, Engineering and Technology.

Roethlisberger, F.J. and Dickson, W.J. (1939) Management and the Worker. Cambridge, MA: Harvard University Press.

Rogers, D.L. and Molnar, J. (1976) "Organizational Antecedents of Role Conflict and Ambiguity in Top-Level Administrators." Administrative Science Quarterly. 21:598-610

Rogers, E.M. (1983) Diffusion of Innovations. New York: Free Press. Third Edition (First Edition, 1962).

Rogers. E.M. (1975) "Innovation in Organizations: New Research Approaches." Paper Presented to the American Political Science Association, San Francisco.

Rogers, E.M. *et al*. (1975) Diffusion of IMPACT Innovations to University Professors. Ann Arbor, MI: Department of Journalism, University of Michigan, Report to the Exxon Educational Foundation.

Rogers, E.M. and Eveland, J.D. (1978) "Communication and Innovation in Organizations." In P. Kelly and M. Kranzberg, Technological Innovation: A Critical Review of Current Knowledge. Volume II. San Francisco, CA: San Francisco University Press.

Rogers, E.M. and Rogers, L.E. (1961) "A Methodological Analysis of Adoption Scales." Rural Sociology. 26:325-336

Rogers, E.M., Eveland, J.D. and Bean, A.S. (1976) Extending the Agricultural Extension Model. Stanford, CA: Stanford University, Institute for Communication Research

Rogers, E.M., Magill, K.P. and Rice, R.E. (1979) The Innovation Process for Dial-a-Ride. Stanford, CA: Stanford University, Institute for Communication Research.

Rogers, E.M., and Leonard-Barton, D. (1980) Investigation of Innovation Processes in the Microprocessor and Solar Collect. Manufacturing Industries of Northern California. Stanford, CA: nford University, Institu for Communication Research

Rogers, E.M. with Shoemaker, F.F. (1971) Communication of Innovations: A Cross-Cultural Approach. N York: Free Press.

Romeo, A.A. (1975) "Interindustry and Interfirm Differences in the Rate of Diffusion of an Innovation." Review of Economics and Statistics. 57:311-319

Roney, T.G. (1966) Report on the First Conference on Occupational Obsolescence. Menlo Park, CA: Stanford Research Institute.

Rose, R. (1977) "Implementation and Evaporation: The Record of MBO." Public Administration Review. 37(1):64-71

Rosenberg, N. (1976) Perspectives on Technology. London: Cambridge University Press.

Rossi, P. and Williams, W. (1972) Evaluating Social Programs: Theory, Practice, and Politics. New York: Seminar Press.

Rothman, J. (1974) Planning and Organizing for Social Change: Action Principles from Social Science Research. New York: Columbia University Press.

Rothwell, R., Freeman, D., Horsley, A., Jervis, V.T.P., Robertson, A.B. and Townsend, J. (1974) "SAPPHO Updated: Project SAPPHO, Phase II." Research Policy. 3:258-291

Rousseau, D.M. (1979) "Assessment of Technology in Organizations: Closed vs. Open Systems Approaches." Academy of Management Review. 4:531-542

Rowe, L.A. and Boise, W.B. (1974) "Organizational Innovation: Current Research and Evolving Concepts." Public Administration Review. 34(3):284-293

Rowe, L.A. and Boise, W.B. (1981) Technological Innovation and Problem-Solving in Local Governments: An Assessment of Current Research Methods. Gary, IN: University of Indiana, School of Public and Environmental Affairs, Report to the National Science Foundation.

Rubenstein, A.H. (1968) "Research-on-Research: The State of the Art in 1968." Research Management. 11:279-304

Rubenstein, A.H. and Ettlie, J.E. (1979) "Innovation among Suppliers to Automobile Manufacturers: An Exploratory Study of Barriers and Facilitators." R&D Management. 9(2):65-76

Rubenstein, A.H. and Haberstroh, C.J. (Eds.) (1966) Some Theories of Organization. Homewood, IL: R.D. Irwin

Rubenstein, A.H. *et al.* (1974) Final Technical Report on Field Studies of the Technological Innovation Process. Evanston, IL: Northwestern University, Report to the National Science Foundation, Grant No. DA-39470.

Ryan, B. and Gross, N.C. (1943) "The Diffusion of Hybrid Seed Corn in Two Iowa Communities." Rural Sociology. 8:15-24

Sabatier, P. and Mazmanian, D. (1980) "The Implementation of Public Policy: A Framework of Analysis." Policy Studies Journal. 8(4):538-560

Sarason, S.B. (1972) The Creation of Settings and the Future Societies. San Francisco, CA: Jossey-Bass Inc.

Schachter, S. (1959) The Psychology of Affiliation. Stanford, CA: Stanford University Press.

Scheirer, M.A. (1981) Program Implementation: The Organizational Context. Beverly Hills, CA: Sage Publications.

Scheirer, M.A. (1982) Measuring the Implementation of Innovations. Annandale, VA: American Research Institute, Final Report to National Science Foundation, Grant No. PRA-8022612.

Schiffel, D. and Kitti, C. (1978) "Rates of Invention: International Patent Comparisons." Research Policy. 7:324-340

Schmidt, S.M. and Kochan, T.A. (1977) "Interorganizational Relationships: Patterns and Motivations." Administrative Science Quarterly. 22(2):220-234

Schmookler, J. (1966) Invention and Economic Growth. Cambridge, MA: Harvard University Press.

Schon, D.A. (1967) Technology and Change. New York: Delacorte Press.

Schon, D.A. (1971) Beyond the Stable State. New York: Norton.

Schultz, R.L. and Slevin, D.P. (Eds.). (1975) Implementing Operations Research/Management Science. New York: American Elsevier.

Schumpeter, J.A. (1942) Capitalism, Socialism, and Democracy. New York: Harper and Row Publishers, Inc.

Schwartzman, D. (1976) Innovation in the Pharmaceutical Industry. Baltimore, MD: Johns Hopkins University Press.

Science Policy Research Unit. (1971) Project SAPPHO: A Study of Success and Failure in Industrial Innovation. Brighton, England: University of Sussex.

Scott, W.R. (1972) "Professionals in Hospitals: Technology and the Organization of Work." In B.S. Georgopoulos (Ed.), Organization Research on Health Institutions. Ann Arbor, MI: Institute for Social Research.

Sechrest, L. and Yeaton, W.E. (1981) "Assessing the Effectiveness of Social Programs: Methodological and Conceptual Issues." New Directions in Program Evaluation. 9:41-56

Selig, E.I. (1973) Effluent Charges on Air and Water Pollution: A Conference Report of the Council on Law-Related Studies. Washington, DC: Environmental Law Institute.

Selznick, P. (1949) TVA and the Grassroots. Berkeley, CA: University of California Press.

Shapero, A. (1979) University-Industry Interactions: Recurring Expectations, Unwarranted Assumptions and Feasible Policies. Columbus, OH: Ohio State University.

Shepherd, W.G. (1971) "The Competitive Margin in Communications." In W.M. Capron (Ed.), Technological Change in Regulated Industries. Washington DC: The Brookings Institution. 86-122

Sherwin, E.W. and Isenson, R.S. (1967) "Project Hindsight: A Defense Department Study of the Utility of Research." Science. 156:1571-1577

Sieber, S.D. (1974) "Toward a Theory of Role Accumulation." American Sociological Review. 39:567-578

Simon, H.A. (1973) "The Organization of Complex Systems." In H.H. Pattee (Ed.), Hierarchy Theory. New York: G. Braziller.

Simon, H.A. (1976) Administrative Behavior. New York: Free Press. Third Edition.

Shull, F.A., Delbecq, A.L. and Cummings, L.L. (1970) Organizational Decisionmaking. New York: McGraw Hill.

Slavin, R.E. (1977) "A Student Team Approach to Teaching Adolescents with Special Emotional and Behavioral Needs." Psychology in the Schools. 14:77-84

Slitor, R.E. (1966) "The Tax Treatment of Research and Innovative Investment." American Economic Review. 56 (May Supplement):217-31

Sloss, J. (1978) "Railroad Volume Coal Rates: A Review of Litigation Accompanying an Innovative Marketing Strategy." Cambridge, MA: Working Paper, Center for Transportation Studies, Massachusetts Institute of Technology.

Smith, T.B. (1973) "The Policy Implementation Process." Policy Sciences. 4:197-209

Smith, V.K. (1974) "The Implications of Regulation for Induced Technical Change." The Bell Journal of Economics and Management Science. 5(2):623-632

Solow, R.M. (1957) "Technical Change and the Aggregate Production Function." Review of Economics and Statistics. 39:312-320

Souder, W.E. (1977) An Exploratory Study of the Coordinating Mechanisms between R&D and Marketing as an Influence on the Innovation Process. Pittsburgh, PA: Final Report, University of Pittsburgh, Grant No. RDA-7517195, National Science Foundation.

Srivastva, S. *et al*. (1975) Job Satisfaction and Productivity. Cleveland, OH: Department of Organizational Behavior, Case Western Reserve University.

Staats, E.B. (1979) "Federal Research Grants." Science. 205:18-20

Steers, R.M. (1975) "Problems in the Measurement of Organizational Effectiveness." Administrative Science Quarterly. 20:546-558

Steers, R.M. and Porter, L. W. (1975) Motivation and Work Behavior. New York: McGraw-Hill Book Co.

Stevens, W.F. and Tornatzky, L.G. (1979) "The Dissemination of Evaluation: An Experiment." Evaluation Review. 4(3):339-354

Stewart, F. (1977) Technology and Underdevelopment. Boulder, CO: Westview Press.

Strasser, S., Eveland, J.D., Cummins, G., Deniston, O.L., and Romani, J.H. (1981) "Conceptualizing the Goal and System Models of Organizational Effectiveness: Implications for Comparative Evaluation Research." Journal of Management Studies. 18(3):321-340

Tannenbaum, A.S. (1968) Control in Organizations. New York: McGraw Hill.

Tannenbaum, A.S. with Conte, M. (1978) "Employee Owned Companies: Is the Difference Measurable?" Monthly Labor Review. 101:23-28

Taylor, F.W. (1947) Scientific Management. New York: Harper Brothers.

Taylor J.C. (1975) "The Human Side of Work: The Sociotechnical Approach to Work System Design." Personnel Review. 4(3):17-22

Taylor, J.C. (1977a) "Experiments in Work System Design: Economic and Human Results." Personnel Review. 6:Issues 2,3

Taylor, J.C. (1977b) An Empirical Examination of the Dimensions of Quality of Working Life. Los Angeles, CA: Center for Quality of Working Life, UCLA.

Taylor, J.C. (1980) Sociotechnical Analysis Applied to a Computer Operations Organization. Los Angeles, CA: Center for Quality of Working Life, UCLA.

Taylor, J.C. and Bowers, D.G. (1972) The Survey of Organizations. Ann Arbor, MI: Institute for Social Research.

Taylor, J.C. *et al.* (1973) Quality of Working Life: An Annotated Bibliography, 1957-72. Los Angeles, CA: Center of Organizational Studies, Graduate School of Management, UCLA, No. 8012.

Terleckyj, N.E. (1977) The State of Science and Research: Some New Indicators. Boulder, CO: Westview Press.

Terreberry, S. (1968) "The Evolution of Organizational Environments." Administrative Science Quarterly. 12:590-613

Thompson, J.D. (1967) Organizations in Action. New York: McGraw Hill.

Tornatzky, L.G. and Johnson, E.C. (1982) "Research on Implementation: Implications for Evaluation Practice and Evaluation Policy." Evaluation and Program Planning. 5:193-198

Tornatzky L.G. and Klein, K.J. (1982) "Innovation Characteristics and Innovation Adoption-Implementation: A Meta-Analysis of Findings." IEEE Transactions on Engineering Management. EM-29:28-45

Tornatzky, L.G., Fergus, E.O., Avellar, J.W. and Fairweather, G.W. (1980) Innovation and Social Process. Elmsford, NY: Pergamon Press.

Tornatzky, L.G., Hetzner, W.A., Eveland, J.D., Schwarzkopf, A., and Colton, R. (1982) University-Industry Cooperative Research Centers: A Practice Manual. Washington, DC: National Science Foundation.

Tornatzky, L.G. and Lounsbury, J.W. (1979) "Dimensions of Interorganizational Interaction in Social Agencies." Journal of Community Psychology. 7:198-209

Tornatzky, L.G., Solomon, T. *et al*. (1982) Contributions of Social Science to Innovation and Productivity. American Psychologist. 37:737-746

Tosi, H.L., Aldag, R. and Storey, R. (1973) "On the Measurement of the Environment: An Assessment of the Lawrence and Lorsch Environmental Uncertainty Subscale." Administrative Science Quarterly. 18:27-36

Trist, E.L. (1981) "The Evolution of Sociotechnical Systems as a Conceptual Framework and as an Action Research Program." In Van de Ven, A.H. and Joyce W.F., Perspectives on Organization Design and Behavior. New York: Wiley-Interscience.

Trist, E.L. and Bamforth, K.W. (1951) "Some Social and Psychological Consequences of the Longwall Method of Coal-Getting." Human Relations. 4:3-38

Trist, E.L., Higgin, G.W., Murray, H., and Pollock, A.B. (1963) Organizational Choice. London: Tavistock Publishers.

Turk, H. (1970) "Interorganizational Networks in Urban Society: Initial Perspectives and Comparative Research." American Sociological Review. 35:1-19

Turk, H. (1977) Organizations in Modern Life. San Francisco, CA: Jossey-Bass.

Udell, G.G., Baker, K.G. and Albaum, G.S. (1976) "Creativity: Necessary, But Not Sufficient." Journal of Creative Behavior. 10(2):92-103

United Nations Industrial Development Organization. (1969) Small-Scale Industry in Latin America. New York: United Nations.

Utterback, J.M. (1971) "The Process of Innovation: A Study of the Origination and Development of Ideas for New Scientific Instruments." IEEE Transactions on Engineering Management. EM-18:124-131

Utterback, J.M. (1973) "The Process of Technological Innovation within the Firm." In L.A. Rowe and W.B. Boise, Organizational and Managerial Innovation: A Reader. Pasadena, CA: Goodyear Publishing Co.

Utterback, J.M. (1974) "Innovation in Industry and the Diffusion of Technology." Science. 183:620-626

Van de Ven, A.H., Delbecq, A. and Koenig, R. (1976) "Determinants of Coordination: Modes within Organizations." American Sociological Review. 41:322-328

Van de Ven, A.H., Emmett, D.C. and Koenig, R. (1974) "Frameworks for Interorganizational Analysis." Organization and Administrative Sciences. 5(1):113-129

Van de Ven, A.H. and Ferry, D.L. (1980) Measuring and Assessing Organizations. New York: John Wiley and Sons.

Van Maanen, J. (1982) Varieties of Qualitative Research. Beverly Hills, CA: Sage Publications.

Van Meter, D.S. and Van Horn, C.E. (1975) "The Policy Implementation Process: A Conceptual Framework." Administration and Society. 6:445-488

Van Rennes, A.B. (1982) "Effective Technology Transfer -- A National Need." Presented to the Conference on Industrial Science and Technological Innovation, Sturbridge, MS.

Visscher, M. (1976) Tax Policies for R&D and Technological Innovation. Chapter 2: "The Effect of Tax Incentives on Investment Behavior." Pittsburgh, PA: Final Report, Graduate School of Industrial Administration, Carnegie-Mellon University, Grant No. RDA-7421227, National Science Foundation.

von Furstenberg, G.M. and Malkiel, B.G. (1977) "The Government and Capital Formation: A Survey of Recent Issues." Journal of Economic Literature. 15:835-78

von Hippel, E. (1976) "The Dominant Role of Users in the Scientific Instrument Innovation Process." Research Policy. 5 (3):212-239

von Hippel, E. (1978) The Role of the Initial User in the Industrial Good Innovation Process. Cambridge, MA: Final Report, Sloan School of Management, Massachusetts Institute of Technology, Grant No. PRA-7420435, National Science Foundation.

von Hippel, E. (1979) "Appropriability of Innovation Benefit as a Predictor of the Functional Locus of Innovation." Cambridge, MA: Sloan School of Management, Working Paper.

Vonnegut, K. (1971) Player Piano. New York: Delacorte.

Walker, J.L. (1969) "The Diffusion of Innovations among American States." American Political Science Review. 63:880-889

Walker, J.L. (1974) "The Diffusion of Knowledge and Policy Change: Toward a Theory of Agenda-Setting." Paper Presented to the American Political Science Association, Chicago.

Wamsley, G.L. and Zald, M.N. (1973) "The Political Economy of Public Organizations." Public Administration Review. January/February: 62-73

Warner, K.E. (1974) "The Need for Some Innovative Concepts of Innovation." Policy Sciences. 5:433-451

Warren, R.L. (1967) "The Interorganizational Field as a Focus for Investigation." Administrative Science Quarterly. 12:396-419

Weber, M. (1947) The Theory of Social and Economic Organization. T. Parsons (Ed.). New York: Free Press.

Weick, K.E. (1976) "Educational Organizations as Loosely Coupled Systems." Administrative Science Quarterly. 21:1-19

Weick, K.E. (1979) The Social Psychology of Organizing. Second Edition. Reading, MA: Addison Wesley, Inc.

Weiss, C.H. (1977 ) "Research for Policy's Sake: The Enlightenment Function of Social Research." Policy Analysis. 3(4):531-546

Weiss, C.H. (1972) Evaluation Research: Methods for Assessing Program Effectiveness. Englewood Cliffs, NJ: Prentice-Hall.

Weiss, C.H. (ed). (1977) Using Social Research in Public Policy Making. Lexington, MA: Lexington Books.

Weiss. C.H. and Bucuvalas, M.J. (1977) "The Challenge of Social Research to Decision Making." In C.H. Weiss (Ed)., Using Social Research in Public Policy Making. Lexington, MA: Lexington Books. 213-234

Weiss, I.R. (1978) Report of the 1977 Survey of Science, Mathematics, and Social Studies Education. Washington, DC: Government Printing Office.

Weiss, R.S. and Rein, M. (1970) "The Evaluation of Broad-Aim Programs: Experimental Design, Its Difficulties, and an Alternative." Administrative Science Quarterly. 15:97-109

Welch, W.W. (1979) "Twenty Years of Science Curriculum Development: A Look Back." In D. Berliner (Ed.), Review of Research on Education, Vol.2. Washington, DC: American Educational Research Association.

Whetten, D.A. (1978) "Coping with Incompatible Expectations: An Integrated View of Role Conflict." Administrative Science Quarterly. 23:254-271

Whetten, D.A. (1980) "Organizational Decline: Sources, Responses, and Effects." In Kimberly J. and Miles, R., (Eds.), The Organizational Life Cycle. San Francisco, CA: Jossey Bass, Inc.

Whitcomb, D.K. (1972) Externalities and Welfare. New York: Columbia University Press.

White, M. (1975) Management Science in Federal Agencies: The Adoption and Diffusion of a Socio-Technical Innovation. Lexington, MA: Lexington Books.

White, R. and Lippitt, R. (1953) "Leader Behavior and Member Reaction in Three 'Social Climates'." In D. Cartwright and A. Zander (Eds.), Group Dynamics: Research and Theory. Evanston, IL: Row, Peterson.

Wilcox, C.W. (1971) Public Policies toward Business. (4th ed.). Homewood, IL: Richard D. Irwin, Inc.

Wildavsky, A. (1964) The Politics of the Budgetary Process. Boston, MA: Little, Brown.

Wilemon, D. (1979) The Role of Industry in Urban Technology Transfer. Syracuse, NY: Syracuse Research Corp., Report to the National Science Foundation.

Williams, W. (1975 ) "Implementation Analysis and Assessment." Policy Analysis. 1(3): 531-566

Williams, W. (1980) The Implementation Perspective. Berkeley, CA: University of California Press.

Williams, W. and Elmore, R.F. (Eds.). (1976) Social Program Implementation. New York: Academic Press.

Williamson, O.E. (1975) Markets and Hierarchies: Analysis and Antitrust Implications. New York: Free Press.

Williamson, O.E. (1981) "The Economics of Organization: The Transaction Cost Approach." American Journal of Sociology. 87:548-579

Witte, E. (1972) "Field Research on Complex Decision Making Processes: The Phase Theorem." International Studies of Management and Organization. 2(2):156-182

Wolfman, B. (1965) "Federal Tax Policy and the Support of Science." University of Pennsylvania Law Review. 114 (December):171-186

Woodward, J. (1965) Industrial Organization: Theory and Practice. London: Oxford University Press.

Wuthnow, R. (1981) Technical Systems Study, Progress Report. Princeton, NJ: Princeton University, Department of Sociology, Report to the National Science Foundation, Grant No. ISI-81-14896.

Wysocki, R.K. (1979) "OR/MS Implementation Research: A Bibliography." Interfaces. 9(2):

Yates, D. (1978) "Decentralization: Innovation and Implementation in New York City." In R.R. Nelson and D. Yates (Eds.), Innovation and Implementation in Public Organizations. Lexington, MA: Lexington Books.

Yin, R.K. (1977) "Production Efficiency versus Bureaucratic Self-Interest: Two Innovative Processes?" Policy Sciences. 8:381-399

Yin, R.K. (1979) Changing Urban Bureaucracies. Lexington, MA: Lexington Books.

Yin, R.K. (1980a) "Studying the Implementation of Public Programs." Golden, CO: Solar Energy Research Institute: TR-352-577.

Yin, R.K. (1980b) "Science and Technology in State and Local Governments: The Federal Role." In National Science Foundation, The Five Year Outlook: Problems, Opportunities and Constraints in Science and Technology. Volume II. Washington, DC: Government Printing Office. 649-661

Yin, R.K. (1981) "The Case Study Crisis: Some Answers." Administrative Science Quarterly. 26:58-65

Yin, R.K., Heald, K.A. and Vogel, M.E. (1977) Tinkering with the System. Lexington, MA: Lexington Books.

Young, H.C. (1973) Some Effects of the Product Development Setting, Information Exchange, and Marketing-R&D Coupling on Product Development. Evanston, IL: Doctoral Dissertation, Northwestern University.

Yuchtman, E. and Seashore, S. (1967) "A System Resource Approach to Organizational Effectiveness." American Sociological Review. 32:891-903

Zaltman, G., Duncan, R., and Holbek, J. (1973) Innovations and Organizations. New York: John Wiley and Sons.

Zeitz, G. (1974) "Interorganizational Relationships and Social Structure: A Critique of Some Aspects of the Literature." Organization and Administrative Sciences. 5:131-139

Zeitz, G. (1980) "Interorganizational Dialectics." Administrative Science Quarterly. 25:72-88