

ORGANIZATIONAL Linkages

UNDERSTANDING THE PRODUCTIVITY PARADOX

Douglas H. Harris, Editor

Panel on Organizational Linkages
Committee on Human Factors
Commission on Behavioral and Social Sciences and Education
National Research Council

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PANEL ON ORGANIZATIONAL LINKAGES

- DOUGLAS H. HARRIS (*Chair*), Anacapa Sciences, Inc.,
Charlottesville, Va.
- PAUL A. ATTEWELL, Department of Sociology, City University of
New York
- JOHN P. CAMPBELL, Department of Psychology, University of
Minnesota
- JEROME I. ELKIND, Lexia Institute, Palo Alto, Calif.
- PAUL S. GOODMAN, Center for Management of Technology,
Carnegie Mellon University
- SARA B. KIESLER, Department of Social and Decision Sciences,
Carnegie Mellon University
- ROBERT D. PRITCHARD, Department of Psychology, Texas A&M
University
- WILLIAM A. RUCH, Department of Decision and Information Sys-
tems, Arizona State University
- BENJAMIN SCHNEIDER, Department of Psychology, University of
Maryland
- D. SCOTT SINK, Virginia Productivity Center, Virginia Polytechnic
Institute and State University
- GEORGE L. SMITH, JR., Department of Industrial and Systems
Engineering, Ohio State University
- DAVID A. WHETTEN, Department of Business Administration,
University of Illinois

COMMITTEE ON HUMAN FACTORS

RAYMOND S. NICKERSON (*Chair*), Bolt, Beranek, and Newman
Laboratories (retired)

PAUL A. ATTEWELL, Department of Sociology, City University of
New York

PAUL S. GOODMAN, Center for Management of Technology,
Carnegie Mellon University

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University

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ania State University

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LAURENCE R. YOUNG, Man Vehicle Laboratory, Massachusetts
Institute of Technology

ALEXANDRA K. WIGDOR, *Director*, Division on Education, Labor,
and Human Performance

BEVERLY M. HUEY, *Senior Staff Officer*

EVELYN E. SIMEON, *Senior Project Assistant*

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Foreword

The Committee on Human Factors was established in October 1980 by the Commission on Behavioral and Social Sciences and Education of the National Research Council. The committee is sponsored by the Air Force Office of Scientific Research, the Army Research Institute for the Behavioral and Social Sciences, the National Aeronautics and Space Administration, the Air Force Armstrong Aerospace Medical Research Laboratory, the Army Advanced Systems Research Office, the Army Human Engineering Laboratory, the Army Natick RD&E Center, the Federal Aviation Administration, the Nuclear Regulatory Commission, the Naval Training Systems Center, and the U.S. Coast Guard. The principal objectives of the committee are to provide new perspectives on theoretical and methodological issues, to identify basic research needed to expand and strengthen the scientific basis of human factors, and to attract scientists inside and outside the field for interactive communication and performance of needed research.

Human factors issues arise in every domain in which humans interact with the products of a technological society. To perform its role effectively, the committee draws on experts from a wide range of scientific and engineering disciplines. Members of the committee include specialists in such fields as psychology, engineering, biomechanics, physiology, medicine, cognitive sciences, machine intelligence, computer sciences, sociology, education, and human factors engineering. Other disciplines are represented in the working groups, workshops, and symposia organized by the committee. Each of these disciplines contributes to the basic data, theory, and methods required to improve the scientific basis of human factors.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Robert M. White is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. Robert M. White are chairman and vice chairman, respectively, of the National Research Council.

Preface

Since its inception in 1980, the Committee on Human Factors of the National Research Council has issued more than a dozen reports regarding the state of knowledge and research needs on topics deemed important by the committee and its sponsors. Some projects undertaken by the committee have been suggested and funded directly by its sponsors: others have been pursued on the committee's initiative. This report is the product of a committee-initiated project.

The initial prospectus for a study on productivity was prepared in 1986 by committee members Jerome I. Elkind, Douglas H. Harris, Thomas K. Landauer, Thomas B. Sheridan, and Stanley Deutsch, the committee study director at that time. The ultimate focus of the study, organizational linkages, resulted from a working paper and study plan I prepared in 1988 and a planning meeting conducted in February 1989. Meeting participants were Jerome I. Elkind, Miriam M. Graddick, Oscar Grusky, Joel Kramer, Grant E. Secrist, George L. Smith, Jr., Barry Staw, and myself (chair). Committee staff attending were Harold P. Van Cott and Beverly M. Huey.

By November 1989, the study plan and study panel had been approved by the National Research Council, and the initial steps in the study had been undertaken. Over the next three years the panel addressed organizational linkage issues during three working meetings, through the development and discussion of numerous concept papers, and finally through the preparation, critique, and revision of the chapters of this report. The principal work of the final meeting, held in

February 1992, resulted in the conclusions of the panel that are presented in Chapter 12. Paul S. Goodman and D. Scott Sink contributed extensively to the preparation of Chapters 1 and 12.

Jean Shirhall, through skillful editing of the entire manuscript, contributed substantially to its readability. The presentation of the volume owes much to her suggestions for consistency and clarity.

Appreciation is extended to Harold P. Van Cott, committee study director, for his participation in the working sessions of the panel; Beverly M. Huey, panel study director, for her coordination of working-session and publication logistics; and Evelyn E. Simeon and Maria M. Kneas for their administrative and secretarial support.

Douglas H. Harris, *Chair*
Panel on Organizational Linkages

1

Introduction

Why do the hundreds of billions of dollars spent annually in the United States on technology to improve the productivity of individuals and groups appear to have so little impact on the productivity of the organizations in this country? Why are increases in individual productivity not reflected in measures of organizational productivity? These and related questions frame the productivity paradox addressed by this report. The position of the Panel on Organizational Linkages, a study panel convened by the National Research Council, is that the answers are to be found in a better understanding of the linkages among individual, group, and organizational productivity.

THE PRODUCTIVITY PARADOX

The ability of nations, and organizations within nations, to enhance the standard of living of the world's growing population depends on continued increases in the productivity of the systems that provide goods and services. In an increasingly competitive global economy, productivity growth is also essential for maintaining or advancing economic opportunities for individuals and societies. Moreover, it is apparent as never before that the peoples and institutions of the world are highly interconnected and that, as a consequence, each nation has a vested interest in the productivity of other nations. A nation might be able to gain short-term advantage over a marginally productive competitor, but over the long term all nations lose from slow productivity growth

regardless of where it occurs. Thus, a productive nation is desirable for the contributions it makes not only to the quality of life of its people but, ultimately, to the quality of life of those in other nations as well. Some management theorists have identified productivity growth, particularly in knowledge and service workers, to be the greatest challenge now facing the developed countries of the world. They predict that it will determine the fabric of society and the quality of life in every industrialized nation and that without productivity growth the world will face increasing social tensions, polarization, and radicalization (e.g., Drucker, 1991).

Trends of Productivity Growth in the United States

The United States has experienced more than 25 years of declining productivity growth. Between 1965 and 1985, for example, the U.S. position in the international automobile, steel, shipbuilding, and textile industries deteriorated significantly. More recently, the U.S. position in electronics, computers, robotics, and biotechnology has slipped (Johnson and Packer, 1987; Wohlers and Weinert, 1988). The U.S. labor force does not appear to be making the contribution it once did to the productivity of the world economy.

In a more recent analysis of U.S. productivity growth, the Urban Institute (Sawhill and Condon, 1992) reported that between 1973 and 1990 the hourly output of an American worker grew only 0.7 percent a year. In contrast, the annual rate of growth between 1948 and 1973 was 2.5 percent. According to this analysis, if worker productivity—the basic determinant of wages—had continued to grow at the same rate after 1973 as it did before, the typical family's income in the United States in 1990 would have been \$47,600 instead of \$35,300.

The Paradox

What is the problem? Has the United States not been investing in productivity growth? There are indeed areas (e.g., infrastructure and education) in which inadequate investment may be inhibiting U.S. productivity. On the other hand, the United States has actually been investing heavily in advanced technologies to enhance productivity growth. The returns, however, do not appear commensurate with the investments. For example, one analysis showed that the data processing budgets for U.S. corporations increased by about 12 percent a year over the previous decade. Productivity increases from those investments, however, averaged less than 2 percent a year (Weiner and Brown, 1989).

In Chapter 2, Attewell reviews a number of investigations of the

impact of investments in information technology (IT) on organizational productivity. Such investments are of particular interest because, for many years, they have accounted for a very large proportion of the U.S. industrial investment. As discussed in Chapter 2, however, the huge annual private sector investments in computers and related technologies (an estimated \$154 billion in 1990) have had no apparent effect on measures of organizational productivity. Although specific applications of IT have made positive contributions to productivity, the overall investment does not seem to have improved industrial productivity in the United States.¹ This and similar evidence presents a paradox: Why have the enormous investments in IT not resulted in clear-cut increases in organizational productivity? It is clear from the analyses reviewed in Chapter 2 that enhancing productivity is a major national challenge and that this productivity paradox must be understood. As a nation, we need to understand better the factors that influence the productivity of our organizations and the methods for addressing the facilitators and inhibitors of organizational productivity.

ORGANIZATIONAL LINKAGES

Focus and Assumptions of Previous Research

The question that has been addressed by most research into the productivity of work units can be framed as follows: How can the productivity of *X* be increased? *X* might be an individual, group, or larger organization. To this end, research has examined a variety of interventions and their impact on the productivity of *X*. They include the design and implementation of new technology; the application of techniques for the selection, training, and motivation of personnel; the design and redesign of jobs and tasks; innovations in organizational development and management methods; and the introduction of new compensation and incentive systems. Traditionally, researchers have focused on a single level of analysis—improving performance at the individual, group, or organizational level. Interventions are made and, in some cases, measurements are made to determine the impact of the interventions, invariably at the same level at which the intervention was made. The linkage between an intervention at one level and the impact on productivity at another level has largely been ignored.

In attempting to increase productivity, human factors specialists,

¹See also *Information Technology in the Service Society: A Twenty-First Century Lever* (Committee to Study Computer Technology and Service Sector Productivity, 1994) for a more in-depth investigation of this particular issue.

industrial engineers, industrial and organizational psychologists, and others, have largely followed the pattern of focusing on a single level of analysis. The principal level has been that of the individual, but groups and higher organizational units are being given increasing attention. Human factors specialists, for example, have attempted to enhance individual and group performance by matching improvements in technology with the capabilities and limitations of operators. The emphasis of this approach has been on increasing productivity by improving the design of the task and job. The goal has been to fit the task to the requirements of operators and, in doing so, to maximize the speed and accuracy of performance and to minimize other measures, such as learning time, work load, and accidents (Sanders and McCormick, 1987). Industrial engineers, on the other hand, have focused on the work system, often in alliance with human factors specialists and industrial and organizational psychologists. They have attempted to integrate people, technology, and methods to improve the performance of systems, with emphasis on quality and productivity. They have assessed the results of their efforts through such measures as efficiency, timeliness, and defect rates (Sink and Tuttle, 1989).

Industrial and organizational psychologists have attempted to enhance productivity principally by improving the capabilities of the individuals performing the work or through interventions in groups or organizations. Their approaches have included matching individuals to jobs and tasks, training individuals in job skills and knowledge, changing the structure of groups, and motivating individuals and groups toward job objectives. The effects of these efforts have been measured mainly in terms of the facility with which tasks are learned, self-reports of job satisfaction, ratings by others of job performance, indicators of group output, and other behavioral indices (e.g., absenteeism and turnover) presumed to be related to organizational effectiveness (Campbell, Campbell and Associates, 1988). A principal assumption underlying these efforts has been that increases in individual or group productivity will ultimately contribute to increases in the productivity of the enterprise. However, as discussed in Chapter 2, there appear to be factors or processes that inhibit the extent to which changes in individual productivity are reflected in changes in the productivity of aggregates of individuals—groups and organizations.

The Question Addressed in This Report

The question addressed in this report is, given an increase in the productivity of X, under what conditions will there also be an increase in the productivity of Y? Y might be a work unit of one or more people at the same or different level of analysis—the group or the organiza-

tion. Hence, this is a study of organizational linkages. In this report, a *linkage* is a change (or hypothesized change) in the performance of one work unit as the result of a change in the performance of another. Say, for example, that the introduction of new computer-based workstations results in an increase of productivity averaging 10 percent across the individuals in a work group. The question of interest here then becomes, under what conditions will the productivity gain of the work group as a whole be the same, less, or greater than 10 percent?

This question is addressed from the views of many different disciplines—psychology, engineering, information technology, and others. As a consequence, the report does not speak with a single voice in answering the question, nor does it examine from a single perspective the various influences that inhibit or facilitate productivity linkages in organizations. It is, rather, constructed as a series of essays. At the present state of understanding, this diversity seemed both necessary and useful. The final chapter summarizes the common themes and findings of the report and presents the conclusions that emerged from the panel's analyses and deliberations.

No claim is made that every possible problem involving organizational linkages has been addressed. There are certainly problems specific to work domains, organizational levels, and so on not examined by the panel. However, the panel believes that the interdisciplinary approach resulted in the identification and examination of the key issues in organizational linkages. Moreover, the panel believes that the findings and conclusions relative to these issues can be generalized to linkage problems that are not specifically addressed in this report.

Linkages and Influences

The unique perspective of this report on productivity is that it addresses the productivity linkages among different levels of analysis—individuals, groups, and organizations—and the factors (processes and mechanisms) that influence those linkages. The goal is to explicate the conditions under which linkages can be positively influenced. How can an organization promote the facilitators and diminish the inhibitors? Once that is understood, the organization can create the circumstances under which new technology can be introduced and the productivity of the organization increased as the expected gains in individual productivity are realized. The important influences on linkages are likely to be found in the nature of the relationships that exist between work units, differences in the states and structures of different work units, and differences in the processes that operate on the organizational linkages.

In Chapter 3, Goodman, Lerch, and Mukhopadhyay examine linkages, processes, and influences. Their goal is to develop a set of conceptual tools that will aid the analysis of linkages and promote the understanding of processes that influence linkages. To that end, they introduce and examine five processes that facilitate changes in individual and organizational productivity: (1) coordination, (2) problem solving, (3) focus of attention, (4) organizational evolution, and (5) motivation. In addition, they present a set of important concepts and definitions, an analytic strategy that addresses linkage inhibitors and facilitators, and a set of hypotheses about organizational linkages.

Linkages and influences are addressed to some extent in each chapter, which provides different perspectives on the issues identified. Some chapters focus on understanding the inhibitors and facilitators of linkages; others are more concerned with addressing the measurement issues raised by linkage concepts. Across all chapters there is a mix of theoretical considerations, interpretation of research findings, and exploration of linkage issues and processes in specific work domains. In addition, because the panel believes that understanding organizational linkages will require additional research, each of the chapters makes recommendations for research that derive from the discussion in that chapter.

Multiple Levels of Reciprocal Linkages

The concept of organizational linkages provides a useful framework within which to examine the productivity paradox. It has led the panel to conclude that one contributor to the productivity paradox is the common attempt to initiate change through the introduction of a single intervention (technology) at a single level in the organization (the individual). In Chapter 4, Schneider and Klein state this conclusion explicitly:

Changing a single aspect of an organization almost never results in a substantial change in organizational performance. Organizations are too complex, their performance too multidetermined, and their inertia is great for a single innovation at the individual level to have a substantial impact on organizational performance.

Schneider and Klein address organizational linkages in the domain of office automation—the application of information and communication technology to tracking, monitoring, recording, directing, and supporting information in the workplace. The launching point for their analysis is the report of the study ordered by the U.S. Congress to de-

termine why office automation has not yielded the improvements predicted (Office of Technology Assessment, 1985).

There are several reasons why innovations such as office automation can fail to yield improvements in organizational productivity. The introduction of new systems may not contribute to productivity at any level because the systems are not successfully implemented. Even if a system is successfully implemented and used as intended, it may do little to enhance, and in fact may impair, individual productivity. Finally, even if the system does in fact augment individual productivity there may be no resulting improvements in organizational productivity. This leads to the requirement for an organizational systems framework to clarify the multiple reciprocal linkages that determine organizational productivity.

An understanding of important processes that affect productivity, within the complexity of organizational linkages, can also be gained from decomposing the productivity paradox—identifying and examining the factors that produce the paradox. This is the approach taken by Pritchard in Chapter 7. He identifies three main types of factors that might account for the paradox: structural characteristics of the organization itself, intervention side effects (unintended consequences of the intervention), and problems associated with the measurement of organizational performance.

A number of structural factors associated with multiple levels of reciprocal linkages are identified and addressed in Chapter 7 and in other chapters of this report. An example is time lag. Because of the way the task is structured, improvements at one level can sometimes take considerable time to show up as improvements in the combined outputs at a higher level. Other examples of structural factors include slack in the process, the degree of centrality of the task to the process, and the degree of interdependence of work units.

An example of an intervention side effect is changing the focus of the effort, inappropriately, from one unit of analysis to another—the introduction of computers might result in low task interdependence when high task interdependence is required. Individual productivity might increase as a consequence, but the output of the group as a whole might decrease. Other side effects might be descriptions in communication patterns and the socialization process, or the generation of resistance to change as a consequence of the way in which the intervention is introduced.

Measurement Issues

Measurement issues have been a principal concern of the study panel. The productivity paradox could, of course, be explained by the inad-

equacy of the measures and processes used to assess organizational productivity. Moreover, the study of productivity linkages among multiple levels of analysis would surely require measurement methods of considerable complexity and sophistication to provide the required validity and sensitivity. Thus, this volume addresses measurement from two important perspectives—as an explanation of the productivity paradox and as a critical tool in the understanding of organizational linkages.

Defining Productivity

The panel deliberated at length about the appropriate concept and definition of productivity within which to address measurement issues, but without satisfactorily resolving the issue. Perhaps the panel is not alone in being unable to arrive at a consensus. In a review of the literature on productivity, Pritchard (1991) found that the term *productivity* was used to encompass constructs as diverse as efficiency, output, motivation, individual performance, organizational effectiveness, production profitability, cost-effectiveness, competitiveness, and work quality. Further, productivity measurement was used interchangeably with performance appraisal, production capability assessment, quality control measurement, and the engineering throughput of a system.

Most panel members held one or the other of two positions regarding the concept of productivity. Some wanted to define productivity as the ratio of outputs to inputs, in line with the original definition of the term by labor economists. They believe that this is the only definition that is unique to the concept. Others argued that this definition is too restrictive. They believe that productivity must encompass concepts such as quality and effectiveness to be meaningful. The panel's solution was to adopt the systems model of organizational performance (described by Sink and Smith in Chapter 6). In this model, productivity is but one of seven interrelated and interdependent criteria of organizational performance. The seven criteria, each of which is operationally defined in Chapter 6, are productivity, effectiveness, efficiency, profitability, quality, quality of work life, and innovation.

Within this model, productivity provides just one part of the total performance picture. The total picture requires the examination of all seven criteria, each of which might necessitate several different measures. The approach advocated in Chapter 6 is to consider the seven criteria as variables that explain variation in performance. Variables can be included and excluded from the analysis to determine which ones explain variation in performance for a particular work unit relative to a specified objective. In Chapter 6, Sink and Smith address

measurement issues and the design of measurement systems within the framework of this model. They conclude that the paradox of unrealized productivity improvements results from incomplete systems thinking and from failure to understand the nature of linkages among the individual, group, and organizational levels.

Measuring Individual Productivity

The characteristics of measures of individual productivity determine the extent to which the measures can be aggregated or related to higher levels of analysis. These characteristics—the definition and scope of individual productivity, the measurement systems employed, and the specific measurement metrics—are the focus of Chapter 5. In that chapter, Ruch introduces a variety of concepts, such as goal alignment, that put these measurement issues in perspective. Goal alignment is the ideal in any system that is assumed to be driven by goal-based measures. In such a system, individual productivity depends on the extent to which individual measures are in line with organizational goals and the extent to which those goals form a logical hierarchy across organizational levels. He also presents two models that provide alternative views of factors affecting individual productivity. The models encompass such variables as individual characteristics, psychological factors, sociological factors, technology, and the characteristics of systems and organizations. He then extends his analysis to examine four key measurement issues to be considered when individuals become groups—complexity, input factors, aggregation, and goal alignment.

Measurement and Its Implications for Research

In Chapter 8, Campbell addresses models of measurement and their implications for research on the linkages between individual and organizational performance. His central argument is that effective measurement depends on the substantive specification of productivity in the specific domain of interest, such as a specific aspect of IT. In support of this approach, he provides a hierarchical measurement model for research application that is consistent with the models provided in Chapters 5 and 6.

Domain-Specific Examinations of Linkages

The chapter authors provide many examples in an attempt to clarify the concepts and ideas they introduce. To reduce further the level of abstraction in this report, some chapters examine linkage issues within

a specific domain. The objective is to determine how linkages, and the processes that influence them, actually work within operational organizations. The panel considers this exercise to be a reality check on the formulations that emerged from its individual study and group deliberations.

Coordination in Software Engineering

Software engineering is the domain of Kiesler, Wholey, and Carley's examination in Chapter 9 of the role of coordination in the linkage between individual and group productivity. The technical project team approach employed in software engineering is actually a paradigm for how various types of technical work are now accomplished. Organizations create a project team when the required technical tasks transcend the assigned functions or capabilities of individuals. A project team can range in size from two to several hundred members, and the membership of larger teams is relatively diverse. The interdependence of tasks and jobs make coordination—those activities required to support group work—a critical factor in team productivity.

In Chapter 9, Kiesler, Wholey, and Carley discuss what is known about coordination in groups and apply that knowledge to the problem of coordination in software development teams. They show that the traditional model of coordination, with its emphasis on sharing ideas through direct communication, is not applicable because of the complexity, uncertainty, and interdependence that characterize software engineering. They emphasize team design and team communications as positive approaches to enhancing the linkages between individual and group productivity, and they provide a set of hypotheses relative to each approach. In addition, they present a set of stimulating research problems and directions, the pursuit of which will enhance understanding of linkages.

Productivity Linkages in Computer-Aided Design

Computer-aided design (CAD) has been introduced into engineering organizations with the expectation of increasing the productivity of the organization by increasing the productivity of individual designers. The principal output of a design effort is a set of design specifications that meet agreed design objectives, guidelines, and constraints. Thus, the core definition of productivity within this domain is the ratio of design-specification output to the input of resources, mainly labor. Productivity gains are anticipated from the capabilities of CAD to automate routine functions, enhance the accuracy and efficiency of design tasks, promote the exchange of information, facilitate the performance

of sophisticated design tasks, and integrate better the design and production processes.

In Chapter 10, Harris examines productivity linkages and influences within the CAD domain. Many of the issues discussed in earlier chapters are relevant to this type of information work. They are examined in Chapter 10 as they relate to linkages among designers, design teams, and engineering design organizations. The central question Harris addresses is, when CAD technology increases the productivity of individual designers, under what conditions will those increases lead to increases in the productivity of the design team and, in turn, the design organization? Among the influences he discusses are the degree of physical isolation of designers, the extent of task specialization in the design team, the mode of team supervision, the nature of controls on the flow and access of information, the burden of design support and coordination, the manner in which technology is implemented, resource management, and system quality and reliability. Each of these influences is examined relative to its impact on organizational linkages.

The Case of Downsizing

Organizational downsizing has been one of the major initiatives undertaken by firms in the United States during the past decade to increase productivity. Downsizing encompasses shrinking, retrenching, or consolidating the organization, principally by reducing the number of employees and hierarchical levels. However, according to the evidence in Chapter 11, the anticipated effects have not been realized. The mounting evidence that downsizing initiatives do not yield commensurate gains in productivity is another form of the productivity paradox. It is a particularly troublesome version of the paradox because removing sizable amounts of overhead slack from an organization would be expected to lead directly to increased organizational productivity. Using the perspective of organizational linkages, Whetten and Cameron examine this productivity paradox within the domain of manufacturing organizations. They report the results of their analyses in the form of a set of myths regarding the best way to design and implement a downsizing program. The prevalence of these myths was verified by a survey of 909 businesses in the United States. The extent to which downsizing programs have been based on these myths helps explain the productivity paradox associated with downsizing. Whetten and Cameron further examine organizational linkages by comparing two approaches to downsizing and their impact on organizational productivity.

In Chapter 12, the panel summarizes the principal themes and common issues that run through the various chapters. These themes and

issues encompass the productivity paradox and organizational linkages. In this chapter the panel also presents the broader conclusions it reached. As noted, the more specific conclusions and recommendations for research are provided at the end of each chapter.

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Coordination as Linkage: The Case of Software Development Teams

Sara Kiesler, Douglas Wholey, and Kathleen M. Carley

This chapter examines coordination in software development teams as a practical context for talking about the linkages between individual and group productivity. We do not discuss individual-organizational nor group-organizational linkages, although many of the points we make pertain to those linkages as well.

Software development is a kind of technical work found in many organizations: the technical team project. Certain technical tasks transcend the ongoing functions of departments or the capabilities of individuals, and thus organizations create a project group or team to do the work. A software development project group can have two to several hundred members. Membership is typically diverse; the work may require the participation of programmers, software engineers, applications experts, researchers, requirements analysts, software testers, documentation writers, project managers, customer support personnel, and perhaps others. Project members may be drawn from different locations and different departments and may even work on the project in different places. The projects have predictable stages but also experience unpredictable changes in the organizational and technical environment—changes in personnel, modifications in available software and hardware technology, changing client expectations, and new economic constraints (Brooks, 1987).

In software development, productivity depends on teamwork. *Teamwork* refers to work done as a team and to the attitudes, skills, and behaviors that subordinate personal prominence to the efficiency of the

whole. Teamwork is crucial because every job and every stage is interdependent. High levels of individual productivity do not ensure success. Productivity depends on leveraging competencies through teamwork (Clark et al., 1987).

Coordination is the overt, behavioral instantiation (representation) of teamwork. That is, coordination is what people, technology, or organizations actually do to integrate team members and their work to form a group product. Measures of coordination include observations that different people and subunits working on a project agree to a common definition of what they are building, share information, hand off components of the work expeditiously, take responsibility for one another's performance, and mesh their activities. Coordination should be distinguished from exogenous forces—prices, monopoly position of the group, resources made available to the group, management priorities, and so forth—that affect group productivity directly rather than through linkages.

THE DOMAIN OF SOFTWARE DEVELOPMENT

Software development is a theoretically interesting context for examining linkages and it also has practical importance. The United States has more than 7,000 software firms; many other firms participate in the development of software systems (National Science Board, 1989). Business, education, government, and technical endeavors ranging from automated manufacturing to financial transactions to national defense require complex software systems. Most experts agree that the demand for software outstrips the ability of firms to produce it. Software systems are notoriously difficult to produce. Problems often force delays in the implementation of new applications, compromises in what those applications can do, and uncertainties about their reliability (National Research Council, 1990).

Coordination in Software Development

Simplified models of the software life cycle break its development into distinct phases. One such breakdown is that suggested by Davis (1987): (1) problem definition, (2) feasibility, (3) analysis, (4) system design, (5) detailed design, and (6) implementation and maintenance. A variety of tasks, each with its requisite skills, must be done during these different phases: analysis, design, coding, documentation, and testing. *Analysis* involves evaluating and translating organizational or individual needs into system capabilities. *Design* involves developing a set of distinct logical units, each of which can be developed and

tested separately; choosing software and hardware; structuring a data base so as to minimize redundancy and improve ease of access; and so on. *Coding* means translating the design specifications into executable instructions that run reliably and efficiently on particular hardware. *Documentation* involves coordinating and maintaining consistency of the human-computer interface, writing manuals and specifications, and preparing the internal code description, as well as recording the rationale behind design and coding decisions. These tasks are highly interactive in that changes in requirements often require changes in design, code, and documentation. Design decisions often feed back to change or limit the capabilities that the system can offer. Changes in the hardware and software, or changes in a company's financial status, may force the team to return to the design phase. This process is iterative in that software systems must be enhanced and changed as the environments in which they exist change and as people put them to new uses.

Achieving a successful software system requires coordination among the various phases and tasks involved in the software development cycle and minimal backtracking. If the software system is small, and members are physically proximate and respect one another, effective coordination can occur because the group can work out problems together and keep all the implementation details in focus. This focus on sharing ideas through direct communication is what traditionally has been meant by teamwork; it is the main emphasis of cooperative team learning in high school and college classrooms (e.g., Bossert, 1988-1989). In many cases of modern technical work, however, this simple model of coordination is impossible. Kraut and Streeter (1990) discuss three reasons why this is so—project complexity, uncertainty, and interdependence.

Complexity

A fundamental characteristic of many software tasks is that they are too big for any one or two skilled programmers to undertake alone. Moreover, a single complex skill like programming is not the only skill required in the software development process. Software development also requires analysis to determine what the software should do; evaluation of alternative platforms; design to shape the basic structure of the programs and their communication with other programs, data bases, and users; tests to ensure that code meets requirements and that users understand the interface; creation of special tools for implementation; hardware and software maintenance procedures; written documentation; and an administrative infrastructure to set priorities on requests for features and to handle feedback from users.

Uncertainty

Complexity per se does not invariably lead to difficulties in coordination. As Kraut and Streeter (1990) note, automotive factories, textile mills, and tuna canneries employ hundreds of people to produce their products, yet many run smoothly. Software development is different in that it is more uncertain. Manufacturing involves routines, doing the same thing repeatedly. But the software development process is nonroutine activity, and specifications for it invariably are incomplete. Incompleteness partly results from limited knowledge of the software development domain (Curtis et al., 1988). At many points the information that designers or programmers need to make decisions is not available to them, although others in the project may have the knowledge needed for those decisions.

Software development is also uncertain because specification of what a software system should do changes over time (Brooks, 1987; Curtis et al., 1988; Fox, 1982). Competition, regulations, standards, company politics, plans, and financial conditions can lead to changes in specifications. Also, it is often only by using software that purchasers understand its capabilities and limitations. As they use the software, they often demand new capabilities that they were not able to envision at the software's creation.

Uncertainty in software development may be reflected in disputes among different groups involved in its development (Curtis et al., 1988; Kraut and Streeter, 1990). People associated with different parts of a project can have different beliefs about what the software should do. For example, analysts translate users' needs into requirements for system capabilities. As a result, they often adopt the point of view of the software's purchasers. On the other hand, designers and programmers may have more of an insider's focus and emphasize ease of development and efficiency of operation. These differences in points of view must be resolved for the team to succeed.

Interdependence

Complexity and uncertainty in software work would be less of a problem if software did not require integration of its components to such a large extent. Software consists of hundreds or thousands of modules or components that must mesh with each other perfectly for the software system as a whole to operate correctly. One mistake in part of a system can have disastrous, unanticipated consequences (Travis, 1990). This required integration, combined with complexity and uncertainty, requires in turn special coordination techniques that may not be neces-

sary in more standardized manufacturing and in developing projects that are merely complex and uncertain (Ouchi, 1980).

Research on Individual-Group Linkages

Much of the existing research on software development and other technical teamwork does not deal with linkages. There has been considerable work on individuals' cognitive problems resulting from creating, understanding, and debugging programs, designs, and other aspects of systems, and on the individual-computer interface. (See Curtis, 1985, for a sample of this kind of research.) This approach ignores the linkage issues inherent in software development. Results from studies of individuals' problems in engineering and interaction with computers do not generalize simply to team problems (Scott and Simmons, 1975). Other research does address linkages, but typically indirectly. A great deal of work has gone into software and procedures that should promote coordination, such as code reuse, computer-aided software engineering (CASE) tools, object-oriented languages, and automatic code generation (Chase, 1987; Sims, 1989; Verastegui and Williams, 1988). However, the effects these developments have on linkages are rarely evaluated. Also, there are descriptive studies of labor costs and delays in software development. Generally, these studies use sophisticated simulation or models but not measures of coordination other than costs (Abdel-Hamid and Madnick, 1989; Beatty, 1986). Hence, much of the research on software development does not help one understand individual-group linkages in this domain.

Outside the domain of software development, in laboratory studies of group decision making and problem solving, there has been considerable research on individual-group linkages. These studies have long shown that group productivity usually does not equal the sum of individual group members' performance.¹ At the least, if individual labor

¹The definition and measurement of performance and productivity at the group or organizational level are not addressed in this chapter. However, to understand the behavioral research on groups and teams, one must know that behavioral scientists primarily use behavioral rather than economic measures of performance. These may be of several kinds: (1) quantity, quality, or cost-effectiveness of per-person output, such as number of problems solved or service calls completed; (2) disruptive behavior, such as absenteeism, accidents, or labor disputes; and (3) attitudes, such as subjective ratings of the quality of work life (Guzzo et al., 1985). Those interested in improving individual productivity have estimated effect sizes for many interventions and the standard

is to be combined into a joint product, some resources must be invested in the combination process itself. For instance, planning as a group takes time and effort. Social psychologists who study small groups have called the transaction costs of coordinating work in a team "process losses" (Steiner, 1972). Three approaches have evolved as ways to reduce process losses and improve coordination: team member selection and training, team design, and team communication.

Coordination Through Selection and Training

In software teams, the top 10 percent of programmers are said to be more than four times as efficient as the bottom 15 percent (Boehm, 1987). These individual differences in ability are relevant to teamwork. If a team is staffed with highly skilled and experienced workers, team tasks such as training, job design, and management are made simpler. More important, because members of a team interact, they influence one another and the team as a whole (McGrath, 1984). Individual competency multiplies through intragroup learning and transfer of skills. Under a competency multiplier process, teams made up of highly competent members outperform other teams even beyond what their individual abilities would predict. The multiplicative effects of individual abilities are particularly important when the team's work is complex, uncertain, and interdependent. Highly able team members can solve nonroutine problems and teach those solutions to one another (Clark and Stephenson, 1989; Hill, 1982; Hinsz, 1990). These members contribute valuable nonoverlapping skills and cancel one another's errors, so team interaction bestows extra benefits on team performance (Porter et al., 1975; Tziner and Eden, 1985).

Competency multiplier effects also may be seen over time because competent members become better at what they are already good at

deviation of job performance in dollar terms. These estimates can be used to show the financial benefit of labor savings that would be achieved by introducing an intervention or even what the net dollar value of the intervention would be, taking into account all business costs and benefits (Hunter and Schmidt, 1983). Several difficulties stand in the way of doing this to estimate the effect of a coordination strategy or intervention on team productivity (Boehm, 1987; Jones, 1986). Agreed team goals may exist but have no metric because the work is unique (e.g., building a space platform). Time-based indices are popular: lead time, time to completion of project, and even time to profit (Clark et al., 1987; Abdel-Hamid and Madnick, 1989). These measures do not, of course, address the quality of work.

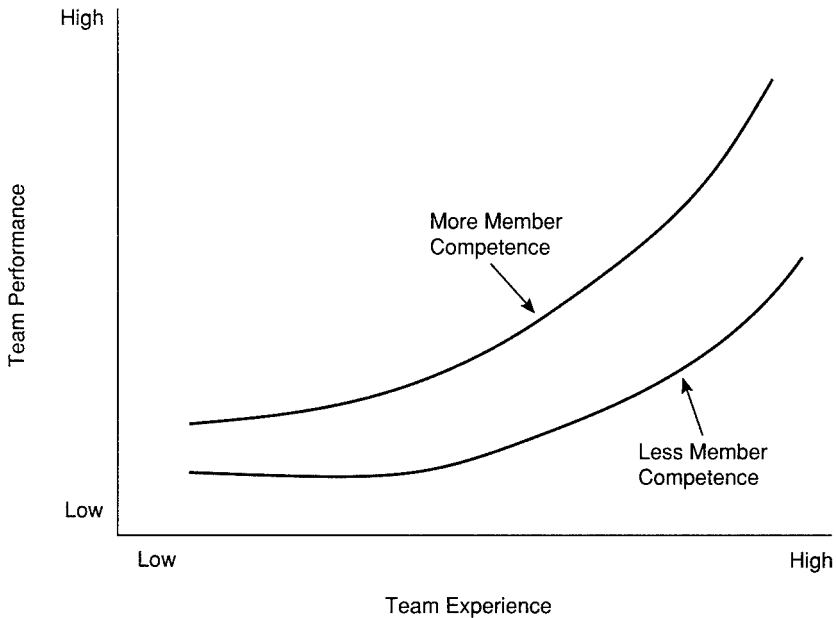


FIGURE 9-1 Competency multiplier effects.

and, together, more uniquely able than other teams (March, 1981). (See Figure 9-1.) Competent teams gain more from technological interventions and tools that increase individual competency and intermember learning, which contributes to an increasing gap between excellent and poor teams. In this manner, selection and training to acquire the most competent team members become a linkage factor, especially over time.

A strategy that focuses exclusively on individual selection and training to achieve teamwork is often impractical and has a number of disadvantages. Organizations often are prevented from hiring only the best people. The best people may lead to higher labor costs than are necessary. Moreover, those whose high talents are hidden initially cannot be discovered if the organization tries to hire only those with excellent resumes. Finally, even a group of highly qualified individual workers, placed on a team, may function poorly as a team unless attention is given to their organization as a team.

Coordination Through Team Design

Organization as a team, or team design, refers to the organizational structure and formal procedures that provide “built-in” solutions to coordination. These solutions may include task decomposition, lines of

authority, centralization of control, and standard operating procedures, or they may include technologies to standardize or rationalize the work itself.² Team design through structure and formalization is theoretically an efficient alternative to direct communication when tasks are complex, uncertain, and interdependent (Aldrich, 1979; Cyert and March, 1963; Downs, 1967; March and Simon, 1958; Simon, 1962). For instance, instead of having to talk repeatedly about what each person should do, formal task decomposition allows a group facing a complex task to divide its work into manageable chunks. It should not be surprising, therefore, to find that recent solutions to effecting teamwork in software development and other kinds of technical work have emphasized team design.

A major emphasis in team design has been the development of formal procedures governing communication at various stages of the work. For instance, formal meetings may be held at predetermined times in order to consider decisions about changes in the design. Brooks (1987), Curtis et al. (1988), and Fox (1982) noted that problems in accurately and completely communicating stable software requirements to members of a software project are among the most difficult to resolve in software development. Formalization is thought to increase control and regulate information flow. Written specifications or plans, documentation, and formal meetings ensure adherence to the plan and system as they evolve and that all the components fit together.

Formalizing project management can also help managers monitor teams' work. Each phase of the work cycle, from planning through operation and maintenance, is supposed to have well-defined products

²Modern software practices (e.g., logical models, well-defined interfaces, modularity, layered architectures, hierarchical management, object orientation) can be considered team designs because they are meant to regulate the number of connections that people and software components have. Modularity and information hiding, hallmarks of object-oriented design and programming languages, are thought to promote independence in programming, ease adaptation, and minimize backtracking (Dietrich et al., 1989; Parnas, 1972; Rumbaugh, 1991). Object-oriented design and programming also directly incorporate team design principles through inheritance. In software engineering, computer-aided software engineering (CASE) tools have been developed to facilitate the development of logical models, coordinate project design through a shared data dictionary, and automate input/output analysis (Sodhi, 1991; Zarella, 1990). The degree to which current CASE tools actually facilitate team coordination still is under contention (Spurr and Layzell, 1990). In a recent comparison of software maintenance teams that did and did not use CASE tools, groups using CASE tools were less productive (Banker et al., 1991; see also Orlikowski, 1988).

and milestones. Thus, it is specified in advance what will be delivered at each stage and how the deliverables will be tested or scrutinized to ensure that they do what they are supposed to do. In software development, all official project documents may be under change control. For example, there are usually naming conventions that must be adhered to project wide. Similarly, code cannot be written without design reviews; code cannot be tested before code walk-throughs; changes cannot be made without issuing a modification request; no piece of code goes to system test without an integration test; and so on.

Another important element in team design is the authority structure, which can be used to resolve disputes and inconsistencies across units. There is some evidence from an extensive comparison of automotive product development teams that significant variance in the authority structure contributes to the superior performance of Japanese automobile design teams over their American and European counterparts. Japanese team managers had greater authority and independence than American and European managers did (Clark et al., 1987). A concomitant of this idea in software development is that a chief designer or architect is the one person in a complex project who has sufficient knowledge of both the application domain and the possible software architectures to integrate the two. Weinberg (1971) advocated the chief programmer role, in which a senior designer/programmer has control over a software project. Problems arise when the design is distributed in more than one head or, worse (and probably more typically), is not in anybody's head. According to Curtis et al. (1988), skilled designers often assume responsibility for communicating their technical vision to other project members and for coordinating the work of the project.

In sum, team design (including group structure, formal procedures, and hierarchy) is advocated in teams to routinize the transfer of information and increase control and reliability. Formality and written documentation also are attempts to reconcile differences of opinion, help people understand their goals and those of others, induce the evaluation of alternatives, and develop agreements that all can accept. The effort expended by a small group writing a formal design document can be more than offset by the communication forgone later when each project member does not need to describe his or her vision separately to the scores of people who need the information. Formal procedures also reduce errors. Thus, for example, in software development one might run automated consistency checks on a formal specification document (cited in National Research Council, 1990) or even use a computer-based system that tracks modification requests to trigger management intervention when a project schedule slips.

Benefits obtained from team design do not come without costs, however. Formal structures and procedures can place an extra burden on development costs by increasing the need for a coordination infrastructure: training, increased clerical and management staff, and increased project reports and archives. Fox (1982) estimated that in large software projects, 50 percent of the cost is for planning, checking, scheduling, managing, and controlling. Tools and techniques that formalize communication or management require that time and effort be spent in teaching people to use them and ensuring that they do. Change-control systems are potential time wasters or distractions from work. Management sometimes uses standardization and rationalization of tasks to increase control, which can sap motivation and increase dependency on outside experts. Design also can impede innovation by limiting the options explored by a team. Finally, the “care and feeding” of bureaucracy can become more significant to employees than the ultimate goals they are supposed to accomplish.

A particularly serious disadvantage of team design as a coordination strategy is that it can depersonalize interaction. For instance, with task decomposition, team members, or subgroups of the team, have different roles. Team members or subgroups working on their own tasks tend to develop divergent perspectives and habits of work (e.g., Brewer and Kramer, 1985; Tajfel, 1982). They may have little opportunity or eagerness to learn from others on the team, which will impede the exchange of expertise and discovery (Burns and Stalker, 1961; Carley, 1990, 1991, 1992; Faunce, 1958; Festinger et al., 1950; Jablin et al., 1987; Monge and Kirste, 1980; Newcomb, 1961). Task decomposition can also exacerbate demographic or skill differences that existed at the start (Barnlund and Harland, 1963; Dearborn and Simon, 1958; Jablin, 1979; Monge et al., 1985; Sykes et al., 1976).

Whether team design through structure, formalization, or technology actually works as well as it is supposed to theoretically, remains debatable. Boehm's (1987) analysis of software productivity indicates that productivity due to changes in team design increased by just 7 percent between 1981 and 1986. Card et al. (1987) reported that software engineering technology improved reliability 30 percent but had no impact on productivity. Chapter 2 reaches the same conclusions as Card et al. did in 1987.

Coordination Through Team Communication

Experience, organizational theory, and behavioral research suggest that team design does not by itself solve all coordination problems in teamwork. No matter how successfully task decomposition, authority

structures, or standard operating procedures reduce the number of interfaces between team members, different members with different skills and perspectives still must negotiate what is to be built and fit together pieces of the design. Consensus formation, sharing of know-how, and integration of work outputs create communication demands that if not met at one level tend to surface at others.

Team design, while necessary for some purposes, is sometimes a misguided attempt to apply structure and formalization when they are not suitable. Formal coordination mechanisms are intended to simplify and disaggregate behavior and therefore increase group resiliency, but they can fail in the face of interdependence under uncertainty, which typifies much software work. Flexibility, texture, richness, expressiveness, and sometimes accuracy—all disappear during the codification of roles, rules, and procedures (Boisot and Child, 1988; Bruner, 1974). Under these circumstances, communication is needed for coordination (Clark et al., 1987; Daft and Lengel, 1984, 1986; Kraut and Streeter, 1990; Stohl and Redding, 1987; Van de Ven et al., 1976).

Direct communication is also referred to as coordination by feedback (March and Simon, 1958), mutual adjustment (Thompson, 1967), organismic communication networking (Tushman and Nadler, 1978), clan mechanisms (Ouchi, 1980), and informal communication (Kraut and Streeter, 1990). These terms convey the unique advantages of talking personally with others: spontaneity, interactivity, richness, friendliness. With communication, people develop deeper relationships and more opportunities to observe and learn from one another. Communication improves group commitment, socialization, and sometimes control. It makes possible the acquisition and maintenance of group culture, authority, and norms that people do not talk about overtly (Levitt and March, 1988; Nelson and Winter, 1982). Communication counters some of the costs to relationships of formal approaches to coordination. Research on communication in organizations has shown the heavy use made of communication in research and development teams where work is uncertain (e.g., Adams, 1976; Allen, 1977; Pelz and Andrews, 1966; Tushman, 1977).

Despite its advantages, constant communication in the traditional sense of face-to-face or telephone conversation is impractical in many software development teams. The ease of acquiring information is at least as important as the quality of the information in determining the sources that people use (Culnan, 1983; Zipf, 1935). Physical proximity is the major determinant of engineers' work-related information exchange and influence on projects (Allen, 1977). Constant communication may be undesirable as well as impractical—who can be reached conveniently is not necessarily the same as who can contribute high-quality infor-

mation. Communication can be costly if highly skilled persons spend too much time communicating with others instead of completing their individual tasks (Scott and Simmons, 1975). New communication techniques can reduce the costs of direct communication. Computer networks with electronic mail and bulletin boards that allow for fast but asynchronous conversation permit project members to talk even though they are geographically dispersed or mobile. Nonetheless, as discussed in Chapter 2, communication networks that are installed to increase efficiency might actually encourage the proliferation of communications, leading people to spend more time screening messages, and thereby reduce the cost advantages of the networks. Also, these media are inefficient for some kinds of communication, notably for collaborative planning and problem solving under uncertainty (Finholt et al., 1990; Galegher and Kraut, 1990). Research on the coordination and productivity benefits and costs of network communication suggests that, appropriately managed, the net effect can be positive. However, networks and other new technologies for communication do not automatically bestow benefits on coordination.

The Dilemmas of Coordination as Linkage

As we have described, coordination does not have a simple one-to-one relationship with team performance and thus is not a simple answer to forming linkages between individual work in a team and productivity as a team. Three dilemmas characterize the linkages. First, too little or too much coordination impedes performance. Hence, the team has to invest in the right amount of coordination. Second, design and communication have different effects on teamwork; the team has to match the appropriate coordination strategy with the tasks and phases of the team's work. Third, any coordination strategy tends to become habitual. Hence, the team must find ways to undo or unlearn design or communication strategies that might have been successful in the past but become inappropriate for a new task. We discuss these dilemmas in turn.

Amount of Coordination

Most teams use design and communication. If a team puts little or no effort into these forms of coordination, its performance will be poor. The more coordination, the better, up to a point. But coordination is costly; in experimental studies, team performance typically is above the level of the average team member but below the level of the most competent member because of coordination costs. At high levels, the

process of coordination is very costly in time, resources, hassles, and distractions (e.g., Abdel-Hamid and Madnick, 1989; Diehl and Stroebe, 1987). Thus, coordination has a curvilinear, inverted U-shaped relationship with performance.

Communication Versus Design

We propose, in addition, a dilemma of balancing approaches to teamwork. Communication and design are somewhat inconsistent with one another. For instance, teams may find task decomposition very efficient and comfortable. But if, because of their separate roles, team members do not talk to one another, friendships deteriorate and free riding increases. Members may begin to put their own prominence above the group's, which is a form of public goods problem.³ Consider a 3×3 matrix, in which communication and design are orthogonal factors (see Figure 9-2). When communication and design are each low, performance is poor because the team is not coordinated. When communication is high, design should be only moderate to achieve high performance at low cost, and vice versa. Finally, when communication and design are each high, coordination costs interfere with performance (Figure 9-3). One can imagine this happening, for instance, in teams in which there are many direct working relationships, many meetings, and many formal procedures that have to be followed.

Most groups combine some measure of design and communication, but they may overemphasize one or the other. It may be that for every task and project, there is an appropriate level of design and an appropriate level of communication for every level of design.

In technical work, the timing of communication and design may be important. It has long been thought that group discussion is necessary at times when tasks are highly uncertain or equivocal—at the beginning of projects and during crises. Communication at these times can

³In public goods theory (Olson, 1971), a dilemma exists when contributions of effort and resources for a group are partly inconsistent with the self-interest of individual group members. Individual members may believe with good reason that they are better off letting others cope with unassigned group tasks, such as teaching new members and handling unplanned client interruptions. As long as someone else does the work, free-riding members still benefit from the group's success. Also, in a complex and interactive project, one person's contribution to the group at any particular moment may seem inconsequential. The public goods problem may increase when uncertainty is high and team design contributes to lack of communication (Macy, 1990).

		Team Communication		
		Low	Moderate	High
Team Design	Little	Poor Performance	Poor Performance	Poor Performance
	Moderate	Poor Performance	Good Performance	Good Performance
	High	Poor Performance	Good Performance	Poor Performance and High Coordination Costs

FIGURE 9-2 Patterns of communication and team design leading to different levels of performance.

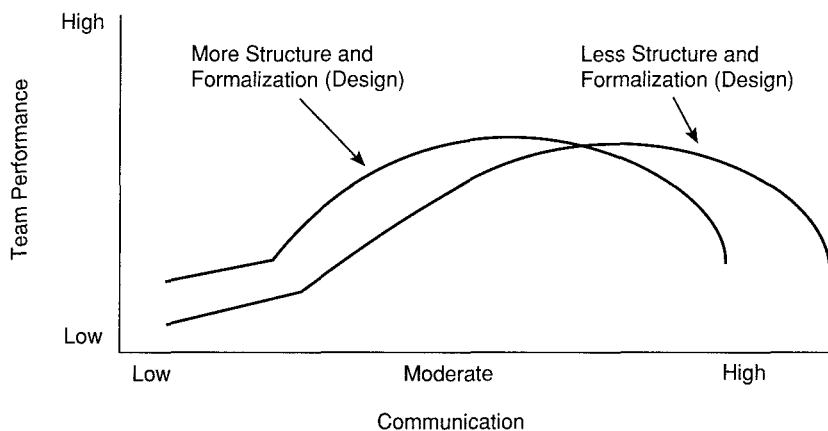


FIGURE 9-3 Complementarity of communication and team design at low levels of both, and substitution of communication and design at higher levels of both.

help create mutual understanding, commitment, and substitutability (because individuals have more common knowledge). Teams that communicate intensively initially and spend more time working out plans may do better than "fast starters" that begin coding and implementing quickly (see Hackman, 1987).

Team design might be a better strategy for coordination than direct communication once a team's plans are in place. Design allows members the most autonomy and time to do individual work. Programming probably is the most individual task in software development. A lead programmer doing coding might be working alone or perhaps with one or two others. Since coding is a conjunctive activity (i.e., the project cannot go forward without it), the programmer is needed by others and is less substitutable than those who have been working on other jobs and jointly with others. Over time, the influence of the programmer increases (assuming this work is individualized), and the rest of the team gets more dependent on the programmer because the work is central and the role is nonsubstitutable. Development of project-specific skills and overall understanding in the programmer can be seen as addressing coordination over time in two ways. First, as more pieces of a project get built, the programmer's competence becomes more critical to the rest of the group. Second, the programmer(s) will exert authority, which will lead to centralization and more design.

Design also addresses problems of heterogeneous skills in a team. Three elements of design are particularly important here: the role structure, the formal authority structure, and formal communication channels. The role structure specifies who does what. The formal authority structure specifies who reports to whom and who has access to what resources (Carley, 1990; Malone, 1987). Formal communication channels specify who is supposed to talk to whom. During coding and implementation phases of software development, these formal structures enable individuals to concentrate on their individual tasks and thereby successfully complete the project. These structures should be particularly useful when there is substantial heterogeneity among group members.

Entrainment

As teams develop ways of coordinating their work, they adopt habitual patterns of coordination, a process called *entrainment* (Kelly et al., 1990). Patterns of coordination become institutionalized and legitimated. As a consequence, it becomes more costly to renegotiate approaches to coordination. Particular styles of coordination and group cultures influenced by those styles emerge in all groups. With this emergence of a team coordination style, individual members are likely to

become more similar to one another in their personal attitudes and ideas about teamwork (e.g., Kiesler and Kiesler, 1969). In experimental studies, entrainment is inferred from a group's tendency to use the same work methods even though the task demands change. In research with ongoing groups, entrainment must be inferred by examining the extent to which coordination approaches become more similar and predictable over time.

Ironically, as teams become better at what they do and better coordinated, they also can become increasingly rigid in their approach to coordination. If their task assignments change, team members may be unable or unwilling to adjust their coordination strategies to the demands of the new tasks. They may be too internally focused and too comfortable, and their previous successful experience will not have suggested ways in which they should change. Research has only begun on this problem.

RESEARCH PROBLEMS AND DIRECTIONS

Much of the research discussed above was conducted with small, homogeneous groups working on well-specified collaborative tasks that can be done in one or a few sittings (McGrath, 1984). Except for the work on lateral coordinative mechanisms (which does not examine the role of groups in particular; e.g., Burns, 1989; Galbraith, 1972; Lawrence and Lorsch, 1967; Pfeffer, 1978), there has been relatively little research on coordination of large and ongoing teams within organizations. Also, little is known about technical teams in organizations that use computer-based technology. Such technology permits organizations to form large, dispersed, and diverse teams working on complex, uncertain, interdependent tasks that would not have been possible in the past. These teams have coordination problems that differ from those of traditional small groups and formal departments whose members are physically proximate. Laboratory and field research must employ technological and other resources to study the modern technical team.

Certain theoretical problems also must be solved if researchers and practitioners are to understand linkages between individuals and teams. Two of these problems are described in the next two sections.

Efficiency Versus Social Effects

Observations of today's technical projects (e.g., Curtis et al., 1988; Sproull and Kiesler, 1991) suggest that multilevel theories may be required to capture fully how coordination acts as a link between individuals and group productivity. In a two-level framework, for instance,

coordination mechanisms are viewed as having efficiency effects and social effects.

Efficiency effects of coordination are the direct, intended benefits of coordination minus its direct costs. These are the benefits and costs discussed above. However, coordination mechanisms can also have systemic, long-term effects on the team, organization, or social system. (For this concept, see Maruyama, 1963; Mason, 1970.) For instance, suppose as a result of using electronic mail to coordinate work, dispersed teams also discover ways to mobilize to influence management policy. Here, communication initially intended simply as an efficiency amplifier for a team also has effects on employee participation and organizational politics. Or, as was observed in one study, management may realize that the communication system can be used to monitor individual team members' performance in ways that used to be too difficult, which changes its authority relationships with the team members (Rule and Brantley, 1990). Social effects can affect linkages and productivity qualitatively and in ways that were entirely unanticipated. For instance, while greater employee participation may have no direct effect on the performance within teams, it can increase interteam learning and exchange of expertise across teams.

Linkages and Scaling Up

Another theoretical problem in the study of linkages is the incomplete understanding of how to study behavior across individual, group, and organizational levels of analysis. Experimental studies of individual behavior and simple tasks are necessary to test causal hypotheses, but one cannot deduce from experimental findings what will happen with real groups in organizations. Experimental group behavior never replicates exactly that of ongoing groups in organizations.

One approach to scaling up from individuals and simple tasks to teams and more complex tasks is to add variables. Amount of discussion (a communication variable) and centralization (a design variable) are variables, for example, that would be appropriate at the group level. A more difficult scaling problem arises, however, when such variables do not scale at the same rate; then multivariate effects change, which causes a phenomenon in the large to look very different from the way it looks in the small. For instance, discussion between two persons working together seems qualitatively different from meetings of 100 or more members of a large team. Ship designers encounter this problem when they try to deduce the behavior of a full-size ship from tests of models. Two important factors in a ship's drag are waves made by the ship's prow and turbulence under the ship. Because wave effects and turbu-

lence depend on fine details of the hull shape, designers cannot rely on mathematical calculations alone. Instead, they build scale models and tow them in water, measuring their drag. Although the model gives an estimate of drag, there is no way to measure how much of the model's drag is accounted for by turbulence and how much by making waves. To complicate matters, the two factors do not scale in the same way. The turbulence under the ship depends on the surface area and the speed to the 1.825 power, but the wave drag is a much more complex function of speed and ship size. Since the two effects are confounded in the model's drag and scale differently, scaling up from model tests is very hard. The ship in its full glory may act very differently than the model did, particularly if the model is small relative to the ship. Ship models and towing tanks are surprisingly large for that reason.

Based on evidence to date, the scaling problem is probably serious in researching the linkages between individual productivity and the productivity of large, dispersed project groups. For example, in asking how computer technologies and networks affect group coordination and productivity, researchers can test some hypotheses in the laboratory, but in reality, networks often inspire more groups, larger projects, more diverse groups, and more flexible group structures (Sproull and Kiesler, 1991). A social consequence of this is that peripheral employees, such as geographically or organizationally isolated employees, gain new opportunities to initiate and receive communication (Eveland and Bikson, 1988; Fanning and Raphael, 1986; Wasby, 1989). If management policies permit such interactions, peripheral employees can increase their membership in groups and their connections to groups. These interactions can increase information flow between the periphery and the center of the organization and among peripheral workers. In short, while increasing connections through network communication could increase the participation of everyone in principle, peripheral employees are likely to see a relatively greater impact than are central employees (Eveland and Bikson, 1988; Hesse et al., 1990; Huff et al., 1989). This chain of events looks very different from a linear scaling up from individual or even small group behavior in relatively simpler settings.

In sum, individual behavior and small group behavior may scale differently to organizational reality. Variables that seem trivial (perhaps because of low variance) in the laboratory may loom much larger in an organization—and vice versa. If so, one may see the same phenomena differently in the two settings, no matter how fine-grained and careful the research is. It is important to do both kinds of research, that is, to study individuals and small groups in the laboratory and in the field and to study large and ongoing groups in organizations. The purpose is not to discover exactly how variables and processes scale at

each level, but to ensure that researchers are always attuned to scaling problems.

Studying Groups in Organizations

Understanding of linkages in group productivity might be more effectively advanced if the tests of models in this domain were more ambitious scientifically. For example, an Israeli study involved a true experiment in the field on the effects of selection on tank crew performance (Tziner and Eden, 1985). The study involved the assignment of 672 soldiers to 224 crews, using a complex Latin square factorial design to control for differential performance ratings by the 28 unit commanders. Assignment on the basis of ability was varied experimentally. No other interventions were made in the natural military environment, but considerable control was exerted on data collection to increase its reliability and validity. There were four waves of measurement using previously validated instruments. The study showed that "spreading the talent around" is an inefficient way to distribute staff for interdependent groups, and the researchers were able to provide empirically supported advice counter to prevailing practices.

A kind of sociological/microeconomic study needed in the domain of software productivity is exemplified by a comparative study of product development teams in the automotive industry (Clark et al., 1987). The unit of analysis in this study was a major car development project; three U.S., eight Japanese, and nine European auto companies participated in the research. The researchers collected data from the companies on 29 projects (6 in the United States, 12 in Japan, and 11 in Europe) involving the development of new sedans, micro-mini cars, and small vans introduced from 1980 to 1987. The researchers used questionnaires and interviews with project managers, heads of R&D groups, engineering administration staff, and engineers, as well as archival data on lead time, engineering hours, technology, subcontracting, and outcomes such as model prices. This study confirmed that Japanese projects were completed in two-thirds the time and one-third the engineering hours of the non-Japanese projects, and it reconfirmed that if schedules are kept under control, cost overruns also tend to be restrained. These results do not refute a time-cost trade-off. Rather, the study points to the potential importance of particular project strategies, kinds of project organization, leadership, and staffing.

CONCLUSION

A changing but mostly large proportion of the variance in the productivity of software development and other technical teams derives from how such teams coordinate their work. Without coordination, individual work cannot be integrated and turned into a group product. Technical teams use team design and communication to coordinate their work, each of which can be considered a linkage process. Research has contributed much to the understanding of the additive and interactive effects of team design and communication on coordination. They are, in part, substitutes for one another. Too much of either one, or of both, creates costs that outweigh the benefits of coordination. There are many unknowns in this domain, however, especially when one tries to predict the side effects and outcomes of linkages over time. The very meaning of productivity in software development has changed as approaches to coordination have changed. Improvements in IT and formal methodologies used for coordination have increased the scope of software engineering projects. In 1963 the Mercury space project required 1.5 million object instructions, whereas a space station of the 1990s requires at least 80 million. Today, software development teams are generally much larger, more diverse, better trained, and more dispersed than they used to be. Moreover, their tasks are more complex, more uncertain, and more fluid than they were in the past—all this despite improvements in hardware and software that have made individual work and coordination less onerous. Hence, as new technological and nontechnological approaches to linkages are developed, there are new efficiency and social consequences, including changes in one's expectations of team productivity.

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Conclusions

In this chapter, the panel presents the key findings that emerged from its analyses and deliberations. The discussion is centered on the broad themes and conclusions that have implications for research policy and program development and for future directions for research in the behavioral sciences—particularly human factors, industrial engineering, and industrial and organizational psychology. Specific research recommendations can also be found in individual chapters.

ORGANIZATIONAL LINKAGES EXPLAIN THE PRODUCTIVITY PARADOX

Processes at and across individual, group, and organizational levels intertwine and affect one another such that productivity improvements at one level do not translate simply into productivity improvements at higher levels. The introduction of an intervention, such as technology, designed to improve productivity creates a series of trade-offs at different levels of the organization. As discussed by Attewell in Chapter 2, the potential benefits of the intervention might be channeled into one of two alternative directions—either in a direction that is productivity enhancing, that is, enabling the original work to be done more efficiently, or in a direction that is not productivity enhancing, such as improving some attribute of the product, expanding the work to be done, or inhibiting the productivity of other entities in the organization.

Most of the evidence in this report, however, indicates that even when productivity improvement is realized at a lower level (e.g., the individual), there are influences that might inhibit improvement from being realized at a higher level (e.g., the organization). We have examined those influences from the individual to the organization and from the organization to the individual. The concepts that aid in the understanding of these dynamics were presented by Goodman, Lerch, and Mukhopadhyay in Chapter 3. Examinations of those concepts and of how they operate in specific work domains were reported for office automation by Schneider and Klein in Chapter 4, for software engineering by Kiesler, Wholey, and Carley in Chapter 9, and for computer-aided design by Harris in Chapter 10.

Another form of the productivity paradox is provided by the practice of downsizing. Organizational downsizing has been one of the major initiatives undertaken by U.S. firms during the past decade to increase productivity. It is an initiative that is assumed to lead directly to increased productivity by increasing the ratio of output to input. However, according to the evidence summarized by Whetten and Cameron in Chapter 11, this intervention (similar to the introduction of technology) has not had the anticipated effects. They concluded that this productivity paradox is explained by the use of downsizing approaches that typically ignore the effects of organizational linkages.

The concept of organizational linkages provides a useful framework for examining the productivity paradox. It has led the panel to conclude that a major contributor to the paradox has been the common attempt to initiate change through the introduction of a single intervention (technology) at a single level in the organization (the individual). As suggested by Schneider and Klein in Chapter 4 and by Sink and Smith in Chapter 6, changing a single aspect of an organization almost never results in a substantial change in organizational performance. Organizations are too complex, their performance is too multidetermined, and their inertia is too great for a single innovation at the individual level to have a substantial impact on organizational performance. Even if an intervention does in fact augment individual productivity, there may be no resulting improvements in organizational productivity. Multiple, congruent interventions are needed to achieve the desired impact. This leads to the requirement for an organizational systems framework to clarify the multiple reciprocal linkages that determine organizational productivity.

As discussed by Sink and Smith in Chapter 6, making an improvement intervention in one entity and projecting positive performance linkages to other entities at the same or different levels require profound knowledge. *Profound knowledge* encompasses a theory of sys-

tems, variation, psychology, and knowledge itself. It equates to a sufficient understanding of the organizational system to identify and predict cause-and-effect relationships. When interventions are made without profound knowledge, they are not likely to have their intended effect—subsystem performance may be enhanced, but the performance of the larger system will not be because the linkages are not understood. The consequence is the productivity paradox—extensive investments in enhancing the productivity of individuals and groups that do not lead to expected improvements in larger organizations or in the enterprise.

ORGANIZATIONAL STRUCTURES AND PROCESSES CAN INHIBIT OR FACILITATE LINKAGES

In our examination of linkages, we identified structures and processes that inhibit increases in individual productivity from increasing organizational productivity. These structures and processes are common to organizations engaged in varied activities—office work, software development, postal services, manufacturing, computer-aided design, and others.

A structural inhibitor, for example, can be found in the existence of core and peripheral activities in most organizations. Core activities, such as the production of engineering design specifications, are directly related to the process of transforming inputs into outputs. Peripheral activities, such as updating computer-aided design software, are only indirectly related to this process. Thus, as a consequence of this structure, increases in individual productivity in core activities will be more likely to contribute to organizational productivity than increases in peripheral activities.

Process operates as an inhibitor when an intervention that increases productivity in one set of activities cancels the gain by decreasing productivity in a related set. For example, the introduction of a computer system resulted in increased productivity on routine tasks by individual customer service representatives. However, the change had negative consequences for the functions of supervisors of the customer service representatives. It reduced the visibility of the operations they supervised and thereby reduced their ability to solve problems and coordinate activities. The net result was no gain in the productivity of the work group, even with the intervention of new technology and the improvement in the productivity of the customer service representatives.

Facilitators are equivalent in importance to inhibitors. Facilitators are processes that can function either to remove conditions that impede linkages or to create conditions that facilitate linkages. Several critical facilitative processes were defined and examined in vari-

ous chapters of the report. Examples include coordination, problem solving, focus of attention, organizational evolution, and motivation. These facilitators were examined and illustrated by Goodman, Lerch, and Mukhopadhyay in Chapter 3.

At a somewhat more specific level, the following facilitators were defined for the domain of software engineering: coordination through team design and coordination through communication. Team design is the development of appropriate structure and procedures that provide built-in solutions to coordination—task decomposition, lines of authority, centralization of control, and standard operating procedures. Communication is the process provided to permit team members to interface with each other, to permit the negotiation of goals and processes by people of different skills and perspectives, and to share information and integrate work outputs. These facilitators might become inhibitors if they are misapplied and lead to costs that outweigh benefits. Coordination issues in software engineering were addressed by Kiesler, Wholey, and Carley in Chapter 9. Additional examples of inhibitors and facilitators, along with descriptions of how they operate in other work domains, were provided by Schneider and Klein in Chapter 4 and Harris in Chapter 10.

There is much to be learned about organizational structures and processes and how they inhibit or facilitate linkages. For example, how do different linkage situations generate inhibitors? What types of interventions or productivity changes will more likely evoke negative consequences under different linkage situations? We have emphasized the role of processes in facilitating individual-organizational linkages. However, in our analyses, processes such as problem solving and organizational evolution were treated as though they were independent of other variables. This gives rise to the question, will these processes affect linkages in the same manner and to the same degree under conditions of complexity and uncertainty as under conditions of stability? In the specific area of software development, a large portion of the variance in the productivity of technical teams is known to derive from how the teams coordinate their work. However, there are many unknowns and questions in this domain alone, such as, what are the side effects and outcomes of linkages over time? The research direction required to provide answers to these and related questions will provide valuable insights into how to realize productivity gains from technology and other organizational interventions.

LINKAGE INFLUENCES ARE SUBJECT TO LEVEL OF ANALYSIS AND DIFFERENTIAL SCALING

Many linkage explanations are likely to be specific to the level of analysis. That is, what accounts for the relationship between individual and group productivity might be different from what accounts for the relationship between group and organizational productivity. For example, the role of the supervisor might be more influential in transforming increases in individual productivity to group productivity than in transforming group increases to organizational increases.

Researchers must also recognize that explanations might scale differentially for different dimensions of an organization. Differential scaling is analogous to the problem faced in designing boats. Estimating hull performance by using a small but accurate scale model may not accurately predict the performance of a full-size version. Differential scaling will occur because different features or dimensions of a hull scale up at different rates, causing relationships between features found for a small hull to be different when scaled up for a large one.

Translated into an organizational setting, this analogy suggests that a change in scale of one feature of a firm may lead to unexpected effects because other dimensions of the organization will not change proportionately. In downsizing, for example, a retrenching firm might shrink its managerial staff by 10 percent. An unintended consequence of this action might be an increase in managerial work load, because each manager now has, on average, a larger number of units reporting than before. Differential scaling occurs because it is unlikely that the number of units reporting to managers will decrease as fast as the number of managers, even if employment in the firm as a whole is cut by an equivalent 10 percent. Thus, span of control does not scale down at the same rate as number of managers, which has potentially negative consequences for organizational productivity. This and other problems associated with attaining productivity gains from downsizing were addressed by Whetten and Cameron in Chapter 11.

HORIZONTAL AND VERTICAL LINKAGES DO NOT NECESSARILY OPERATE IN THE SAME MANNER

In this report, influences on organizational linkages have been invoked as both inhibitors and facilitators of the spread of productivity from one work unit in an organization to other work units. The point has been made in Chapter 9, for example, that coordination and communication mechanisms are important determinants of the extent and degree of this spread. It is less clear whether horizontal and vertical

linkages operate in the same manner—horizontal linkages being between units at the same level and vertical linkages being between units at different levels.

Differences between horizontal and vertical linkages might be viewed as inhibitors to the transfer of productivity gains from one unit to another. For example, if horizontal and vertical linkages require different coordination modes, that degree of specialization might be difficult or impossible to provide. On the other hand, an understanding of the differential characteristics might be a key to the development and implementation of successful coordination and communication mechanisms. In Chapter 4 Schneider and Klein introduced the concept of open systems and discussed the principle of differentiation, integration, and coordination within this context. They summarized previous research that indicates the need to counterbalance organizational movement toward differentiation with integrating and coordinating mechanisms that bring the system together for unified functioning. An understanding of the differential effects of horizontal and vertical linkages may be required to develop the appropriate mechanisms.

METHODS AND MEASURES ARE NEEDED FOR TRACING LINKAGES

A principal focus of our study has been on methodological and measurement issues surrounding the linkage question. These issues were addressed specifically by Ruch (Chapter 5), Sink and Smith (Chapter 6), Pritchard (Chapter 7), and Campbell (Chapter 8). A principal theme of each of these chapters is that methods are needed to determine, analytically, whether specific productivity changes in one work unit are passed through to others. That is, methods are needed for tracing changes through the system from individual to group to organization.

Empirical research is needed to identify the significant linkage variables and their relative importance. To do such research, multiple links within multiple organizations must be studied using longitudinal research designs. First, improvements in outputs at the most molecular level must be shown to have occurred because of an intervention and those improvements must then be traced through the various linkages to the broadest organizational level. The idea would be to measure each explanatory factor (slack, conflict in objectives, and so on) along with the amount of loss of output across the linkage. Then, the importance of each could be assessed empirically. Ideally, the data would be collected so that the variance accounted for by each factor could be estimated.

The macro models now used to assess the effect of information technology on productivity are informative but not very precise. They do

not do a good job of capturing the nature of the specific form of information technology, determining the degree to which this technology has an impact on individual performance, or revealing the structure of linkages and their influences. Consequently, there are a number of challenges in conducting research on linkage questions. First, one has to develop a reasonable representation of the production function of a firm. Second, one needs a model that can capture changes at different levels of analysis. Third, one needs a strategy to identify the lag structure between changes at the various levels. The lag structure is likely to be a critical issue and to be influenced by the specific technology and by many of the variables discussed earlier.

LINKAGES SHOULD BE EXAMINED RELATIVE TO OTHER CRITERIA OF PERFORMANCE

The performance of an organization is a function of at least seven interrelated criteria: effectiveness, efficiency, quality, productivity, innovation, quality of work life, and profitability. A complete picture of organizational performance over time requires measures of these criteria. Operational definitions of each of these criteria were provided by Sink and Smith in Chapter 6. Productivity has been our main criterion as we have focused on understanding how changes in one work unit might lead to changes in other work units. We have examined factors that facilitate or inhibit the transfer of changes. An important challenge is to extend this type of analysis to the other criteria.

As an example, suppose the introduction of information technology improved quality at the individual level. Are the nature of linkages, and the factors that facilitate and inhibit quality changes at the organizational level, the same as would have been predicted for changes in productivity? Would the analysis of linkages be different if one looked at other performance criteria, such as effectiveness, quality of work life, innovation, or customer satisfaction? An underlying theoretical question is whether there is similarity or dissimilarity in the structure of the criteria. That is, given an understanding of the factors that facilitate linkages between individual- and organizational-level productivity, will those same factors predict linkages for other criteria? The practical issue is that a more complete understanding of facilitators and inhibitors will require the examination of linkages relative to the complete set of performance criteria, not just productivity.

In our study, we did not explore how changes in individual productivity might affect these other criteria of organizational performance. For example, the conditions that enable changes in individual productivity to increase organizational productivity might actually decrease

other organizational criteria, such as quality, innovation, or quality of work life. Ultimately, it will be necessary to address the functional or dysfunctional consequences of how other criteria change as individual and organizational productivity are more strongly linked.

A THEORY OF ORGANIZATIONAL LINKAGES IS NEEDED

A theory of linkages is required and should be developed. We have focused on the productivity paradox and have suggested explanations and solutions. However, the paradox is only an example of the importance of studying and understanding the linkages among organizational subsystems. What is needed at this point is a better understanding of how outputs get combined and transformed across organizational levels, the identification of important factors that facilitate and inhibit those linkages, and the determination of conditions under which facilitators and inhibitors operate.

Panel members agree that a theory of linkages is an important goal. However, they are not all in agreement on the direction to take to reach that goal. Some members (see Chapters 5 and 7) propose to develop a composition theory of linkages—an explication of the variables that affect the translation of outputs from one unit or level of the organization to the next. They claim several advantages for such a theory. First, it would provide an integration of all the factors, as argued in the previous chapters of this report, that define and influence linkages. Second, it would provide a description of how those factors are combined and an explanation of how the factors interact. Finally, if valid mathematical functions could be developed to describe the relationships, one could predict the effects that changes at one unit or level would have on changes at other units or levels. They point out, however, that attempts to aggregate individual productivity measures or to disaggregate organizational measures are thwarted by the dissimilarity in measures of output. At the individual level, for example, output is often counted in units of product produced or service provided. At higher levels of analysis, however, different outputs from different sources are combined by means of some form of accounting scheme that is incompatible with measures at the individual level.

Other panel members (see Chapter 6, for example) conclude that composition approaches would not be fruitful. They would emphasize the application of systems theory and statistical approaches to the measurement of total system performance. Rather than pursuing the aggregation or disaggregation of measures at various levels, they would attempt to construct cause-and-effect relationships among measures. For example, they claim that modeling organizational linkages and ana-

lyzing the productivity paradox for a selected set of specific examples could generate tangible theories about cause-and-effect relationships and permit the framing of the problem in a manner susceptible to a solution. Their view is that the paradox of unrealized productivity improvements is an example of incomplete systems thinking and failure to understand the nature of organizational linkages. Their approach would provide answers to such questions as, at which level would one expect performance to improve as a result of an intervention? What aspects of organizational performance will be quantifiable, and which will not? To what extent has what is known versus what is believed about cause and effect relative to linkages been clarified? Thus, an important issue to be resolved is which direction to take in developing a theory of organizational linkages.

IMPLICATIONS

We believe that the findings presented in this report have significant implications for policy and research. Our study has focused on the widely reported productivity paradox—successful interventions at individual and group levels have not led to increased productivity at higher organizational levels. We have studied this paradox by examining linkages among individuals, groups, and organizations and have found that those linkages can not only explain the paradox, but also provide the systems framework necessary for determining much of what needs to be learned about improving organizational performance. A key implication of our study is that organizational change, from the introduction of information technology to the downsizing of the enterprise, is an extremely complex endeavor. Recognizing this complexity and addressing it by means of systems thinking are the first steps in successful intervention programs. A successful intervention to increase performance requires that a number of actions be taken at different organizational levels and that they be congruent in their goals, strategies, actions, and measures. As stated earlier, organizations are too complex, their performance too multidetermined, and their inertia too great for a single innovation at the individual or group level to have any substantial impact on organizational performance.

We have described in this report many of the inhibitors and facilitators that influence the extent to which changes in the productivity of one entity result in corresponding changes in the productivity of another entity. We have also identified specific organizational structures and processes that can inhibit or facilitate linkages. Moreover, we have examined and illustrated, in detail, how those structures and processes

affect organizational linkages in several specific domains—office operations, software engineering, and computer-aided design.

The major contribution of our effort, however, lies in our identifying what is known about organizational linkages and in providing a framework for designing and conducting needed research. Although most of our specific research recommendations have been provided in the individual chapters in which the issues related to them were introduced, we complete our report by listing what we consider to be the three most compelling research opportunities.

1. Theory and methods are required for the measurement of performance across work units of different sizes at different levels in an enterprise. For example, methods are needed that will permit changes to be traced through the system, from individual to group to organization. Because the tools now available are at such an immature stage of development, research on organizational linkages and their influences is difficult to conduct at the level of precision required.

2. Much more needs to be learned about how structures and processes inhibit and facilitate organizational linkages. The dynamics of these interactions are very complex, and enhancing linkages is likely to be more than simply a function of removing inhibitors and activating facilitators. At this point, possible inhibitors and facilitators have been identified, but a theory is lacking for relating the structures and processes involved to organizational linkages. For example, it is not known when certain structures will inhibit the transfer of productivity gains and when they will not. Nor is it known under what conditions certain processes will facilitate productivity gains and under what conditions they will not.

3. The analysis of productivity linkages should be expanded to encompass other aspects of organizational performance—effectiveness, efficiency, quality, quality of work life, innovation, and profitability. Focusing on a single performance criterion, productivity, does not provide a complete and true picture of the effects of an intervention, even if the goal of the intervention was solely to improve productivity. Do the conditions that increase productivity also increase or decrease product quality or the level of innovation in the organization? A different question to be addressed by an expanded analysis is, will a theory of organizational linkages developed for productivity apply as well to other criteria of organizational performance?

As we look ahead, we cannot help but conclude that attaining a more productive society and higher overall standard of living will require a better understanding of organizational linkages. The United

States and the rest of the world will inevitably continue to invest more heavily in technological solutions. However, as this report has demonstrated, implementation of new technology is not enough. Organizational linkages must be understood well enough to permit the creation of conditions that will ensure that investments in technology provide the returns of which they are capable.

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