Transforming Coordination: The Promise and Problems of Information Technology in Coordination

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ABSTRACT

The Advanced Integrated Manufacturing Environments (AIME) project has been a multi-year study of coordination changes in US manufacturing firms implementing new information technologies. The AIME project research has confirmed the need for a *behavioral* as well as an *information-processing* view of how IT changes coordination in practice. Information-processing views of coordination change show how inherent attributes of IT directly improve organizational performance by solving key coordination problems of scheduling, synchronizing, and allocating. The information-processing approach has special appeal because it gives a way to think about optimizing organizational structures to be reduce coordination costs. This information-processing view, however, gives us an incomplete understanding of how to cope with the chronic organizational problems of *changing coordination practices* within a world of powerful social and economic logics.

The AIME project has used behavioral theories from organizational sociology and institutional economics to create an understanding of IT as a shifter of potentials and constraints in a world of existing economic and social coordination processes. IT can be used to solve many existing coordination problems without any substantial side effects. This is especially the case when the problems and technologies are simple and straightforward. But as the coordination problems become more complex and interdependent, so often do the information technologies intended to solve them. In such instances, it is more accurate to speak of the use of IT as *transforming* one set of coordination problems into another set of coordination problems. The new set of coordination problems may be more or less tractable for the organization. The "irony" of IT and coordination is that the new kinds of interdependencies created by the sustained use of IT may, in some circumstances, be more difficult to coordinate than the original problems IT use was supposed to address. Much of the difficulty is due to the relative inexperience organizations have in dealing with these new coordination problems. New design techniques and new institutional arrangements for organizational usability have the potential to make these coordination problems much less severe.

INTRODUCTION

Information technology (IT) has the **potential** to change the way organizations coordinate. Because the effective coordination of separate activities within organizations and between organizations plays such a large role in organizational performance, it is important to know how organizations use IT to actually coordinate their activities. What coordination problems does IT solve in practice, and what new coordination problems does it bring to the surface? What is easy about turning technological potential into organizational performance, and what is difficult?

The Advanced Integrated Manufacturing Environments (AIME) project has been a multi-year study of coordination changes in US manufacturing firms implementing new information technologies. AIME project research has confirmed the need for a *behavioral* as well as an *information-processing* view of how IT changes coordination in practice. There is a long tradition of organizational analyses of information systems in organizations -- how social forces influence their selective adoption, shape their configurations, enhance or undermine their implementation, and influence their subsequent uses (see for example reviews in, Kling, 1980; Kling 1987).

Information-processing views of coordination change show how structural features of IT directly improve organizational performance by simplifying key coordination problems of scheduling, synchronizing, and allocating (see, for example, Malone and Crowston, 1994). The information-processing approach has special appeal because it gives a way to think about optimizing organizational structures to reduce coordination costs. Information processing formulations, such as Malone and Crowston's, emphasize *static*, relatively optimal, solutions to organizational problems. This information-processing view, however, gives us an incomplete understanding of how to cope with *dynamic* organizational problems that arise from changing coordination practices within a world of powerful social and economic logics.

The AIME project has used behavioral theories from organizational sociology and institutional economics (see below) to create an understanding of IT as a shifter of potentials and constraints in a world of existing economic and social coordination processes. This chapter identifies some key findings from the project. At the project's inception, the dominant discourse about coordination and information technology was frames in terms of information processing theories of coordination. While we anticipated that behavioral analyses would add depth to the information processing analyses, we did not know how much these alternative approaches would be complementary, conflicting or synergistic. Many of the observations in this paper came from detailed empirical field studies of the use of IT to coordinate manufacturing activities (see below).

We did find that IT can be sometimes used to solve many existing coordination problems without any substantial side effects. This is especially the case when the problems and technologies are simple and straightforward. But as the coordination problems become more organizationally complex and interdependent, so often do the information technologies intended to solve them. In such instances, it is more accurate to speak of the use of IT as *transforming* one set of coordination problems into another set of coordination problems. The new set of coordination problems may be more or less tractable for the organization. The "irony" of IT and coordination is that the new kinds of interdependencies created by the sustained use of IT may, in some circumstances, be more difficult to coordinate than the original problems IT use was supposed to address. Much of the difficulty is due to the relative inexperience organizations have in dealing with these new coordination problems. New design techniques and new institutional arrangements for organizational usability have the potential to make these coordination problems much less severe.

Information Technology and Changes in Coordination

Though a distinction is often made between coordination activity and production activity in organizations (e.g., Scott Morton, 1991), coordination itself is an extremely broad term. It is usually defined at a very abstract level, as the alignment of distinct but interdependent activities (Malone and Crowston, 1994). Everything from human communication, to factory scheduling algorithms, to an international currency market can be conceptualized as a coordination problem. To give more concreteness to the kinds of organizational coordination issues the AIME project has focused on, we briefly discuss examples of the difficulty of coordination changes through IT.

One kind of organizational coordination problem arises when the value of a shared information system depends on how different individuals and groups use the system jointly. For example, managers who have acquired group calendar systems that help their subordinates automatically schedule meeting times, or at least be aware of each others schedules, have faced significant organizational difficulties (Grudin, 1994; Bullen and Bennett, 1991). Each person must maintain an accurate, up-to-date personal calendar that publicly defines their appointments and "free time." Maintaining personal calendars on a computer system is a significant amount of work -- work done largely for the benefit of other group members, and the clerical staff that schedules meetings. Group calendars -- in practice -- have a political economy of effort that can make it hard for those who do most of the record keeping to feel that they have gained proportional value (Kling, 1980; Grudin, 1994).

There is also a politics to allocating time and having one's time commitments be publicly visible. The men and women who use the system have to agree upon the meaning of "free time." Can a person have no free time? Is a person allowed to block off time on his or her calendar for any reason, or only for official company events? The coordination problems of organizational systems such as group calendars are not limited to providing electronic communications and scheduling.

Wagner (1993) found one intriguing challenge when she tried to design a surgical calendar system for a surgical teams that were composed of (typically) male surgeons and (typically female nurses. She noted that:

> If ... women's (nurses) voices are not heard, the resulting rules and regulations concerning "privacy versus transparency" will reflect a one-sided tendency to protect primarily the needs and interests of surgeons, hereby disregarding the organizational problems created when in an organization characterized by strong dependencies and frequent emergencies one group enjoys a high level of time autonomy (and privacy).

A coordination solution, such as using a temporal database -- calendars -- to manage commitments and to more efficiently schedule people and resources can be very appealing, especially when it is abstracted from concrete working conditions and social relationships. But it rapidly becomes a problem of managing incentives to keep personal calendars up-to-date, agreeing upon the meaning of "free time," giving different workers effective voice in scheduling major events, and facing the local politics of temporal privacy.

Another example of organizational coordination difficulties comes from the use of massive, technically complex computer systems that span an entire organization. While a complex system may improve aspects of a firm's coordination, making these systems run smoothly on a daily basis is a huge coordination challenge of its own. In manufacturing, for example, MRPII (Manufacturing Resource Planning) systems have faced significant implementation difficulties (Hayes et al, 1988; Warner, 1987). As different groups are more tightly linked together, the new dependencies between groups have to be coordinated (Kling and Iacono, 1984; Attewell, 1991). The technical capabilities of the system, and any modifications, have to be negotiated by all of the groups relying upon the system. The organizational complexity of using MRPII for coordination is shown by the fact that internal politics have been a better predictor of the extent of MRPII use than purely technical factors (Cooper and Zmud, 1990).

These two examples illustrate the kinds of issues organizations face in translating the potential of IT into improved organizational coordination. IT, because of its inherent capability to

store, process, and transmit vast amounts of information, has rightly been seen as a powerful enabler of new forms of organizational coordination (e.g., Scott Morton, 1990). However, the specific ways that IT changes organizational coordination in practice cannot be fully described by inherent technological capabilities such as "reducing time and space to zero." These examples are consistent with previous research on computing and organizations, which shows that the use of IT may lead to different coordination outcomes, depending on existing social and economic logics (e.g., Dunlop and Kling, 1991). The actual coordination changes that take place in the presence of IT is a question that has to be answered through empirical, behavioral study.

In the AIME project, we have studied coordination in manufacturing, for both practical and theoretical reasons. Manufacturing is of undeniable practical importance to the US economy, and thus is important to study (Cohen and Zysman, 1987). From a theoretical viewpoint, however, studying coordination in a domain such as manufacturing is particularly interesting because of the harsh technical demands of manufacturing coordination, the rich institutional environment that brings many different groups and activities together, and the constant experimentation taking place with new forms of coordination.

THEORETICAL RESEARCH ON COORDINATION

When individuals and groups specialize, by concentrating their expertise within a narrow range of activities, there is a need for coordination. Coordination among specialized individuals and groups takes place by ordering and arranging the interdependencies among their separate activities (Kling et al, 1992). Manufacturing firms, like all firms, coordinate extensively at many levels. Different groups, such as engineering, marketing, production, and materials each have deep specialized knowledge of their own domains. But their decisions and behavior are frequently interdependent with other activities outside of their domain. Though the skill and attention of these different groups must be focused and choreographed

for good organizational performance, it is common for there to be conflicts of perspective and practice between any of these groups.

To explain this diversity of organizational action, the AIME project used multiple theoretical perspectives to account for actual coordination behavior in IT-using manufacturing firms. This section describes those theoretical perspectives. It begins with the initial theoretical critiques of a view of manufacturing coordination that depends too heavily on the inherent attributes of the technology, a view that is widespread in the literature on computer-integrated manufacturing. Next, it reviews the theories from organizational sociology the project found useful for studying coordination behavior. Finally, the work on theoretical perspectives from institutional economics is presented as another useful lens for viewing the role of IT in manufacturing coordination.

Basic Critiques of Information-Processing Centered Visions of Coordination

For the past 20 years, discussions of IT's potential for changing manufacturing coordination have taken place under the banner of Computer-Integrated Manufacturing (CIM). CIM is a strongly information-processing centered vision that emphasizes the need for greater computerization, and greater data integration, around a single, enterprise-wide data base (e.g., Harrington, 1973; Melnyk and Narasimhan, 1992). The CIM vision argues that the path to more effective coordination is to more tightly link together separate areas of the factory through data bases and computer-mediated communication--integrating the "islands of automation" to achieve global optimization.

Over the past decade, practical problems with the CIM vision have been discussed in the research literature, and the popular press. A common observation in popular articles is that the problem of CIM are "more organizational (or cultural) than technical" (e.g., Sheridan, 1992). Social researchers also note the importance of organizational issues, and their

elusiveness. In writing about less ambitious incremental changes in manufactuirng systems, Shani, Grant, Krishan, and Thompson (1992) note:

> "One result that is abundantly clear is that critical management problems arise not in the adjustment of the technical system, but in the adjustment of the social system. Not only are the time frames required for adjustment much longer (for example, in employee training and in gaining the commitment of managers at different levels and in different functions), but the problems of interpersonal relations and organizational structure are far less transparent and much less easy to define than those of technology."

Analysts who have critiqued US manufacturing computerization make a distinction between computerizing direct (production) activities versus indirect (coordination) activities. While US manufacturers are seen as not making enough appropriate use of computerization for direct production activities (e.g., Jaikumar, 1986), they have been criticized for excessively computerizing, and overcomplicating, indirect activities such as scheduling, production planning, and production control (e.g. Hayes et al, 1988; Dertouzos et al, 1989; Roven and Pass, 1992).

The AIME project began its conceptual work by identifying the kinds of organizational issues that were repeatedly being observed in real coordination behavior, but that were not being addressed by the information-processing focus of CIM. From existing research on the impacts of computer technology, the AIME project was aware that organizational change is not dictated solely by the inherent capabilities of a new technology. When an IT system becomes sufficiently large in scope (involving numerous groups), it can be seen as a social and economic institution (Kling and Iacono, 1989) shaped by behavioral as well as technological forces. As a recent National Research Council study concluded (National Research Council, 1994):

> IT alone does not create impacts; its effects reflect a host of decisions made and actions taken--wisely or not--by a range of stakeholders including senior managers, technical professionals, and users.

To understand how manufacturing firms actually use IT to facilitate coordination, the first task of the analyst is to define a set of theoretical concepts that can account for changes in coordination technology, but within a framework of human decision, behavior, belief, and history.

There has been a substantial body of research on common organizational problems with computer systems (Laudon, 1974; Gasser, 1986; Orlikowski, 1993; Knights and Murray, 1994). Our reading of this literature indicates that the appropriate theories would have to account for: the social relationships between participants who influence the adoption and use of computer-based technologies, the infrastructures for supporting systems development and use, and the history of local computing developments (Kling, 1987). Special attention would have to be paid to information-processing views of coordination that assume harmony and cooperation, rather than the possibility of partially conflicting preferences, interests, or values (Kling, 1991; Orlikowski, 1993). Purely technological theories of coordination also tend to overestimate the ability of different subgroups to coordinate quickly and smoothly. The capacity to coordinate can be limited by organizational processes (Beuschel and Kling, 1992; Kling, 1992b).

Coordinating manufacturing operations through IT raises important, recurring organizational issues. Addressing these issues requires the use of social and economic perspectives, that assume actors will behave as groups in a social context, or as economic agents (Kling et al, 1992).

The Sociology of Complex Organizations Limits the Possibilities of Coordination Through IT.

The first set of behavioral perspectives used by the AIME project comes from organizational sociology (Perrow, 1986; Scott, 1992; Pfeffer, 1982). Sociological theories of coordination assume that groups will conflict over goals and interests. They identify social bases for group differences and interests, such as status, power, and social identification. Sociological theories are pertinent to understanding IT and coordination in manufacturing because such systems tie together organizational units with different occupational cultures and work practices (Kling et al, 1992).

The AIME project used three theoretical perspectives from organizational sociology, each with their own strengths and weaknesses: institutional theory, structural contingency theory, and resource dependency theory. Each of these perspectives has their own language for describing the nature of "alignment" between separate activities. The main concepts from each theoretical perspective, along with key examples from our research, are presented below. More detail on each of these perspectives can be found in Kling et al, 1992.

Institutional Theory

Institutional theory views organizations as groups of people who embody and enact loosely coupled standardized packages of rules, procedures, and beliefs (Powell and DiMaggio, 1991). These standardized packages, or "rationalized myths" (Meyer and Rowan, 1977), are adopted primarily to maintain organizational legitimacy in the eyes of powerful external actors and belief systems. Maintaining organizational legitimacy in the eyes of outside institutions, such as government regulators, professional organizations, and powerful clients, contributes to the survival of the organization. Over time, the institutionalized packages become "taken-for-granted"--organizational actors can no longer think of legitimate alternatives, and the packages become extremely difficult to change.

Our research found institutional theory especially useful for explaining coordination changes in situations where manufacturers face strong external legitimacy demands, and cope with complex sets of technologies that are sensitive to the organizational assumptions embedded within them. We found institutional forces shaping coordination outcomes in both the AIRTECH and DISKCO cases.

We conducted a case study at the Wing Control Division (WCD) of AIRTECH, a Southern California aerospace manufacturer. WCD produces sophisticated control equipment for airplanes, helicopters, and missiles that requires the integration of mechanical, hydraulic, and electronic technologies. WCD's 10-12 product lines are evenly split between commercial and military markets. In terms of market positioning, WCD has a reputation for high-tech design skill, and high prices. As one design engineer said, "we'll win [the contract] on technology if the price doesn't kick us out." Our data collection over the 18-month period consisted of three waves of 22 total individual and team interviews. DISKCO is one division of a multinational computer manufacturing company that manufactures disk drives for mainframes, minicomputers, and workstations. We studied the efforts of DISKCO's manufacturing engineers and IS specialists to develop an effective CIM system to support a new assembly line that manufactures 1-2GB disk drives for workstations.

One of the most potent examples of the power of strong external belief systems comes from the AIRTECH case. AIRTECH used a complex computerized scheduling and logistics system to tightly couple many different factory activities. This Manufacturing Resource Planning (MRPII) system used assumptions about how long it takes to build certain parts, how long it takes to move parts between areas, and how many usable parts are output to tightly coordinate activities. One set of mid-career operations managers, fresh from their professional seminars on "just-in-time" manufacturing, reduced many of these systems assumptions to overly optimistic levels -- what their professional ideology told them should be the case. (For example, they reduced the parameters for the times to move materials between

work centers to zero). Short term schedule improvements turned into long term chaos, and the operations managers were eventually dismissed (Allen et al, 1994a).

AIRTECH offers an extreme example of how institutionalized beliefs about ideal forms of managing that are legitimate in managerial worlds can cause coordination difficulty. Another kind of institutional problem is seen in the DISKCO case. A shop floor control system designed that it would be used by skilled workers who needed little monitoring caused new coordination problems for another DISKCO division that adopted the system (Allen et al, 1994b). Complex computer systems for manufacturing coordination tightly link groups together. These tight linkages contribute to inertia (Beuschel and Kling, 1992), somewhat reduce local experimentation (Allen, 1992), and create a new set of horizontal coordination and control needs that is open to institutional clash (Allen, 1994b).

These horizontal linkages are complicated by the multiple institutional forces that manufacturers have to answer to, or try to take advantage of, simultaneously. Manufacturers answer to multiple sets of government regulators for labor issues, safety issues, and business law; multiple customers, each with their own requirements for quality and product flexibility; and multiple professional organizations, each with their own growing body of dogma. We found these partially competing logics permeating our two major case sites (Allen et al, 1994a; Allen et al, 1994b). Also, as organizations face more intense time and cost pressures, they tend to make more use of available institutionalized packages such as temporary workers, or standardized software (Allen et al, 1994b). This process leads to a new institutional challenge: trying to effectively fit together fixed packages of organizational procedures from the outside world.

In our research, we also found institutional theory useful for describing how organizational actors initially choose a legitimate new form of coordination. Of the many alternatives, organizational actors tend to repeatedly select from those few options that are publicly visible, and seen as legitimate. Teams are chosen as a popular coordination mechanism, even if their primary purpose is for cost reduction rather than involvement (Allen et al, 1994a). Groups

choose to coordinate others through a computer system, rather than engaging in a process of organizational redesign (Allen et al, 1994a; Allen, 1992). Understanding the process of choosing coordination methods is an important part of accounting for IT's role in manufacturing coordination.

In sum, institutional theory allowed us to account for how external belief systems could become a significant force in coordination change, the tensions between different external logics that permeated the organizations, and the particular mechanisms used to choose new coordination techniques. Institutional theories expanded our ability to account for coordination issues that lie outside organizational boundaries. Institutional theories also gave us a way of understanding how different groups rely upon different logics of coordination, rather than sharing a common unifying logic.

Structural Contingency Theory

Structural contingency theory views organizations as bureaucracies designed to complete tasks. The structure of any particular bureaucracy is determined largely by the uncertainty involved in their formal tasks (Galbraith, 1977). The greater the task uncertainty, the greater the amount of information processing required. Each kind of coordination structure, from standardized rules to cross-functional teams, can cope with a different level of uncertainty at a specific cost to the organization. Structural contingency theory is the behavioral perspective most closely associated with an information-processing view of coordination.

In our research, we found structural contingency theory most useful for characterizing the internal technical needs of manufacturers for coordination. While institutional theory provided a better explanation of why particular coordination methods were selected and used in the AIRTECH case (Allen et al, 1994a), structural contingency theory was able to explain the technical reasons why certain coordination choices were able to persist or perish. Structural contingency theory provides the vocabulary--task uncertainty, interdependence, and complexity--for discussing generic technical needs for coordination (Allen et al, 1994a). It

explains the most when there are strong technical demands on interdependent tasks, but (perhaps surprisingly) many manufacturing activities do not have strong technical demands. With its emphasis on information processing in the organization, however, structural contingency theory views can lead to an overemphasis on coordination as formal information exchange, instead of the interconnection of distinct groups (Beuschel and Kling, 1992).

Resource Dependency Theory

Finally, resource dependency theory holds that organizations obtain resources from their environments for survival (Pfeffer, 1982). According to resource dependency theory, organizations respond most readily to the demands of outside organizations that control critical resources. Groups within organizations who manage relations with powerful external organizations gain internal influence. Organizations strive to increase their autonomy relative to powerful organizations in their environment, and organizational sub-units seek autonomy from each other.

Resource dependency theory, despite its early promise, was not used much by AIME research. AIME researchers did see some early examples of manufacturing coordination where resource dependency would appear to be an issue. The question of standardized computer systems is a resource dependency issue, both within and between firms. For example, one powerful customer demands the use of a standard CAD package, while another customer demands an entirely different package with different systems needs. Internal groups can be reluctant to become dependent on a shared, centralized system under the control of other groups. Despite this seemingly natural desire for autonomy, what remains to be explained is the incredible extent to which computerized coordination is creating new interdependencies between groups in manufacturing (Allen, 1994a), and the extent to which separate groups have been receptive to this linkage (Allen, 1994b). Autonomy-seeking does not seem to be a powerful explanatory tool across our multiple cases.

IT and the Balance between Internal and External Coordination Costs: An Institutional Economics Perspective

Theoretical perspectives from institutional economics forms the other, complementary set of theories for AIME project research. Economic theories examine optimal ways to allocate resources under uncertainty and under the assumption that actors are individual utility maximizers. Institutional economic theories seek to identify effective ways to coordination and govern groups of economic agents in their transactions with each other (Kling et al, 1992).

Economic perspectives generally assume that agents behave opportunistically and rationally in their own interests. Organizations, markets, and institutions provide incentive and enforcement mechanisms for governance. The choice among governance mechanisms, as well as their structure and effectiveness, are dependent on the costs of the underlying processes. To the extent that IT affects the governance processes in organization, institutional economics perspectives can show how IT influences changes in organizational structure and performance.

Gurbaxani and Shi (1992) developed a comprehensive theory of the impact of IT on coordination in manufacturing organizations. This theory, based on the institutional economics perspectives of agency theory and transaction cost economics, provides a set of hypotheses about the impact of advanced manufacturing information technologies on coordination, and its resulting influence on organizational structure, processes, and performance.

In the Gurbaxani and Shi framework, manufacturing firms strive to select the incentive and governance structures that maximize economic returns. Manufacturing costs are determined by the sum of internal coordination costs, external coordination costs, and operations costs. Internal coordination costs are the combination costs incurred due to goal differences between economic principals and the agents they hire (agency costs), and the costs of making decisions

with less than perfect information (decision information costs). According to agency theory, decision rights in an organization should be located where the total internal coordination costs are minimized. External coordination costs are the sum of costs associated with establishing and maintaining contractual relationships with other parties (contractual costs), and the costs resulting from losses of operational efficiency (operational costs). Operations costs refer to all other non-coordination costs, such as production.

The Gurbaxani and Shi framework predicts the following organizational outcomes from the use of IT for coordination. Coordination through IT will lead to the use of more performance-based compensation schemes. IT use will also lead to a flattening of organizational hierarchy. The reduction in internal coordination costs leads to a larger firm size, especially horizontal firm size. Effects on the location of decision rights are more complicated, since IT-based coordination tends to reduce both agency and decision information costs, potentially leading to increased decentralization or centralization, depending on other contextual factors. Changes in vertical firm size are also contextually dependent, since IT-based coordination leads to a simultaneous reduction in internal coordination costs, and the external coordination costs of using market-based mechanisms.

In practice, however, IT use has been broadly correlated with a decrease in firm size (Brynjolfsson et al, in press). The decrease in firm size across a variety of measures--number of employees, revenues, and value-added per firm--suggests a decrease in both horizontal and vertical firm size. According to the Gurbaxani and Shi framework, this appears to make reductions in external coordination costs a more powerful explanation of economy-wide changes in firm size than reductions in internal coordination costs. However, as Brynjolfsson et al (in press) argue, even if both internal and external coordination costs decrease relative to production costs, firms will favor the use of external markets to coordinate rather than their own internal hierarchies.

AIME project research has developed new institutional economy theory to better explain the complexities of reduced coordination costs. For example, a reduction in coordination costs

due to IT should lead firms to increase the number of suppliers they use. While there is evidence of increases in outsourcing, we find that leading firms in many industries are using fewer suppliers. (Bakos and Brynjolfsson, 1993a).

The key to understanding this anomaly is to add the problem of incentive to a theory of coordination costs, particularly the supplier's incentive to invest in activities which improve quality (Bakos and Brynjolfsson, 1993a; Bakos and Brynjolfsson, 1993b; Bakos and Brynjolfsson, 1993c). By decreasing the number of suppliers, the buyer makes the relationship more permanent by making it more difficult to switch to alternative suppliers. The stability in the relationship gives the supplier the incentive to make "non-contractible" investments in quality, or investments that are difficult to specify and verify in contracts. Because the use of IT has increased the importance of product quality, this theory predicts that many firms will use fewer suppliers even when search and coordination costs are low.

This same analysis of the new importance of reward and incentive can be applied within the firm as well, to the relationship between managers and operators. The initial survey research indicates that the extremely dynamic computer disk drive industry has reduced the relative importance of individual production quantities, and has begun to reward behaviors which are difficult to quantify. As job design moves from individual operators to more of a team and process centered model, firms are most interested in rewarding skill acquisition and retention. This is despite the fact that CIM technologies are providing greater information than ever before on the details of the production process. Firms in these dynamic industries are more likely to make "non-contractible" investments in their labor force, such as training, and treat operators as less of a commodity.

EMPIRICAL RESEARCH ON COORDINATION

AIME project research has used the theoretical research described above to guide its empirical investigations of how manufacturers use IT to coordinate in practice. The empirical research, which integrates the results from the case studies and the pilot surveys, documents both the

potential for IT to solve existing coordination problems, and to create new coordination problems that are sometimes easier, sometimes harder to solve.

How Do Organizations Use IT to Solve Coordination Problems?

There is widespread agreement that IT has the potential to solve important coordination problems. The economy-wide reductions in US firm size (Brynjolfsson et al, in press) suggest that IT use is already enabling new ways of organizing that emphasize the use of network and market based coordination mechanisms.

The ways that IT is used to solve coordination problems in manufacturing are illustrated by the AIME project's long-term study of AIRTECH. In the AIRTECH case, we sought to explain the adoption of new coordination practices that fall under the label "World Class Manufacturing" (Allen et al, 1994a). Many of these World Class Manufacturing techniques were being proposed as solutions to the problems of poor coordination in US manufacturing, which had become a leading explanation of poor US manufacturing performance in the 1980's. The ideal descriptions of these techniques, from just-in-time inventory control to concurrent engineering, suggest that they increase the quality of coordination between value-adding production activities.

The case study looked at the adoption of three coordination reforms--lead time reduction through MRPII systems, core competencies through manufacturing cells, and cross-functional teaming. Each of these coordination reforms solved key coordination problems for the organization (Allen et al, 1994a). The MRPII computer system allowed operations management to quickly modify the assumptions built into the scheduling model across the entire organization. The manufacturing cells allowed AIRTECH to easily identify parts that fell outside of their core competencies, and thus could be outsourced. And the cross-functional teams enabled the early and continuous involvement of many functional areas in group projects. Coordination reforms which help the organization allocate and schedule,

identify key products and processes for further improvement, or enhance communications are likely to solve some existing coordination problem. Clearly, information technology has the ability to contribute to all three of these possible kinds of solutions.

In another extended case study of a disk drive manufacturer, DISKCO, IT was able to help the organization coordinate in a different way. DISKCO required substantial improvements in both its production and coordination capabilities because of severe new market demands. The lifetime of products in their industry was being reduced from 5-7 years to 12-18 months. DISKCO's existing means of coordinating design, production, and sales were not intended to deal with this kind of time pressure, and a solution had to be found quickly, under severe resource constraints and a shrinking profit margin. Much like a design engineer might turn to an industry standard part, rather than custom designing in-house, when time is short and costs must be low, DISKCO changed its policy to buy as much standardized software and automated tooling from the outside world, rather than designing them in-house (Allen et al, 1994b). These standard solutions allowed DISKCO to resolve an important, recurring coordination problem--how to bring up a new assembly line in a fraction of the time and cost of its traditional methods, involving many different functional areas and activities.

What New Coordination Problems Does IT Raise?

Each of the preceding cases above revealed a number of fundamental strategies for coordination improvement, the possible role of IT in those improvements, and the actual use of IT for such improvements in selected firms. However, while IT use solves some coordination problems, it also raises other new coordination problems. These new coordination problems are sometimes less important than the ones they help solve. However, sometimes they are so new or unconventional that they make the original coordination reform unsustainable (Allen et al, 1994a). What makes some of these new coordination problems especially difficult is that they are often new types of problems, which conventionally organized manufacturing firms have little experience coping with.

Though specific coordination reforms are often described as changing the amount or quality of coordination, it may be more useful to view them as transformations, or transforming the set of coordination problems faced by the organization (Allen et al, 1994a). Particularly as coordination problems become more complex and interdependent, transformations from one set of coordination problems to another may result in a new set of issues that may be less tractable for the organization.

In the work on supplier relationships described above, the ability of IT use to reduce the coordination problems of outsourcing brings an entirely new kind of coordination dilemma to the surface. How can we ensure that suppliers will participate in necessary, but difficult to verify, mutually beneficial investments? (Bakos and Brynjolfsson, 1993a) The problem of coordinating incentives to invest appears to be more challenging than the old coordination problems of finding suppliers in directories and paying the bills, if for no other reason than firms have less experience with managing this problem.

In the AIRTECH case, each of the coordination reforms created its own new set of coordination problems. In the case of cross-functional teaming, career paths and job performance evaluation were more problematic because both the cross-functional team and the traditional functional area was involved. When conflicts arose between different cross-functional teams, there was less of a clear hierarchy for resolving disputes. However, these new problems were less critical than the gains from early cross-functional communication. In the case of the MRPII scheduling system, AIRTECH faced the difficult task of how to coordinate belief systems. The belief systems of operations management worked to unilaterally change the assumptions built into the factory scheduling model, with ultimately disastrous results (Allen et al, 1994a). Operations management, fresh from a just-in-time seminar, decided to reduce the move and queue times in the scheduling model to zero, in accordance with what they saw as good just-in-time practice. Instead of encouraging reduced cycle times, the changes to the model, without corresponding changes in shop floor practice, made scheduling priorities even more unstable. AIRTECH fell further and further behind schedule.

It was clear that AIRTECH had no developed means of discussing or challenging these assumptions--they could only wait until the daily production situation deteriorated to the point where new operations management people were brought in. Despite the coordination gains of instantaneous, uniform updating of schedules and scheduling assumptions, AIRTECH was much less experienced with the problem of reconciling strong world views, and the effort to reduce lead time by modifying the MRPII systems was scaled back considerably.

The DISKCO case illustrates a new set of coordination dilemmas created by what we refer to as the *off-the-shelf* organization (Allen et al, 1994b). When the technical demands of a market or key customers increase dramatically, organizations turn to pre-existing pieces of institutionalized practices (such as temporary workers) and technologies (such as standardized software packages). The set of coordination problems in this case shifts in emphasis from coordinating traditional production and administration activities to coordinating the combining and fitting of standardized organizational parts, imported from the outside world, that may have partially competing logics (Allen et al, 1994b).
At DISKCO, both temporary workers and the purchase of sophisticated automated tooling from the outside world were pursued as strategies for ameliorating tough coordination problems, yet their presence together created predictable tensions. A new software package, brought in from another division, made the skills developed on an internally developed system obsolete. DISKCO employees had spent years learning how to do ad-hoc data queries with their homegrown system. The new system, however, used an industry-standard database that DISKCO workers were unfamiliar with. The lack of programmers and users with the skills to use the new system reduced their access to important production data. Though DISKCO reaped tremendous coordination gains from using these standardized organizational pieces, by reducing the time to bring new products to market, they are still inexperienced with the new problems of coordinating the different pieces.

Other new coordination problems associated with IT relate to the infrastructure and skills required to make technology-centered visions of coordination work smoothly. Though a vision such as Computer-Integrated Manufacturing might emphasize coordination through

cross-functional database linkage, this linkage requires significant amounts of resources and attention that often are not planned for, talked about, or sometimes even possible in an era where all organizational activities labelled as "support" are being cut from manufacturing budgets. A simple view of computerized coordination as a lower cost replacement for other organizational means of coordination, as in the example of a configuration management committee in the AIRTECH case, unrealistically discounts the amount of continuing human effort needed to coordinate (Beuschel and Kling, 1992). What kinds of coordination are viable depends on the existing institutionalized social arrangements? An increasingly centralized vision of IT-enabled coordination also contributes to inertia and reduced organizational experimentation, when more functional areas have to approve of all changes (Allen, 1992). Changing a particular technology is much faster than changing the skill and experience base that makes a technology useful for the manufacturing organization.

Addressing the New Coordination Dilemmas: Design for Organizational Usability

Some of the new coordination dilemmas posed by IT, such as a society-wide lack of key technical skills or an increase in quality awareness, cannot be solved by the individual manufacturing organization. However, other coordination dilemmas can be anticipated, given an understanding of the organization's history and configuration. Some of IT's coordination dilemmas can be partially managed by involving key organizational actors in a joint process of organizational and technological design, informed by behavioral theory. One method the AIME project has explored to address these problems is "design for organizational usability".

"Systems usability" refers to how well people can actually exploit a computer system's intended functionality. Usability can characterize any aspect of the ways that people interact with a system, even its installation and maintenance. There are two aspects of IT usability—interface and organizational. Interface usability is centered around an individual's effective adaptation to a user interface, while organizational usability is concerned with how computer systems can be effectively integrated into work practices of specific organizations.

While the Human-Computer-Interaction (HCI) research community has helped pioneer design principles to improve interface usability, organizational usability is less well understood.

"Design for organizational usability" is a new term that refers to a process of designing computer systems so that organizational usability is the key focus of design (Kling and Elliott, 1994). It includes, but goes beyond, the focus on user interfaces which is the subject of "design for usability" as currently understood in the HCI community. "Design for organizational usability" includes designing the infrastructure of computing resources that are necessary for supporting and helping people learn to effectively use systems. It encourages system designers either to accommodate to people's mix of skills, work practices, and resources, or to try to systematically alter them.

"Design for organizational usability" can be applied to the selection and integration of existing computer systems, or to the design of new systems, to improve the likelihood that people will use them effectively. Coordination issues within an organization's various departments are considered when designing for organizational usability, including: the design of the infrastructure of computing resources which are needed to support and coordinate various groups of users; the appropriate "fit" of computer systems into workers' mix of skills, work practices and resources; and the compatibility of data linkages and architectures between groups within an organization.

The motivation for "design for organizational usability" comes from the technical and organizational complexity of manufacturing firms which we have observed in our AIME project case studies. The collection of computing systems in a medium to large scale manufacturing firm are likely to be complex, both individually and as linked together. It is common for such systems to be ineffectively used by an organization in a way that does not realize the system's full potential. For example, CIM software may include an end-user database reporting package, but if it physical location in an organization is inaccessible to most employees, then many people who might benefit from this reporting facility are unable to do so. Reasons for ineffective use include poor user interface design; lack of adequate training; missing or unnecessary functionality; and/or a lack of coordination of systems usage

by varying groups within an organization such as marketing, engineering, information systems (IS), manufacturing, distribution, and sales. The first two reasons for ineffective use are examples of traditional interface usability. In contrast, the second two are concerned with organizational usability. They involve training, and the facilitation of effective systems use in real working environments. The techniques associated with "design for organizational usability" are described in more detail in (Elliott et al, 1994).

IT CAN FACILITATE OR COMPLICATE COORDINATION IN SOCIALLY AND ECONOMICALLY COMPLEX SETTINGS

AIME project research has identified many specific kinds of coordination changes in manufacturing firms using IT, and has explored a set of economic and sociological concepts for explaining these changes. In this section, we summarize two main themes of our research. First, the explanations we have found most useful regarding how changes in coordination are actually taking place, and the role of IT in those changes. Second, describing the balance of new coordination opportunities and new coordination problems that are commonly found in IT-using organizations.

Environmental Demands Influence IT in Manufacturing Coordination

The starting point of AIME research was that information technology could play an important role in changing coordination, a role that needs to be investigated and understood. However, changes in coordination behavior are heavily dependent on existing features of the organization, and its environment. Inherent technological capabilities, we find, are selectively invoked and maintained by social and economic logics in the organization. Our research results are consistent with the claim that behavioral theories of coordination activity are needed to cope adequately with the new organizational challenges of coordination change.

AIME project research supports the contention that theories which take seriously the open systems nature of organizations (Scott, 1992; Kling and Jewett, 1994) are indispensable for describing changes in coordination. Both the institutional economics and organizational sociology perspectives foreground the dilemmas of coordinating multiple streams of activity, performed by individuals and groups with conflicting preferences. Despite their differences, institutional economics and organizational sociology share a fundamentally human concern with incentive and payoff, obligation and reciprocity.

Of all the open systems perspectives described, which ones "best" answer the question of how coordination changes? The answer depends, of course, on which question you most want to answer. Each of the theoretical perspectives used by the AIME project focuses on only a few significant parts of the larger coordination picture. The institutional economics perspectives used here are particularly appropriate for questions of incentive, monitoring, and contract enforcement. The organizational sociology perspectives are more useful for questions of group belief and power struggles. The key observation here is that "coordination" is defined so broadly that many different questions can be asked. Even questions that are largely unrelated.

The fundamental assumptions of each type of theory, however, define the limits of their practical usefulness. If a situation can be adequately described by utility maximizing individuals pursuing defined costs and benefits, economic perspectives have insight. If group phenomena, or group membership, is important, a sociological theory opens the possibility for that kind of analysis. These theoretical assumptions also suggest limits in practical use. In the AIRTECH case, the focus on taken-for-granted beliefs in institutional theory was more useful for describing the process of group selection and consensus around a particular reform than the more task-minded structural contingency theory. Structural contingency theory better explained the recurring technical barriers to the sustainability of some of the new coordination reforms (Allen et al, 1994a).

This observation leads us to the most important tool we have discovered for evaluating the relative explanatory power of these theories: the nature of the environmental demands. Scott and Meyer (1991) define two different dimensions to environmental demands: technical demands, and institutional demands (Allen et al, 1994a). All organizations face technical and institutional demands from their environments, though to varying degrees. In technical environments, organizations are rewarded for effective and efficient control of their production systems as their products or services are exchanged in a market. In institutional environments, organizations must conform to an elaborate set of rules and requirements if they are to receive support and legitimacy. Institutional requirements may come from regulatory agencies, professional or trade associations, or from general belief systems held by society. A computer chip manufacturer in a commodity market may only strong technical demands. A public school may face only strong institutional (regulatory and formal education) demands. A bank in a highly competitive market may face both strong technical demands (from customers) and strong institutional demands (from government regulators).

To the extent that organizations face strong technical demands, rational perspectives on organizations (such as agency theory, transaction cost theory, and structural contingency theory) will have the most explanatory value (Scott, 1992). To the extent that organizations face strong institutional demands, natural perspectives on organizations (such as institutional theory, and resource dependency theory) will have the most explanatory value. This hypothesis is consistent with the results reported in (Allen et al, 1994a).

Manufacturing firms are typically seen as having strong technical environments, and relatively weak institutional requirements. Thus, rational theories should have the most explanatory power. AIME research suggests, however, that many manufacturers, particularly high tech manufacturers in industries such as aerospace and health care, also face very strong institutional demands (Allen et al, 1994a). These surprisingly strong institutional demands, which are increasing, imply that accounting for coordination changes will increasingly require natural, as well as rational, perspectives on organizations. Even in manufacturing industries with only strong technical demands, however, we have found that large increases in the

severity of technical demands force organizations to turn to institutionalized coordination methods from the outside world, in a process that is best understood through natural perspectives (Allen et al, 1994b).

The special role of IT in these coordination choices is best understood in terms of how they tend to shift key parameters in the existing economic and social logics of the situation. In the Gurbaxani and Shi (1992) framework, IT plays a role in shifting internal and external coordination costs. Some of the impacts will likely be unidirectional, such as the increase in output-based compensation schemes. Others, such as the relative decrease in internal vs. external coordination costs, are more dependent on the particular set of choices, previous commitments, and features of the environment in any particular situation. In institutional theory, the role of IT as an embodiment of a particular belief system is essential in describing its coordination impacts. Institutional theory highlights the importance of the inherent attributes of a technology, but in this case it is the ability of IT to embody a particular set of values, and a definition of reality, rather than a generic ability to store, process, and transmit more information (Allen et al, 1994a). The role of IT in coordination change is a tendency to shift key parameters in important pre-existing behavioral logics.

IT is Most Difficult to Use When Organizations Need it Most: Opportunities and Challenges of IT in Practice

In evaluating the costs and benefits of using IT to change coordination, researchers have understandably emphasized the obvious potential benefits. Many problems of coordination can be framed in terms of formal information exchange, and formal information processing--scheduling, communication, and simulation are a few examples. We have seen in our cases a significant number of opportunities for improving coordination through the application of IT's increased storage, processing, and networking power.

Information technology by its very nature, however, is a technology that opens up significant new coordination challenges. Unfortunately, these costs are often harder to see for those analyzing the problem than the benefits. They are also difficult to manage, because

manufacturers typically have less experience with these coordination problems. The practical challenge of IT is to ensure that it solves more important coordination problems than it creates.

The coordination challenges most often mentioned in the context of IT use have to do with issues of infrastructure and skill (Kling, 1987; Kling, 1992a). The use of IT, particularly complex sets of multiple ITs joined together, requires a massive infrastructure of support and services that must be coordinated and maintained. Computer hardware and software costs are only a small fraction of the total "costs" of keeping IT running smoothly, and are increasing. Complex IT tends to demand new skills, both conceptual and technical, that are difficult to acquire and maintain. Because these coordination activities are often seen as "indirect", or "support" activities, they are particularly difficult to maintain and coordinate. Manufacturing is no exception to this. Indeed, the hostility towards "support" activities is probably even more intense than in other economic sectors.

Perhaps a more important new coordination challenge found in AIME project research is the problem of coordinating "worldviews". Coordination takes place between different groups, and individuals (Beuschel and Kling, 1992). IT has the potential to embed particular organizational values, both in terms of the resources and skills it requires to be maintained, and in the very design assumptions used in the definition of data models, access rights, and data policies. Through the viewpoint of institutional theory, many groups tightly coordinated through IT must also align the working assumptions built into the system. Through agency theory, the emphasis on tighter output monitoring begs the question of what exactly should be monitored, and how, since people have a strong tendency to work to what is measured, rather than what management intends (e.g., Grant et al, 1988). The coordination of assumptions is a particularly difficult coordination problem because it explicitly focuses on differences in purpose. When combined with a dependence on distant technical personnel, and a tight interlinkage with other groups that makes agreement on change difficult, the strong embedding of organizational assumptions makes for a particularly troublesome new category of coordination problems. The AIME project techniques of "design for organizational

usability" are intended to address some of these new coordination dilemmas (Elliott et al, 1994).

CONCLUSION

The AIME project has engaged in a multi-year research study of the role of IT in manufacturing coordination. The role of IT is best seen as introducing powerful new capabilities and constraints to an existing world of strong economic and social logics. Understanding the organizational challenges of these changes is possible with the use of behavioral theories from the social sciences.

Observers are often enthusiastic about the tremendous potential of IT to change manufacturing coordination for the better. This enthusiasm for new technological capabilities is understandable, but history suggests that the design, implementation, use, and impact of IT is shaped in important ways by established patterns of institutional behavior. AIME project research has investigated this process through the use of theoretical perspectives from institutional economics and organizational sociology.

The AIME project research on the role of IT in manufacturing coordination has been exploratory. However, the results from our multi-year study have been strongly consistent with the following claims:

1. *Efforts to improve coordination through IT need for a behavioral as well as an information-processing view of how IT changes coordination in practice.*

   Information-processing views of coordination change show how inherent attributes of IT directly improve organizational performance by solving key coordination problems of scheduling, synchronizing, and allocating. This information-processing view, however, gives us an incomplete understanding of how to cope with the chronic

organizational problems involved in changing coordination practice within a world of powerful social and economic logics.

2. *The explanatory value of different behavioral theories of coordination depends on the nature of the environmental demands faced by an organization.*

   Rational systems perspectives on organizations, such as agency theory and structural contingency theory, explain coordination behavior in the face of strong technical demands. Natural systems perspectives on coordination, such as institutional theory, explain coordination behavior in the face of strong institutional demands. We find institutional demands to be surprisingly strong in manufacturing firms.

3. *IT can be used to solve many existing coordination problems without any substantial side effects.*

   This is especially the case when the problems and technologies are simple and straightforward. For example, IT has played a useful role in communicating production schedules, cross-functional team communications, and the ability to link organizational groups together to reduce new product and process introduction times. Standardized IT systems also allow organizations to dramatically change production processes quickly, at a low up-front cost.

4. *As coordination problems become more complex and interdependent, so often do the information technologies intended to solve them*.

   In such instances, it is more accurate to speak of the use of IT as *transforming* one set of coordination problems into another set of coordination problems. The new set of coordination problems may be more or less tractable for the organization. The "irony" of IT and coordination is that the new kinds of interdependencies created by the sustained use of IT may, in some circumstances, be more difficult to coordinate than the original problems IT use was supposed to address.

5. *The implementation of IT-based coordination technologies is easier when the new coordination problems do not face strong institutional demands.*

IT-based coordination can bring to the surface the difficult problem of coordinating different "worldviews" and incentives, both within the organization and from outside professional and regulatory bodies. For example, centralized databases and close IT-mediated supplier relationships reveal differences in fundamental assumptions that have to be coordinated. Much of the difficulty is due to the relative inexperience organizations have in dealing with these new coordination problems. New design techniques and new institutional arrangements for organizational usability have the potential to make these coordination problems much less severe.

6. *The theoretical flexibility of IT makes it especially attractive when the dynamism of changing organizational practices can benefit from quick changes in information formats and information flows.*

However, the actual implementation of IT-based coordination technologies locks in many specific design choices which can require substantial skilled labor time to renovate. Thus, IT use for coordination is more smooth when the formal, technical demands of production are clear, and do not create fundamentally new kinds of social and economic interdependencies. Even in these cases, however, a lack of infrastructural resources for skill-building and support can, and do, hamper technical implementation, given the severe resource constraints manufacturers are facing. Changing a particular technology is much faster than changing the skill and experience base that makes a technology useful for the manufacturing organization.

7. *The use of IT for coordination is simplest in stable environments, but much more challenging in fast-moving industries.*

The more rapidly information changes, the more that manufacturers turn to IT as a coordination solution. However, the time and discipline required for computerization and automation conflicts with the need for short time to market and frequent product changes. Firms in fast-moving industries, such as disk drive manufacturing, are focusing on non-IT changes to cope with the pace of the industry. Specifically, they are changing their reward and incentive systems to encourage skill acquisition, retention, and effective use for continuous improvement. Despite the increase in detailed process information, reward systems are increasingly concerned with encouraging behaviors that are difficult to quantify.

AIME project research has begun the important work of identifying and studying these practical opportunities, and problems. These results have the following implications for manufacturing practice:

1. *Efforts to implement IT for coordination are more likely to succeed if they consider social and economic aspects.* What must be carefully considered is the extent to which proposed information technology fits the organization's coordination problems, solves those problems, and/or creates new coordination problems.

2. *The less the degree of change required by the implementation of new information technologies, the greater the likelihood of successful implementation of the technology.* However, such incremental change might be part of radical organizational change brought about by business reengineering or other broader change in management or operational processes.

3. *The key to success in implementing more advanced IT for coordination is to plan for the greater complexity and organizational impacts brought about by the technology, and to provide social and institutional supports that facilitate the organization's adaptation to these changes.* Chief among the institutional supports are adequate

financial resources, effective communication channels, and robust computing infrastructure.

The use of IT for coordination is more complex than much of the academic and practitioner literature suggests. Developing a better understanding of this complexity is the main challenge for scholars and researchers. Coping with this complexity is the main challenge for practitioners. This research is a first but important step in these directions.

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REFERENCES

Allen, Jonathan P. (1992). Enabling Participatory Design in a Hierarchical, Tightly Integrated Setting. In *PDC '92: Proceedings of the Participatory Design Conference*. M. J. Muller, S. Kuhn, & J. A. Meskill (Eds.). Cambridge, MA: Computer Professionals for Social Responsibility.

Allen, Jonathan P. (1994a). Advanced Manufacturing Technology/Computer Integrated Manufacturing (AMT/CIM): A Review of Organizational Impacts. Working Paper. Irvine, CA: Center for Research on Information Technology and Organizations, University of California.

Allen, Jonathan P. (1994b). Mutual Control in the Newly Integrated Work Environments. *The Information Society, 10*(2), 129-138.

Allen, Jonathan P., Bakos, Yannis, and Kling, Rob (1994a). Sustaining New Coordination Methods: The Case of World Class Manufacturing. Working Paper. Irvine, CA: Center for Research on Information Technology and Organizations, University of California.

Allen, Jonathan P., Kling, Rob, and Elliott, Margaret (1994b). Technology and Skills in Off-The-Shelf Organizations. Working Paper. Irvine, CA: Center for Research on Information Technology and Organizations, University of California.

Attewell, P. (1991). Skill and occupational changes in U.S. manufacturing. In P. S. Adler (Ed.), *Technology and the Future of Work*, 46-88. New York: Oxford University Press.

Bakos, Yannis, and Brynjolfsson, Eric (1993a). Why Information Technology Hasn't Increased the Optimal Number of Suppliers. In *Proceedings of the 26th Hawaii International Conference on System Sciences*, January 1993.

Bakos, Yannis, and Brynjolfsson, Erik (1993b). Information Technology, Incentives and the Optimal Number of Suppliers. *Journal of Management Information Systems, 10*(2), 37-53, Fall 1993.

Bakos, Yannis and Brynjolfsson, Erik (1993c). From Vendors to Partners: Information Technology and Incomplete Contracts in Buyer-Supplier Relationships. *Journal of Organizational Computing, 3*(3), 301-328.

Beuschel, Werner, & Kling, Rob (1992). How Coordination Processes Influence CIM Development. In P. Brödner & W. Karwowski, (Eds.), *Ergonomics of Hybrid Automation Systems-III: Proceedings of the 3rd International Conference on Human Aspects of Advanced Manufacturing and Hybrid Automation*, Gelsenkirchen, Germany.

Brynjolfsson, Erik, Malone, Thomas, Gurbaxani, Vijay, & Kanbil, Amit (in press). Does Information Technology Lead to Smaller Firms? Management Science.

Bullen, C. V. & Bennett, J. L. (1991). Groupware in practice: An interpretation of work experiences. In C. Dunlop & R. Kling (Eds.), *Computerization and Controversy: Value Conflicts and Social Choices*, 257-287. San Diego: Academic Press.

Cohen, S. S. & Zysman, J. (1987). *Manufacturing Matters: The Myth of the Post-Industrial Economy*. New York: Basic Books.

Cooper, R. B. & Zmud, R. W. (1990). Information technology implementation research: A technological diffusion approach. *Management Science, 36*(2), 123-139.

Dertouzos, M. L., Lester, R. K. & Solow, R. M. (1989). *Made in America: Regaining the Productive Edge*. Cambridge, MA: MIT Press.

Dunlop, C. & Kling, R. (1991). *Computerization and Controversy: Value Conflicts and Social Choices*. San Diego: Academic Press.

Elliott, Margaret, Kling, Rob, & Allen, Jonathan (1994). Organizational Usability of Information Systems: Strategies for Assessment. Working Paper. Irvine, CA: Center for Research on Information Technology and Organizations, University of California.

Galbraith, J. (1977). *Organizational Design*. Reading, MA: Addison-Wesley.

Grant, R. A., Higgins, A. & Irving, R. H. (1988). Computerized performance monitors: Are they costing you customers? *Sloan Management Review, 29*(3), 39-45.

Gasser, Les. (1986). "The Integration of Computing and Routine Work." *ACM Transactions on Office Information Systems*. **4**(3)(July):205-225.

Grudin, J. (1994). Groupware and social dynamics: Eight challenges for developers. *Communications of the ACM, 37*(1), 92-105.

Gurbaxani, Vijay, & Shi, Edmond (1992). Computers and Coordination in Manufacturing. *Journal of Organizational Computing, 2*(1), 27-46.

Harrington, J. (1973). *Computer Integrated Manufacturing*. Huntington, NY: Krieger.

Hayes, R. H., Wheelwright, S. C. & Clark, K. B. (1988). *Dynamic Manufacturing: Creating the Learning Organization*. New York: Free Press.

Jaikumar, R. (1986). Post-industrial manufacturing. *Harvard Business Review*, November-December, 69-76.

Kling, Rob. (1980). "Social Analyses of Computing: Theoretical Orientations in Recent Empirical Research." *Computing Surveys.* 12(1):61-110.
Kling, Rob. (1987). "Defining the Boundaries of Computing Across Complex Organizations." *Critical Issues in Information Systems*. Richard Boland and Rudy. Hirschheim (eds.) London: John Wiley.

Kling, Rob (1991). Cooperation, Coordination, and Control in Computer-Supported Work. *Communications of the ACM, 34*(12), 83-88.

Kling, Rob (1992a). Behind the Terminal: The Critical Role of Computing Infrastructure In Effective Information Systems' Development and Use. In William Cotterman and James Senn (Eds.), *Challenges and Strategies for Research in Systems Development*. London: John Wiley, 1992.

Kling, Rob (1992b). The AIME Project. I*n Coordination Theory and Collaboration Technology Workshop Proceedings.* Washington, DC: National Science Foundation.

Kling, Rob (1993). The AIME Project. *In Coordination Theory and Collaboration Technology Workshop Proceedings.* Washington, DC: National Science Foundation.

Kling, R. & Elliott, M. (1994). Digital design for organizational usability. In *Proceedings of Digital Libraries '94 Conference*, pp:146-155. John L. Schnase, John J. Leggett, Richard K. Furuta, and Ted Metcalfe (Eds.). June 19-21, 1994. College Station, TX.

Kling, R. & Iacono, S. (1984). Computing as an occasion for social control. *Journal of Social Issues, 40*(3), 77-96.

Kling, R. & Iacono, S. (1989). The institutional character of computerized information systems. *Office: Technology and People, 5*(1), 7-28.

Kling, Rob and Tom Jewett. (1994). "The Social Design of Worklife With Computers and Networks: An Open Natural Systems Perspective." in *Advances in Computers.* Volume 39. Marshall C. Yovits (ed.) San Diego: Academic Press.

Kling, Rob, Kraemer, Kenneth L., Allen, Jonathan, Bakos, Yannis, Gurbaxani, Vijay, and King, John (1992). Information Systems in Manufacturing Coordination: Economic and Social Perspectives. In *Proceedings of the Thirteenth International Conference on Information Systems,* Dallas, TX.

Knights, David and Fergus Murray. 1994. *Managers Divided. Organization Politics and Information Technology Management.* London: John Wiley.

Laudon, Kenneth. (1974). *Computers and Bureaucratic Reform.* Wiley-Interscience: New York.

Malone, T. W. & Crowston, K. (1994). The interdisciplinary study of coordination. *ACM Computing Surveys, 26*(1), 87-119.

Melnyk, S. A. & Narasimhan, R. (1992). *Computer Integrated Manufacturing: Guidelines and Applications from Industrial Leaders*. Homewood, IL: Business One Irwin.

Meyer, J. W. & Rowan, B. (1977). Institutionalized organizations: Formal structure as myth and ceremony. *American Journal of Sociology, 83*(2), 340-63.

National Research Council, Computer Science and Telecommunications Board (1994). *Information Technology in the Service Sector: A Twenty-First Century Lever.* Washington, DC: National Academy Press.

Orlikowski, Wanda J. 1993. Learning from Notes: Organizational Issues in Groupware Implementation. *The Information Society* 9(3) (Jul-Sep):237-250.

Perrow, Charles. 1986. *Complex Organiations: A Critical Essay. (3rd Ed)*. Random House, New York.

Pfeffer, J. (1982). *Organizations and Organization Theory*. Boston: Pitman.

Powell, W. W. & DiMaggio, P. J. (Eds.) (1991). *The New Institutionalism in Organizational Analysis*. Chicago: University of Chicago Press.

Roven, B. & Pass, S. (1992). Manufacturing management information systems require simplification. *Industrial Engineering*, February, 50-53.
Scott, W. R. (1992). *Organizations: Rational, Natural, and Open Systems*. (3rd edition). Englewood Cliffs, NJ: Prentice Hall.

Scott, W. R. & Meyer, J. W. (1991). The organization of societal sectors: Propositions and early evidence. In W. W. Powell & P. J. DiMaggio (Eds.), *The New Institutionalism in Organizational Analysis*, 108-142. Chicago: University of Chicago Press.

Scott Morton, M. S. (Ed.) (1991). *The Corporation of the 1990s: Information Technology and Organizational Transformation*. New York: Oxford University Press.

Shani, A. B. Robert Grant, R. Krishnan, and Eric Thompson. (1992) Advanced Manufacturing Systems and Organizational Choice: Sociotechnical System Approach. *California Management Review* v34, n4 (Summer 1992):91-111.

Sheridan, J. W. (1992). The CIM evolution: Bringing people back into the equation. *Industry Week*, April 20, 1992, 29-51.

Wagner, Ina. 1993. "A Web of Fuzzy Problems: Confronting the Ethical Issues." *Communications of the ACM* 36(4)(June):94-101.

Warner, T. N. (1987). Information technology as a competitive burden. *Sloan Management Review*, Fall 1987, 55-61.