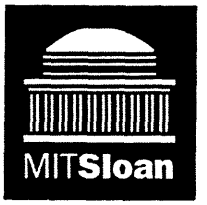

The International Center for Research on the Management of Technology

Interdependency: Conceptual, Empirical, & Practical Issues

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June 1997 **WP # 162-97**

Sloan WP # 3971

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INTERDEPENDENCY: CONCEPTUAL, EMPIRICAL, & PRACTICAL ISSUES

This paper surveys the literature on interdependency, defined as a contingent relationship among tasks or activities. It identifies three distinct theoretical paradigms about interdependence (information processing theories, resource-based theories, and theories of sense-making) and develops a multi-dimensional conceptual framework that places these competing paradigms in perspective. It also documents how researchers have measured and evaluated interdependence. The paper concludes with an overall assessment of the current state of interdependency theory and some suggestions for a new research agenda on this fundamental concept.

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June 11, 1997

1. Introduction

Many scholars have identified interdependence as a critical variable for understanding organizations. Overall, this body of research has progressed from some early ideas to a vast spectrum of work by various authors. One unfortunate outcome of this rich history, however, is a confusing multitude of conceptualizations and operationalizations. Most organization theorists adopt Thompson's basic definition of interdependency as a contingent relationship among tasks or activities (Thompson, 1967). Yet March and Simon describe interdependence as a "felt need for joint decision-making" (March & Simon, 1958), while others depict it in terms of individuals (Granovetter, 1973), departments (Gresov & Stephens, 1993), and even firms (Roth, 1995). Mitchell and Silver examine the role of goal interdependence in team cooperation (Mitchell & Silver, 1990). Ancona and Caldwell focus on the importance of external environment interdependencies for successful product development (Ancona & Caldwell, 1990). Interdependence is both a process "that happens to X over time," but it can also be viewed as a variable (tasks can be more or less interdependent) (Selznick, 1957). Interdependence sometimes appears as a task dimension (Hrebiniak, 1974; Lynch, 1974; Van de Ven & Ferry, 1980), but other times it is a variable ("task interdependence") in its own right (Allen, November 1986; Tushman, 1976; Tushman, 1978). In fact, this variety is not surprising given that interdependence is a very difficult concept to define both theoretically and operationally (Pennings, September 1975).

But as scholars we are also left with a high degree of ambiguity and confounding with respect to the concept of interdependency. Often, a single label is used to refer to a broad spectrum of interaction (e.g., Thompson's definition of internal interdependence, which includes the "exchange of resources, information, and products as well as contingencies of action") (Thompson, 1967). A variety of different terms also appear, even though they conceivably refer to conceptually and empirically similar concepts

(e.g., component interdependency (Dellarocas, 1995), subsystem interdependence (Allen, November 1986), and technical interdependence (Eppinger, Whitney, Smith, & Gebala, 1994); coordination tasks (Hauptman, 1986) and interdepartment interdependence (Adler, March-April 1995)).

Even when authors use the same terminology, they often take very different perspectives on the concept, which reflect fundamentally different assumptions about the nature of technology, organizations, and people. For example, Thompson, March and Simon, and Weick all write about "task interdependence." But whereas Thompson views it as inherent in the technology or task (Thompson, 1967), March and Simon depict interdependence as a characteristic of the way people behave and make decisions while executing their work (March & Simon, 1958). Karl Weick rejects the very notion that task interdependencies are completely apprehensible, arguing that some relationships are too complex, ephemeral, or subtle to be completely understood via rational analysis (Weick, 1974; Weick, 1990). Clearly, further use of the interdependency concept would benefit from an attempt to reconcile and understand this diversity.

A primary purpose of this paper is to review the literature on interdependency in such a way as to place competing paradigms in perspective. The contribution here is a synthesis of theory, which reconciles existing conceptualizations and identifies some assumptions taken-for-granted as well as gaps in our understanding. A second purpose is to suggest new questions and opportunities in the study of interdependency. The survey reveals that the information processing perspective originating with Thompson has heavily influenced our current knowledge of interdependence, a narrowness perpetrated by a decidedly limited range of empirical approaches to the topic.

Furthermore, although much progress has been made in our knowledge of interdependency, this existing knowledge is currently fragmented, unreconciled, and relatively simplistic. It primarily focuses on one type of interdependency at a time, embracing single elements more than the conflicts or complements among those elements. Now, therefore, represents an opportune time for new kinds of studies of interdependence in that the real world of work and organizing is getting more complicated than our existing theories acknowledge. The second contribution of this paper is thus a research agenda. In particular, it proposes creating more realistic views of interdependency through the application of more grounded methods, which enable us to move beyond current simplistic conceptualizations and begin to think about interdependence as a more multi-dimensional construct. Building a firmer foundation for this central organizational variable should, in turn, lead to its better application in normative or causal modeling efforts.

The paper begins below by outlining the overall approach to the survey, which included both a theoretical analysis and a simple quantitative analysis of citation rates (reported on in Appendix A). Section 3 describes the principal analytical dimensions of the framework before proceeding to examine how representative authors from three different perspectives have studied interdependency. Section 4 critiques the literature and offers suggestions about how we might achieve a more integrated framework. This paper also reviews the various definitions and operationalizations of interdependence used by scholars. The latter forms the basis for an assessment of the empirical study of interdependency in Section 5. The paper concludes in Sections 6 and 7 with a summary and some suggestions for future research.

2. Overall Approach to the Survey

2.1 Constructing the Analytical Framework

This theoretical review draws upon analytical frameworks developed by (Astley & Van de Ven, 1983; Burrell & Morgan, 1979; Markus & Robey, 1988; Orlikowski & Baroudi, 1991) and follows the approach taken by (Allison, September 1969; Eisenhardt & Zbaracki, 1992; Kogut, 1988; Markus, June 1983). For example, Burrell and Morgan categorized theories as functionalist, interpretive, radical humanist, or radical structuralist according to their assumptions about the nature of science and society (Burrell & Morgan, 1979). Orlikowski and Baroudi propose alternative conceptualizations of technology as a key method of distinguishing among theories (Orlikowski & Baroudi, 1991). Kogut compares three perspectives (transaction cost economics, strategic behavior, and organizational learning) on the motivation to joint venture (Kogut, 1988). Eisenhardt and Zbaracki compare and contrast dominate paradigms (rationality, bounded rationality, politics and power, and the garbage can model) on strategic decision-making (Eisenhardt & Zbaracki, 1992). These frameworks and analyses served as a starting point for examining different theories of interdependence. Figure 1 outlines the dimensions used for this comparison. The results yielded the multi-dimensional framework presented in Figure 2.

3. A Framework for Understanding Interdependency

3.1 Three Perspectives and the Analytical Dimensions

As indicated above, the interdependency literature is vast, ranging from case study illustrations to quantitative surveys, all of which span many types of technology, firms, and industries. Despite an initial appearance of randomness, a more thorough scrutiny of the literature suggests three main theoretical perspectives (information processing theories, resource-based theories, and sense-making theories), which vary along the following analytical dimensions: (1) the primary driver of interdependency

(internal technology, internal firm environment, external firm environment), (2) the structure of task relationships (sequential, pooled, reciprocal), and (3) the nature or content of tasks (loose versus tight coupling) (Figure 2). This review was shaped around these perspectives and dimensions for the following reasons.

The notion that tasks are related for a variety of different factors is well established in the organization theory literature (Bowditch & Buono, 1985; Daft, 1983). Likewise, scholars increasingly acknowledge the importance of considering theories of structure and content (Van de Ven, May 1986). Each of the three theoretical perspectives represents a relatively coherent and distinct body of research, and yet taken together they seem to capture the cumulative aspect of interdependency research to date. Moreover, these three research streams imply starkly different recommendations for the management of interdependence. Although in some sense much of interdependency theory can be traced back to Thompson (1967), resource-based views of the firm, as well as more recent research on the problems associated with sense-making under conditions of complexity, challenge some of information processing's basic assumptions.

For example, the information processing perspective portrays interdependence as clearly visible, recognizable, and stable dyadic interactions which are, therefore, amenable to integration and decision-making mechanisms that can be set up in advance. The resource-based viewpoint focuses on controlling resource allocation as the solution to issues of interdependence. The description of interdependency arising from the sense-making stream, in contrast, emphasizes our inability to comprehend and reason about the structure of certain forms of work and thus calls for more dynamic, real-time solution strategies.

FIGURE 1
DIMENSIONS OF THE THEORETICAL ANALYSIS

THEORETICAL STRUCTURE:
What are the basic underlying assumptions of this perspective in terms of the nature of technology, organizations, and people?

- Ontology: is reality objective and external to the individual or the product of individual consciousness? Can we make sense of an organization by measuring it or is it necessary to consider the way people experience it by studying their perceptions and interaction with the world (realism - nominalism)
- Epistemology: is knowledge real/hard or subjective/soft? (positivism-antipositivism)
- Human Nature: do people respond mechanistically to their environment/are they conditioned by external circumstances or are people depicted as active, creative, free willed entities? (determinism-voluntarism)
- Methodology: is the theory searching for universal laws or trying to explain and understand by getting close to the phenomenon? (nomothetic-ideographic)
- Model: does the model primarily focus on conditions/identify factors responsible for a particular outcome or does it focus on dynamics and the how and why? (factor/variance-process)
- Causal Agency: who or what is depicted as causing change? what is the relationship between technology and organizations? (technical imperative-- technology is an objective, external force that has a deterministic impact on organizations; organization or strategic imperative-- change is the product of on-going human action; sociotechnical-- technology is physically constructed through social interaction and political choices of actors; social constructionism-- shared interpretations around a technology arise and affect its development; marxism-- technology is used to further the political and economic interests of powerful actors)

CONCEPTUALIZATION OF INTERDEPENDENCY:
How do authors in this perspective conceptualize interdependency? What do they conceive of as the sources and consequences of interdependency? What factors affect the level of interdependence?

- Is interdependence an independent variable or a dependent variable?
- What are the antecedents and consequences of interdependence?
- What dimensions or constructs affect interdependence?
- What are the implicit assumptions about interdependency?

STRENGTHS AND WEAKNESSES:
What aspects of interdependency does this perspective emphasize or highlight? What does it ignore or neglect?

OUTCOMES OF PERSPECTIVE:
What sort of managerial recommendations with respect to interdependency does this perspective lead to? What are its implications for organizational design and team affect or behavior?

FIGURE 2
A FRAMEWORK FOR UNDERSTANDING INTERDEPENDENCY

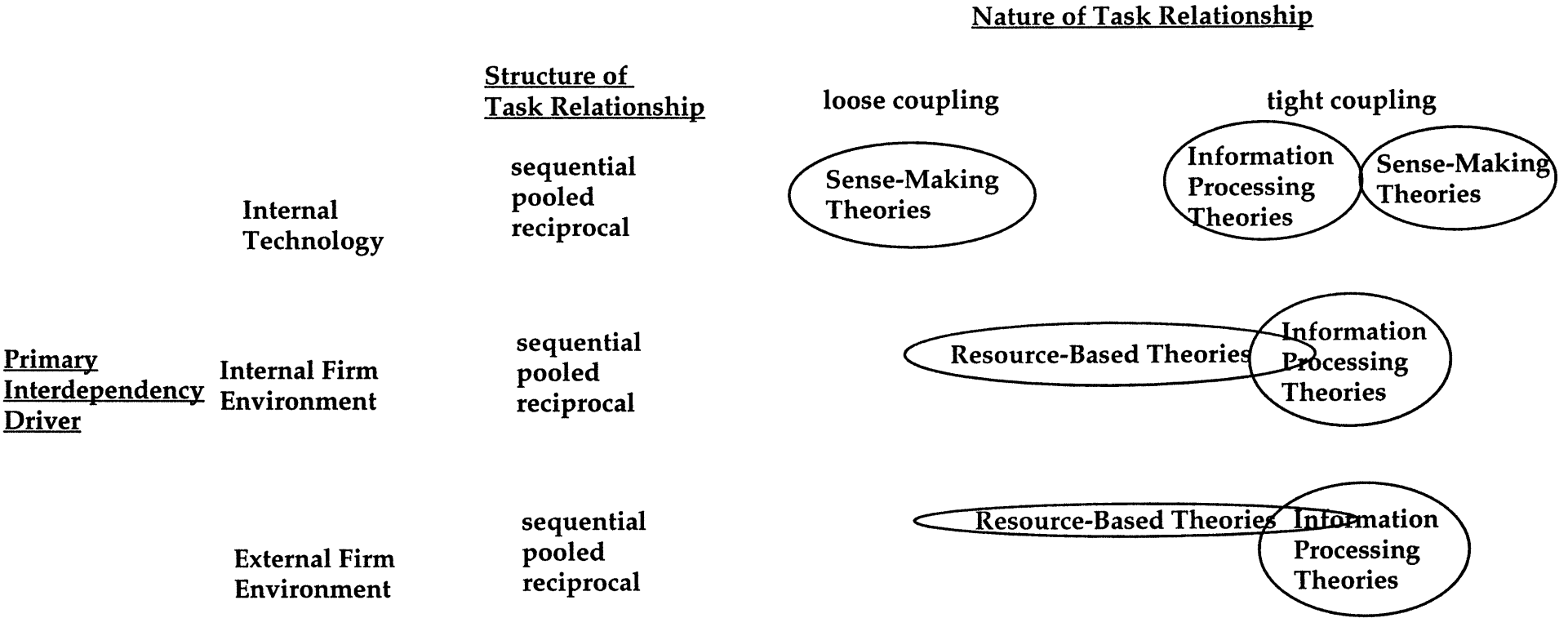

Table 1 summarizes the three theoretical perspectives along some key dimensions. The next section reviews how they each relate to one aspect of organizational life, interdependency. Each paradigm review begins by describing the basic underlying model and then discusses its variants and implications. Each concludes with a brief summary and assessment of the strengths and weaknesses of the perspective.

TABLE 1
OVERVIEW OF THREE THEORETICAL PERSPECTIVES

	INFORMATION PROCESSING THEORIES	RESOURCE-BASED THEORIES	SENSE-MAKING THEORIES
REPRESENTATIVE RESEARCH	Thompson (1967); Nadler & Tushman (1983); Tushman & Nadler (1996)	Salancik & Pfeffer (1974); Malone & Crowston (1994); Roth (1995)	Granovetter (1973); Schelling (1978); Weick (1976, 1990)
THEORETICAL STRUCTURE	realism, positivism, deterministic, nomothetic	realism, positivism, deterministic, nomothetic	nominalism, antipositivism, voluntaristic, ideographic
CONCEPT OF INTERDEPENDENCY	Interdependency as a (bilateral) pattern of tasks	Interdependency as a pattern of relationships within a given context	Interdependency as equivoqual systems of relationships
UNIT OF ANALYSIS	Tasks performed by work units, depts or indivs	Tasks performed by depts	Tasks performed by "things"
ANTECEDENTS OF INTERDEPENDENCY	Inherent in the information requirements of internal or external tasks	Uncertainty with respect to the task or environment and limited (shared) resources	Abstract nature of work; Dynamic patterns of action
CONSEQUENCES OF INTERDEPENDENCY	Uncertainty and information processing	Differences in power; conflict	Seemingly random and surprising events; An inability to comprehend and reason about work structure
FACTORS AFFECTING THE DIFFICULTY OF ACHIEVING INTEGRATION	Degree of contingency between tasks as represented by pattern of relationship	Criticality, value and availability of resource	Degree of coupling, timing and visibility
IMPLICIT ASSUMPTIONS	Pre-identifiable and stable tasks; clearly visible and recognizable patterns	Mutual agreement about what resources are most critical	Interdependencies are subjectively defined
PREDICTIONS DERIVED FROM THEORY	Tight couplings are most difficult to coordinate; matching coordination mechanisms to interdependency results in higher performance	Interdependency determines power relations and competitive advantage of firm	Loose couplings are most difficult to coordinate
REC'D FOR MGT	Adopt appropriate information processing mechanisms and structures	Control decisions about resource allocation or avoid interdependencies.	Impossible to design an ideal organization structure a prior; Individuals must act heedfully with respect to interdependency

3.2 The Information Processing Perspective

Basic Underlying Model

The information processing perspective emphasizes the uncertainty associated with performing complex tasks in a given environmental context. The most basic assumption underlying this perspective is that organizations are open systems that must process information (to accomplish internal tasks, coordinate diverse activities, and interpret an external environment) but have limited capacity to do so (Galbraith, 1973). Uncertainty is defined as "the difference between the amount of information required to perform the task and the amount of information already possessed" (Galbraith, 1973), and the technology (task) and environment are seen as the major sources of that uncertainty. Strength of interdependence between tasks, along with other task characteristics such as complexity and unpredictability, are conceived as major influences on uncertainty and hence the need for information processing. The basic underlying model of interdependency according to the information processing perspective is therefore:

Interdependency Among Internal or External Tasks ----------> Uncertainty ----------> Information Processing

Table 2 displays work representative of the information processing perspective

Variants

Internal Technical Interdependency

Early theorizing by Thompson is particularly influential within this research stream (Thompson, 1967). (Refer to Appendix A.) Thompson characterized an organization as "a complex set of interdependent parts which together make up a whole because each contributes something and receives something from the whole, which in turn is interdependent with some larger environment (p. 6)." Holding the environment

constant, he defined internal interdependence as "the extent to which a task requires organizational units to engage in work flow exchanges of products, information, and/or resources and where actions in one unit affect the actions and work outcomes in another unit" (p. 54).

TABLE 2
INFORMATION PROCESSING PERSPECTIVE, SELECTED STUDIES

Author(s)	Key Word(s)	Method	Sample	Description
Thompson, 1967	internal interdependence (pooled or generalized, serial or sequential, reciprocal)	theoretical	not applicable	classifies interdependency according to its logical structure
Van de Ven, Delbecq & Koenig, 1976	task interdependency within work units	survey	197 work units in a large state employment security agency	classifies alternative mechanisms for coordinating work activities
Tushman, 1979	task interdependence within and across sub-units	survey and communicat-ion records	44 R&D projects	relates sub-unit structure and performance with work characteristics
Kmetz, 1984	maintenance work flow	descriptive case study	7 sites in U.S. Naval Air Systems	analyzes work flow problems and informal adjustments
Allen, 1986	subsystem interdependence	theoretical	not applicable	interaction of project characteristics guides decision about organizational form
Gresov, 1990	external (work unit) interdependence	survey database	230 work units in employment security offices	explores effect of external dependency on work unit design and efficiency
Eppinger, Whitney, Smith & Gebala, 1994	technical relations among design tasks (serial, coupled, parallel)	matrix analysis	2 cases from auto industry	links structure of complex products and projects with coordination and cycle time
Wagerman, 1995	outcome, goal and reward interdependence	intervention	150 teams in large corporation	examines differential effect of task design and reward system on group effectiveness

According to Thompson, internal interdependence stems from the task requirements and can be classified according to its form or logical structure. Pooled or generalized (internal) interdependence exists when "each part renders a discrete contribution to the whole and each is supported by the whole although the parts do not interact in any direct way. ... They are interdependent in the sense that unless each performs adequately, the total organization is jeopardized" (p. 54). One example provided is the relationship between corporate headquarters and each of the product divisions of a multidivisional firm, which are mutually dependent in terms of viability. Interdependence may also take a serial or sequential form in which the output of one part is the input to another. Here "direct interdependence can be pinpointed between them, the order of that interdependence can be specified... and it is not symmetrical" (p. 54). A cited example is the relationship between production departments in a manufacturing plant. A third form of internal interdependence, labeled reciprocal, refers to situations in which the outputs of each part become inputs for the other. An example is the relationship between R&D and manufacturing in product innovation.

According to Thompson, the three forms of interdependence represent different degrees of contingency, which translate into varying degrees of coordination difficulty. With pooled interdependence, contingency is non-existent or minimal. Action in each position can proceed without regard to action in the other positions as long as the overall organization remains viable. With sequential interdependence, however, there is always an element of potential contingency since each task in the set must be readjusted if another departs from expectations. With reciprocal interdependence, such contingencies are not merely potential but actual. When interdependence is high, frequent and unexpected adjustments are needed, and uncertainty increases in the form of "constraints and contingencies;" when interdependence is low, organizational units experience greater autonomy, stability, and certainty with respect to their coordination.

In summary, Thompson conceptualized interdependence as a dyad of tasks with a definite, visible, and stable structure. That pattern arises from the nature of the tasks, and the implied level of analysis is work unit relationships (i.e., tasks are defined at the level of work units). Thompson's definition of interdependency is also one predicated on literal action; unless tasks "interact in a direct way," interdependence is assumed to be minimal. Thus, mutual or pooled relationships are depicted as lowest in the hierarchy of contingency. As described below, subsequent scholars have taken issue with this viewpoint, arguing that tasks can be highly interdependent even if they involve little or no direct interaction.

Thompson's research is purely theoretical; he includes no empirical verification of his ideas other than some general illustrative examples. However, a line of subsequent empirical research and additional theorizing lends some credence to this early work. For example, Eppinger et al. focus on the form or pattern of task relationships in complex design projects, contrasting interdependent (coupled) tasks ("when task A needs information from task B, and task B also requires knowledge of A's results"), dependent (serial) tasks ("if task B simply requires the output of task A"), and independent (parallel) tasks ("if tasks A and B could be performed simultaneously with no interaction between the designers") (Eppinger, et al., 1994). Other studies support a positive relationship between task characteristics such as difficulty, variability, and nonroutineness indicative of high uncertainty and interdependence and the amount of information processing within units (Daft & Lengel, May 1986; Gerstberger, 1971; Gerstenfeld, 1967; Tushman, 1976; Van de Ven & Delbecq, June 1974). Van de Ven et al. found that communication increased as intra-unit task interdependency among participants increased (Van de Ven, Delbecq, & Koenig, 1976). Kmetz applied an

information processing perspective in a detailed qualitative study of the repair process and maintenance work flow aboard U.S. navy aircraft carriers (Kmetz, 1984).

The above group of authors and others have followed closely in the Thompson tradition, gradually translating Thompson's term 'internal interdependence' into the more general label of task interdependence or simply interdependence but making few modifications to the basic conceptual idea in Thompson's thesis. Another common term is work flow interdependence (e.g., "the extent to which individuals are dependent on other personnel in the performance of their jobs") (Van de Ven, et al., 1976). Vaughan defines it as informational interdependencies (Vaughan, 1990). Note how we are beginning to see diversity not only in the terminology used to describe interdependency but also in the level of analysis (i.e., tasks are associated with work units or individuals).

Another group of scholars, while still remaining in the Thompson tradition, portray tasks in terms of the architecture of a problem or product. For example, Allen defines subsystem interdependence as the extent to which work on one subsystem depends upon progress on another subsystem area and argues that the degree of interdependence is determined by the complexity of the interface requirements among the different areas (Allen, November 1986). Pimmler and Eppinger studied product component interdependencies varying along four different dimensions: spatial interaction (the need for adjacency or orientation), energy interaction (the need for energy transfer), information interaction (the need for information or signal exchange), and material interaction (the need for actual physical material transfer) (Pimmler & Eppinger, 1994). Each component interaction was operationalized as a vector of four scores. Other work explores the implications of alternative product architecture on interdependency (Cusumano & Selby, 1995; Dellarocas, 1995; Henderson & Clark, 1990; Iansiti, 1994; Ulrich & Eppinger, 1995).

A search of the literature revealed a final category of information processing scholars who have sought to refine the definition of task interdependency. For example, Wagerman argues that outcome interdependency is used synonymously with task interdependency when they are in fact conceptually and often empirically distinguishable (Wagerman, 1995). Outcome interdependence, which can be further differentiated into goal interdependence and reward interdependence, may exist without any interdependence in the means of accomplishing the work (e.g., a room full of telemarketers may be held accountable for a collective goal, but they complete independent tasks) (Wagerman, 1995) and vice versa (Mitchell & Silver, 1990).

Pennings proposes four distinct bases of interconnectedness: task interdependence, rooted at the task level, refers to the inter-relationship of a set of discrete operations such that each operation may have consequences for the completion of some others; role or positional interdependence is the interconnectedness of a set of role players, reflecting the position of actors engaged in a concerted action; skill or knowledge interdependence arises from the differentiated expertise of actors due to education, training, and expertise; social (goal or need) interdependence is defined in terms of the reward system and its impact on individual motivation (Pennings, 1975).

Empirical research supports making these kinds of distinction. For example, Andres tested the differential effect of task and goal interdependence on software project success (Andres, August 25-27, 1995). Other studies suggest that group members experience task and outcome interdependency differently such that changes in one form influence the experience of the other and subsequently change the way people approach their work (Berkowitz, 1957; Guzzo & Shea, 1987).

External Environment Interdependency

The focus on internal (task) interdependence yielded a rich stream of research but also provoked a countersurgence of studies stressing the importance of external forms of interdependency. Gresov points out that the bulk of the research has been directed at documenting task-design linkages to the neglect of other important context factors (Gresov, 1990). He defines external or work unit interdependence as existing "when task performance is related to (and thus dependent on) the actions and outcomes occurring outside the unit," operationalized as the extent to which resources or information from outside sources are deemed necessary inputs to a work process (Gresov, 1989). Ancona and Caldwell define a similar concept at the group level describing external interdependence as "the external activities groups undertake in dealing with others in the organization" (Ancona & Caldwell, 1990). Other similar work is (Adler, March-April 1995; Ito & Peterson, 1986).

Gresov argues that although work unit and task interdependency are obviously related, they are distinct concepts. Work unit interdependence generally arises in connection with a unit's position in the organizational work flow whereas task interdependence arises from the content of the work flow in a particular focal unit (Gresov, 1989). Empirical research tends to substantiate this claim. Van de Ven and Ferry performed correlation and regression tests between dependency, external communication, and efficiency in a sample of employment security agencies (Van de Ven & Ferry, 1980). The results indicated that the effects of external dependency and communication varied depending on the task. In a study of R&D projects, Tushman found that both task predictors and department dependency were significantly related to structure (Tushman, 1979).

Just as we saw in the case of technical (task) interdependency, scholars have sought to refine the external interdependency concept. Some authors differentiate between different types of external interdependence depending on the hierarchical relationship of the work units involved: horizontal dependency (other units inside or outside the organization) versus vertical interdependency (higher levels within the organization) (Gresov, 1990). Tushman (Tushman, 1976) and Gerstberger (Gerstberger, 1971) use a more subjective categorization, distinguishing between organizationally "close" (outside the R&D project but within the same department) and organizationally "distant" (outside the department but within the organization) relationships. Others have suggested that there exist two layers of unit context: organizational context (composed of factors that affect the state of the organization as a whole and its interface with its environment) and inter-unit relations (the more immediate context of the unit) (Gresov & Stephens, 1993).

Implications of the Model

The primary goal of the information processing paradigm is to match the organization's capacity to process information with the information requirements of the task. This line of reasoning began with Galbraith who integrated work by others (Burns & Stalker, 1968; Lawrence & Lorsch, 1967; Perrow, 1967; Thompson, 1967; Woodward, 1965) to explain the variation in organizational form as stemming from the amount of information needed to reduce task-related uncertainty and attain an acceptable level of performance (Galbraith, 1973). The focus of the perspective is, therefore, on finding or "matching" information processing mechanisms, which are capable of coping with the level of task contingency.

For example, Thompson (1967) proposed parallels between his three types of internal interdependence and three types of coordination. Standardization, involving

the establishment of routines or rules, which constrain the action of each unit into paths consistent with those taken by other interdependent units, is appropriate for pooled interdependence. Plans, involving the establishment of coordinated schedules, address the needs of serial interdependence. Coordination by mutual adjustment, analogous to March and Simon's term "coordination by feedback" (March & Simon, 1958) transmits new information during the process of action and is thus best suited for cases of reciprocal interdependence.

Galbraith identified two general classes of solution strategies (Galbraith, 1973). Provided the interdependency is relatively simple (as is presumably the case with pooled and sequential forms), rules, programs, hierarchy, and targets or goals are usually adequate. As complexity increases, however, (e.g., reciprocal interdependence) additional mechanisms are needed to handle the information overload. One approach is to reduce the need for information processing by lowering performance standards, utilizing slack resources, or creating self contained tasks. A second category of solutions seeks to increase the organization's capacity to handle more information by investing in vertical information systems or lateral roles. That is, one increases the amount of information flowing across the interdependency in order to make coordination more efficient.

The large body of research on task partitioning adheres to the reductionist approach (Alexander, 1964; Eppinger, et al., 1994; Simon, December 1962; Von Hippel, 1990). These theorists propose that organizational work can be divided up (partitioned) into a number of sub-tasks in such a way as to reduce the problem solving interdependencies among them. For example, Von Hippel argues that interdependence can be reduced via alternate specifications of the task-- in other words, task partitioning

is a manipulatable variable (Von Hippel, 1990).[1] Simon theorized that partitioning work into hierarchical systems, defined as subsystems that in turn have their own subsystems, represented one such solution:

> Hierarchies have the property of near decomposibility. Intra component linkages are generally stronger than inter component linkages. This fact has the effect of separating the high frequency dynamics of a hierarchy-- involving the internal structure of the components-- from the low frequency dynamics involving interaction among components (Simon, December 1962).

Building on work by Steward (Steward, August 1981), Pimmler and Eppinger describe a technique called the Design Structure Matrix (DSM) for capturing the complex interactions between components of a product design and finding alternative sequences and definitions of tasks (Pimmler & Eppinger, 1994). (See also (Eppinger, et al., 1994; McCord & Eppinger, August 1993; Morelli, Eppinger, & Gulati, August 1995; Smith & Eppinger, December 1994).)

Examples of the capacity-increasing approach are increasing the capacity of existing channels of communication, creating new channels, introducing new decision-making mechanisms, or utilizing direct contact, liaison roles, task forces, teams, integrating roles, and matrix designs (Galbraith, 1973). For example, when task interdependence is high, information processing tends to shift from impersonal rules to personal exchanges including face-to-face and group meetings such as task forces and committees (Van de Ven, et al., 1976). Van de Ven et al. show how impersonal, personal, and group modes of coordination vary with increased task interdependency (Van de Ven, et al., 1976). Daft and Macintosh found that managers favor rich

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[1] Though he later notes that such partitioning changes will not necessarily reduce the total amount of interdependency, they simply affect how it gets distributed. This point represents an area of active debate among theorists. Some scholars argue that the total amount of interdependency is fixed while others argue that it can be reduced.

communication media such as face-to-face meetings and telephone conversations for difficult and equivocal messages over other forms of communication such as impersonal memos and documents because the former allowed for greater feedback, cues, and language variety (Daft & Macintosh, 1981).

Examples of full-time integrators are product and brand managers (Lawrence & Lorsch, 1967) and gatekeepers (Allen, 1977). Ancona and Caldwell identified a set of boundary spanning roles that new product development teams rely on to interact with their environment (Ancona & Caldwell, 1987; Ancona & Caldwell, 1990). Task coordinator involved coordinating technical and design issues, scouting consisted of general scanning for useful information, and guard activities were those intended to avoid the external release of proprietary information. Adler presents a taxonomy of design-manufacturing mechanisms which distinguishes four modes of interdepartmental interaction (standards, schedules, mutual adaptation, and teams) in each of three temporal phases (pre-project, product and process design, and manufacturing) (Adler, March-April 1995). Research in the auto industry also tends to support the contingency hypothesis in that teams which adopt mechanisms of "integrated problem solving" (e.g., overlapping problem solving phases, frequent and continuous communication, cross-functional structures) show improved performance (Clark & Fujimoto, 1991; Clark & Wheelwright, 1992).

Summary and Critique

In summary, we can identify two main branches of research stemming from the classic information processing model. One branch of sub-theories has kept relatively close to the tradition of Thompson (1967), viewing task interdependence as a relationship among internal tasks stemming from the nature of the work, and simply applied tasks to different levels of analysis (e.g., individuals, work groups,

departments) or clarified the basis of connection (e.g., pure task, goal, reward, outcome, role, skill or knowledge). A second branch of research expanded the definition of task to include internal and external (environment) activities.[2] The common thread uniting this work is (1) a focus on the pattern or flow of work between entities, (2) an assumption that the nature of the task (i.e., form and content of the work flow) or the environment are the sources of that contingency pattern, and (3) the identification of the degree of direct contingency between tasks as a critical dimension affecting coordination difficulty. In particular, activities that are tightly and directly linked are viewed as being the most difficult to coordinate.

This perspective is heavily rooted in the economic paradigm of a deterministic world and reflects the nineteenth century physical science belief that dynamics always yield unique and predictable outcomes (Orlikowski & Baroudi, 1991). The recommendations stemming from this research stream rest on the key assumptions of determinism, objectivity, and stability. Information processing theorists look at interdependence from an outsider's objective perspective; tasks are assumed "to be" reciprocal or sequential. Other research suggests that subjective judgments about interdependency may vary considerably within a firm due to the differentiation process (Lawrence & Lorsch, 1967; Lorsch, 1977; March & Simon, 1958). Because departments differ in terms of their degree of structure, leadership style, tolerance for ambiguity, etc., members of each unit will tend to see interdependencies that involve them with other units primarily from their own point of view (Lorsch, 1977). Not only does such variance in perception mean that members may perceive the same interdependency

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[2] This splintering of theory potentially stems from (and has surely contributed to) confusion over Thompson's original use of the word "task." Scholars have subsequently interpreted the label as referencing any or all of the following: a relationship between tasks, the source of the contingency, or the direct (literal) interaction of tasks.

differently. They also may deem different interdependencies as being more or less important.[3]

A second major characteristic (and limitation) of research in this category is its focus on predictable, static tasks, thereby ignoring situations where tasks cannot be fully specified in advance as well as unpredictable aspects of timing. For example, one could imagine having a very routine, serial interdependency, but when and how the sequential actions take place could depend on certain unpredictable stimuli. March and Simon define contingent interdependencies as those for which timing is a major uncertainty (March & Simon, 1958).

3.3 The Resource-Based Perspective

Basic Underlying Model

Like the information processing perspective, resource-based theories start with the observation that organizations exist in an uncertain task and external environment, but this view shifts the emphasis from information processing to the resources organizations need to remain viable and compete. The resource-based perspective conceptualizes firms as unique bundles of accumulated tangible and intangible resources, defined broadly as assets, capabilities, processes, routines, and knowledge (Barney, 1991; Wernerfelt, 1984). Interdependence is the pattern of task relationships resulting from the flow and control of critical and valued resources, which reduce task or environmental uncertainty. Thus, according to this perspective, interdependencies are the outcome of trying to cope with uncertainty, not its source:

Task or Environment ----------> Flow & Control of Resources ----------> Interdependence
Uncertainty

[3] Some scholars get around this problem by defining interdependency as existing only when relationships are "consensually validated" (Gresov & Stephens, 1993).

Table 3 summarizes selected studies within the resource-based perspective.

TABLE 3
RESOURCE-BASED PERSPECTIVE, SELECTED STUDIES

Author(s)	Key Word(s)	Method	Sample	Description
Salancik & Pfeffer, 1974	dependency	ratings and rankings from interviews	29 university departments	shows how department power results from acquisition of external grants and contracts
Clark & Fujimoto, 1989; 1991	problem solving cycles among activities	questionnaire, in-depth interviews and documents	24 automobile development projects	studies effect of product and project characteristics on development lead time
Ancona & Caldwell, 1990	external interdependency	questionnaire	45 new product development teams in 3 industries	identifies four strategies teams use toward their environment
Ancona & Caldwell, 1992a	external activities	interviews, log data and questionnaire	new product team managers in high technology companies	links type of external activity and group strategy to performance
Iansiti & Clark, 1994	internal and external integration	questionnaire and case studies	29 automobile development projects, 27 computer development projects	illustrates dynamic processes used to build and integrate knowledge and solve problems
Malone & Crowston, 1994	dependencies among activities	theoretical survey	not applicable	reviews coordination process across disciplines
Roth, 1995	international interdependence	regression analysis	74 CEOs in global companies	show how influence of locus of control, information evaluation style and international expansion on firm performance vary with interdependency
Miller & Shamsie, 1996	property-based and knowledge-based activities	regression analysis	7 Hollywood film studios	relates different kinds of resource-based activities to performance in different environments

Variants

Resource Flow Interdependency

One variant of the resource-based perspective on interdependency focuses on the implications of flows of resources within and across organizational boundaries. This variant can be further sub-divided into a stream of research emphasizing power and politics and a more recently emerging set of strategy literature.

The power and politics stream can be traced back to Crozier who, in a study of a French factory, observed that power accrued to the plant's maintenance engineers because they possessed the skill and knowledge relevant to the repair of equipment, an area of uncertainty affecting plant operations (Crozier, 1964). Based on this finding, Crozier proposed that uncertainty critical to the organization's technology determined the pattern of dependency (and power) across the organizational groups.

Salancik and Pfeffer made a substantial theoretical contribution to this line of reasoning by identifying the control of critical and valued resources as an intervening variable between uncertainty and interdependence (Salancik, 1987; Salancik & Pfeffer, 1974; Salancik & Pfeffer, 1988). Although their thesis focused on the power implications, these authors describe interdependence among and within departments as reflecting the historical flow of resources into an organization and the role those resources play in its functioning. Salancik and Pfeffer tested their theory in the context of a large university where they reasoned that ensuring an adequate flow of grant money addresses an important type of uncertainty. They found that a department that depends on many other departments is in a low power position; a department that supplies resources to many departments is in a strong power position (Salancik & Pfeffer, 1974).

The power view is also reflected in research on new product development projects, which emphasizes that frequent political communication (typically external) leads to higher performing development projects by increasing the resources (e.g., budget, personnel, equipment) available to the team (Ancona & Caldwell, 1992; Brown & Eisenhardt, April 1995). For example, the ambassador role in Ancona and Caldwell's typology consisted of activities such as lobbying for support and resources.

A resource-based view of the firm has also recently emerged in the strategy literature.[4] This stream articulates the relationships among firm resources, capabilities, and competitive advantage, arguing that the flow and control of valuable, costly to copy resources and capabilities represent the key sources of sustainable competitive advantage (Barney, 1991; Peteraf, 1993; Prahalad & Hamel, 1990; Rumelt, Schendel, & Teece, 1991; Wernerfelt, 1984). For example, Roth portrays international firms as a collection of interdependent resources in different locations that must be connected or integrated to some degree (Roth, 1995). Iansiti and Clark argue that the roots of dynamic capability and long term performance in product development reside in a firm's capacity to respond to internal and external contingencies (Iansiti & Clark, 1994).

Several points are worth emphasizing about the resource-power and resource-strategy lines of research. First, it is often not clear whether these theories are referring to internal or external interdependencies. Some scholars interpret this research as primarily emphasizing external interdependency (Brown & Eisenhardt, April 1995). Others argue that one of the advantages of a resource-based perspective is that it integrates false debates about the relative importance of internal versus external factors

[4] The resource-power perspective articulated by Salancik & Pfeffer is sometimes referred to as strategic contingency theory.

(Hart, 1995). We also see, as was the case in information processing theories, considerable variance in the level of interdependent units.

The concept of resources also remains an amorphous one (Miller & Shamsie, 1996). For example, the early work by Crozier emphasized skill and knowledge resources, a theme carried through in more recent research (Teece, Pisano, & Shuen, 1990). Other scholars distinguish between property-based and knowledge-based resources, generally arguing that the former are likely to contribute most to performance in stable and predictable settings whereas the latter will be of the greatest utility in uncertain (changing, unpredictable) environments (Miller & Shamsie, 1996). Another characteristic of this literature is its lack of explication of the interdependency consequences of resource flows. Most of the researchers cite interdependency as a key intervening variable but primarily focus on the power or competitive performance implications of those linkages (Hart, 1995; Salancik, 1987).

Resource Sharing Interdependency

The above research depicted interdependency as existing when materials, money, or knowledge flow between organizational units in one direction, a form of sequential interdependency (Thompson, 1967). Another variant of the resource-based perspective has explored the mutual interdependency relationships resulting from resource sharing.

This line of reasoning can be traced back to March and Simon, who refer to interdependence as a "felt need for joint decision making" and note that "the greater the mutual dependence on a limited resource, the greater the felt need to coordinate" (March & Simon, 1958). Malone and Crowston likewise propose that whenever multiple activities share some limited resource (e.g., money, storage space or an actor's

time), a resource allocation process is needed to manage the subsequent interdependencies (Malone & Crowston, March 1994). Note that in contrast to the resource flow literature, this variant of research tends to emphasize primarily internal interdependency. The portrayal of resources is also slightly different with less of an emphasis on knowledge associated capabilities in favor of physical or capital-based assets.

Implications of the Model

The management implications coming out of the resource-based perspective are relatively straightforward. In general, they suggest that one should assess one's interdependencies and attempt to influence or even control decisions about critical resource allocation. The ultimate goal, according to this viewpoint, is to minimize interdependencies as much as possible, discretion being the ultimate and most important resource (Salancik, 1987).

For example, the resource-strategy literature emphasizes control (ownership) of rare, specific, non substitutable resources that are difficult to imitate (Teece, et al., 1990). Ancona and Caldwell propose different product development team roles for controlling resource flows (i.e., ambassador, scout) (Ancona & Caldwell, 1990). March and Simon contrast solutions involving coordination by plan (i.e., preset schedules) and coordination by feedback (i.e., mutual adjustment) and propose that the more stable and predictable the context, the greater the reliance on plans and preset schedules (March & Simon, 1958).

In a survey of coordination processes, Malone et al. identified rules such as "first come/first served," priority ordering, budgets, managerial decisions, and market-like bidding as alternative ways of managing shared resource interdependency (Malone,

Crowston, Lee, & Pentland, 1993). Malone and Crowston report specifically on the use of various forms of information technology including cooperative work tools, to coordinate activities (Malone & Crowston, March 1994).

Summary and Critique

In summary, we can again identify several variants of the resource-based perspective on interdependency. One stream of research depicts interdependencies as arising from the flow of resources between a supplier and a consumer (activity) and focuses on the implications of that interdependency for either the distribution of power within an organization or the strategic advantage of a firm. A second branch of theories portrays interdependencies as stemming from shared access and/or use of a common stock of resources. What unites this work is an assumption that there are three necessary and sufficient conditions for the creation of interdependency: (1) resource demand, (2) limited availability, and (3) unequal allocation.

Note how this conceptualization of interdependency both resembles and differs from that in information processing. According to both viewpoints, interdependence exists among the tasks or activities in an organization and is evident in the ability (or inability) of a sub-unit to take (or not take) actions. Studies within each perspective are also quite inconsistent with respect to the level of task execution (i.e., individual, group, department, firm). But, in the resource-based perspective, interdependency is not rooted in the task or environment as information processing theories suggest. Rather, it is situational and varies depending upon the demand, supply, and value of a particular resource.

In other words, resource-based interdependency is an attribute of a relationship within a particular context, not a task. This is consistent with work from sociology,

which defines dependency as a property of a social relationship as opposed to an attribute of a person (Emerson, 1962). Also reflecting a sociology perspective is the implicit note of conflict that runs through much of this work but is largely absent in the more objective information processing lens. For example, Deutsch suggests distinguishing promotive interdependence in which units depend on one another in positive and negative ways from contrient interdependence or pure conflict of interest (Deutsch, 1973). Pfeffer and Salancik make a similar distinction, labeled symbiotic versus competitive interdependency (Pfeffer & Salancik, 1978).

3.4 The Sense-Making Perspective

Basic Underlying Model

Like the previous two perspectives, the sense-making paradigm acknowledges the complexity and uncertainty of organizational work. But rather than examining dyadic interdependencies (information processing) or resource linkages among common units (resource-based), scholars within this line of research attempt to relate micro-level interactions to macro-level patterns and, therefore, bridge the two levels of theory. These researchers argue that one cannot simply extrapolate from the local to the aggregate because individual incentives and motives are rarely attuned to some collective accomplishment (Schelling, 1978).

A central concept in this perspective is that of equivoque. Technical and organizational systems are equivocal insofar as they are amenable to several possible or plausible interpretations (Weick, 1990). Theories of sense-making suggest that the transformation and interaction of local (micro) relationships results in interdependency patterns that are so complex that people have limited and variable ability to reason about and understand the structure of their work. Note how, according to this model, complexity is an output of interdependency, not its source:

Micro Task <----------> Macro Level Patterns ----------> Complexity & Equivocality
Interdependency

Table 4 contains some of the key sense-making references.

TABLE 4
SENSE-MAKING PERSPECTIVE, SELECTED STUDIES

Author(s)	Key Word(s)	Method	Sample	Description
Granovetter, 1973	small scale interactions	theoretical	not applicable	proposes links between strength of dyadic ties and macros sociological theories
Weick, 1976	loose coupling	descriptive case study	educational organizations	proposes that loose couplings are ubiquitous and functional
Schelling, 1978	contingent behavior	theoretical	not applicable	explores the relationship between behavior of individuals and social aggregate
Perrow, 1984	interactive complexity	case study	nuclear power plants	proposes that coincidence of tight coupling and technical complexity create normal accident failures
Hutchins, 1990; 1991	activities	descriptive case study	navigation team	illustrates how real-time adaptations are essential to flexible system deployment
Resnick, 1992	actions and interactions	computer simulation	students	probes how people think about decentralized systems
Weick & Roberts, 1993	cognitive interdependence	descriptive case study	flight operations on aircraft carriers	suggests that continuous, high reliability situations require 'heedful inter-relating

Variants

As this research stream is the newest and least fully developed of the three paradigms, clearly identifiable variants have yet to fully emerge. Instead, this section begins by noting some mainly descriptive studies illustrative of this perspective and

then describes two of the central concepts in this literature having to do with the nature of the interdependent tie.

Descriptions of Interacting Systems of Interdependency

Schelling presents one of the best introductions to this perspective in a book entitled Micromotives and Macrobehavior (Schelling, 1978). Drawing upon a series of mundane yet compelling examples (e.g., ant colonies, people waiting in line, Christmas card exchanges, traffic jams), he explores the relationship between the behavior of individual actors who compose some social aggregate and the characteristics of the aggregate and notes how the motives of individuals can sometimes lead to striking and unexpected outcomes:

> These situations, in which people's behavior or people's choices depend on the behavior and choices of other people, are the ones that usually don't permit any simple summation or extrapolation to the aggregate. To make the connection we usually have to look at the system of interrelationships between individuals and their environments, that is, between individuals and other individuals or between individuals and the collectivity (Schelling, 1978).

Examples of other rich descriptive research are work on the processes teams use to navigate a large ship (Hutchins, 1990; Hutchins, February 1991), the interdependent know how of flight operations on aircraft carriers (Weick & Roberts, 1993), the different forms of interdependence leading to the space shuttle Challenger disaster (Vaughan, 1990), and experiments with an interpersonal computer game (Resnick, 1992).

Strong versus Weak Interdependency

In an early precursor of network theory, Granovetter considered the macro implications of one aspect of small scale interaction, the strength of dyadic ties (Granovetter, 1973). Defining the strength of a tie as "a (probably linear) combination of

the amount of time, emotional intensity, intimacy, and reciprocal services flowing between two points," he proposes that the stronger the tie between A and B, the larger the overlap in their friendship networks (defined as the proportion of individuals to whom they will both be tied out of the set of people with ties to either or both). One possible interpretation of this is that the stronger one type of interdependency ties two units together, the greater the overlap in the set of their other interdependencies.

The flip side of strong ties are weak ties, one example of which is a bridge or line in a network, which serves as the only path between two points (Granovetter, 1973). Weak ties are, therefore, more likely to link members of different small groups than are strong ones, which tend to be concentrated within groups.[5] Granovetter stresses the cohesive power of such weak ties by showing how information can reach a larger number of people and traverse greater social distance when passed through weak ties rather than strong. Recent research by Krackhardt has explored the integrating function of strong ties (Krackhardt, June, 1996).

Loose versus Tight Interdependency

Closely related to the above distinction is Weick's concept of loose versus tight coupling, which he first explored in the context of educational organizations (Weick, March 1976). Weick defines loose coupling as connoting "things that are tied together either weakly or infrequently or slowly or with minimal interdependence ... such things are somehow attached, but each retains some identity and separateness and their attachment may be circumscribed, infrequent, weak in its mutual affects, unimportant, and/or slow to respond" (Weick, March 1976). Note how, whereas Granovetter defined ties in terms of the strength of the social relationship, Weick's definition adds a

[5] Note the similarity to Simon's propositions about the strength of interdependency within and across subsystems.

temporal element (i.e., "infrequently," "slowly"). Like Granovetter, Weick goes on to suggest seven potential functions of loosely coupled systems.

Whereas Weick emphasizes the functions and benefits of loose coupling, Perrow stresses the disadvantages and malfunctions associated with tightly coupled relationships (Perrow, 1984). He categorized organizations on the basis of their complexity (linear or complex) and coupling (loose or tight) and found that tightly coupled systems were more vulnerable to breakdown. Subsequent empirical research supports some of these propositions. For example, Hutchins shows that a loosely coupled work group was remarkably adaptive in the face of a change in its informational environment (Hutchins, February 1991).

Implications of the Model

The sense-making perspective is strikingly different from the previous two paradigms both in its implications for work processes as well as its prescriptions for management. Theorists working in this stream have, in particular, emphasized the difficulty of sense-making in highly complex, interdependent situations. For example, they point out that as tasks and task relationships become more automated, abstract, continuous, flexible, and complex, they also become less analyzable via traditional (rational) means such as inference or problem solving.

Weick notes that the combination of increased cognitive demands, complexity, and dense interdependence over large areas increases the incidence of unexpected outcomes that can ramify in unexpected ways. As a result, people increasingly operate in a work environment characterized by seemingly random, unpredictable events and in which they cannot analyze interdependencies or are not even aware that they exist. He proposes that such systems make both limited sense (because so little is visible and

so much is transient) and many different kinds of sense (because the dense and complex interactions they embody can be modeled in so many different ways), in other words, they are equivocal (Weick, 1990). Perrow likewise points out that under conditions of interactive complexity events are minimally buffered, and people tend to lose sight and comprehension of cause and effect relations (Perrow, 1984).

The sense-making perspective therefore questions the notion that managers and scholars can identify interdependencies by a priori analyzing task or resource structures and, thus, differs from the two previous paradigms in terms of its implications for organization design. According to many of these authors, organizations are often not planned, and in fact, it may be impossible to rationally and forthrightly design structures to address certain kinds of interdependence. For example, Hutchins followed a work group's response to a change in its informational environment and found that the resulting reorganization of work could not be attributed to the conscious reflection of its members or an outside manager (Hutchins, February 1991). Rather, it arose through local design and adaptation by individuals to what appeared to them as local task demands. Furthermore, and surprisingly, the solution reached was the one recognized in retrospect as being the "ideal design."

Some network theorists, on the other hand, reject the notion of a self-designing organization and argue that effective structure does not occur naturally but must be designed consciously and carefully. They propose using computation tools and graph theory techniques to do so, an area of active research enabled by advanced computation methods (Krackhardt, 1994; Krackhardt & Stern, 1988; White, Boorman, & Breiger, 1976).

Schelling emphasizes the need for different forms of incentive structures in order bring perceived individual interests in line with collective goals (Schelling, 1978). He notes that sometimes the problem is to get people to abstain from something that imposes costs on others (i.e., incent people to not do something, raise their awareness of impact they have on others). Other times, the problem is to get people to take the trouble to do something of no perceived benefit to themselves but great benefit to others (i.e., incent people to do something). Hutchins' research on team navigation suggests that system robustness and flexibility depend on a certain level of redundancy in the distribution of knowledge and ability (Hutchins, 1990). His work illustrates how raising the visibility of tasks linkages, by, for example, altering the physical arrangement of tools and work stations, increases people's awareness of their interdependency and need to interact. Other researchers propose that the more 'heed,' defined as "a disposition to act with attentiveness, alertness, and care" reflected in the pattern of inter-relations in a system, the greater the capability to comprehend and respond to unexpected events that evolve rapidly (Weick & Roberts, 1993). Possible promoters of heed suggested by these authors include the use of vivid stories, common language, apprentice-mentor roles, and careful socialization of newcomers.

Summary and Critique

In summary, sense-making theories explore the relationship between micro-level linkages and higher-level patterns and, therefore, constitute a multi-level perspective on interdependency (Rousseau, 1985), although the precise units are often only vaguely specified. Whereas information processing and resource-based theories tend to focus on the structural or process dimensions of interdependency, sense-making theories emphasize the content or nature of the relationship, in particular its strength and comprehensibility. This perspective is also decidedly less rational and more dynamic than the other two, highlighting the lack of visibility and determinism governing many

task relationships. Finally, sense-making assumes that interdependencies are subjectively defined. For example, these writers portray people as "responding to an environment that consists of other people responding to their environment" (Schelling, 1978), implying that the very definition of environment and interdependency depends on a subjective experience. The management implications arising from this theory largely reflect these very different assumptions.

In many ways the sense-making viewpoint represents the most contemporary and realistic paradigm of interdependency in organizations precisely because it challenges some of our most basic and simplifying assumptions (i.e., that organizations are rational with static and uniform tasks). It suggests instead that, although parts of work may be rational or amenable to rational analysis, other parts prove more intractable. By emphasizing the need to find ways of working, coordinating, and structuring that are more dynamic and flexible, sense-making theories also converge with observations made by other scholars (Eisenhardt & Tabrizi, 1995).

One major limitation of this category, however, is its lack of empirical validation. Precisely because it drops such simplifications, sense-making theories tend to be somewhat abstract, relying on purely theoretical arguments illustrated by carefully chosen anecdotes (Granovetter, 1973; Schelling, 1978; Weick, March 1976) or highly descriptive studies in a single setting (Hutchins, 1990; Hutchins, February 1991; Weick & Roberts, 1993).

4. Critique: Toward An Integrative Model of Interdependency

The previous section reviewed three ways in which interdependency has been studied in organizations. The perspectives tend to conceptualize task relationships very differently and offer complementary and sometimes overlapping insights. This raises

an important question. Are these perspectives talking about the same interdependencies, and thus merely alternative conceptualizations, or do they address conceptually and empirically distinct phenomena? In other words, how can we develop a more integrated model of interdependency?

As illustrated in Figure 2, there appears to be some degree of overlap between information processing interdependencies, which involve the transfer of information, and those parts of the resource-based perspective which describe flows of knowledge. The present survey revealed a similar confusion among concepts of environment. Some scholars portray environment as referencing internal firm unit relations (external to a focal unit), while others define environment as strictly outside the organization. Finally, there is a general lack of clarity and distinction among four variables: technology, environment, internal, and external. For example, are technical interdependencies and internal interdependencies always the same thing? Some authors appear to interpret internal/external as referencing the source of contingency, while for others it refers to the structure of the organization.

Other scholars have made similar observations. Pennings points out a lack of distinction between technical and environmental interdependencies due to varying (and unclear) conceptual and operational definitions, which tend to emphasize a single variable (usually uncertainty) or a cluster of conceptually similar variables (Pennings, September 1975). For example, he identifies a large number of cases where authors equate dimensions of environment with dimensions of technology and cite references to studies of technical interdependence in support of their thesis on environmental contingencies (or vice versa). Wagerman suggests the need to distinguish cases of <u>pure resource-based interdependency</u> (when each member can complete his part of the whole but resources such as skills and information are distributed among members)

from those of pure task-based interdependency (where task accomplishment requires collective action) (Wagerman, 1995). As a scholarly community, we need to begin to sort through this confusion and be more consistent in our future use of these variables.

On the other hand, opportunities to integrate complementary viewpoints also abound. This survey suggests three in particular. First, we need to study the relationship between interdependency process and content. Process descriptions of interdependency focus on the pattern or form of the task relationship. They emphasize how tasks are contingent, the best illustration being Thompson's (1967) categorization of pooled, sequential, and reciprocal. Content-based approaches to classification address the nature of the tasks and connection.

For example, referring again to Figure 2, we see that information processing theories explore many kinds of structures, while the resource-based perspective has primarily concentrated on sequential and pooled forms (or left the structure undefined). We might combine Thompson's three forms with Karl Weick's notion of loose and tight coupling, and ask which forms tend to be more tightly coupled. Are there examples of reciprocal interdependencies that are loosely coupled and others that are tight? Another possible combination of content and process would link the source or primary driver of the interdependency (technology and internal or external environment) with its structure. Do technical interdependencies tend to be more reciprocal? Are there greater lags in sequential interdependencies driven by the environment? Can we identify certain ubiquitous process types?

A second possible integration would look for evidence of predictable and unpredictable interdependencies in both micro-level dyadic relationships and higher-level patterns. Although sense-making theorists attempt to link the two levels, their

work primarily focuses on the "unexpected and surprising" macro-level outcomes. Ample and compelling evidence exists from information processing and resource-based research studies that at least some task relationships are predictable, rational, and stable. How do the latter sometimes get transformed into unexpected patterns? Where and when do they remain predictable?

Finally, we need to better integrate knowledge about interdependencies with theories of organizational design and structure. While all three perspectives agree that structure matters in terms of interdependency management, they offer different opinions as to the feasibility and desirability of organization design itself. More rational theories based on information processing or resources presume that the design of structure can and should be planned in advance. In particular, we can rationally determine the appropriate structure for an organization by looking a priori at its tasks or resources. Many (although not all) proponents of sense-making argue that the idea of pre-planned design assumes a foreknowledge of objectives, constraints, and possibilities when in fact rationality and information are often limited, goals and preferences conflicting.

This debate between organization design as a process of management reflection and intervention versus organization design as self-organization strongly resembles classic debates in design theory over the concepts of design and evolution (Alexander, 1964). Design refers to a process conducted by an outsider or representative of the system, as in information processing or resource-based solutions. In evolution, the search for design is conducted by the system itself in terms of itself via a series of local adaptations.

The focus on single dyadic task relationships in interdependency research, particularly in the case of information processing and resource-based studies, has also tended to promote very localized management recommendations. Especially popular are so-called congruence or contingency models of organization behavior, which focus on the degree of fit between features of context and design and its relation to efficiency and effectiveness (Bailetti & Callahan, 1995; Burns & Stalker, 1968; Lawrence & Lorsch, 1967; Nadler & Tushman, 1983). Although most theoretical formulations include multiple features of context (Burns & Stalker, 1968; Galbraith, 1973; Lawrence & Lorsch, 1967), empirical research has usually tested single contingency factors and therefore failed to fully test the fit hypothesis.

Some theorists are beginning to question the basic congruence approach and assumptions (Andres, August 25-27, 1995; Drazin & Van de Ven, 1985; Gresov, 1989; Miller, 1981; Miller, May 1992; Scott, 1990). Among other things, these scholars argue that designing to several contingencies at once involves tradeoffs that prohibit overall fit. For example, organizations must perform many tasks simultaneously, suggesting the possibility of coordination conflicts (Andres, August 25-27, 1995; Pfeffer & Salancik, 1983) and coordination costs and overload (Malone, February 1988; March & Simon, 1958), prospects largely ignored in early theorizing.[6] There may also be opportunities for synergy if we can identify certain solutions which involve managing clusters of like interdependencies.

We need to document frequently occurring design conflicts and identify structures and processes organizations can use to surmount them. One example of this

[6] Thompson does propose that different types of internal interdependence form a Guttman-type scale. For example, all organizations have pooled interdependence, more complicated organizations have sequential as well as pooled, and the most complex organizations exhibit all three types. But he never considers the implications of this heterogeneity nor how one type of interdependence relates to another.

approach is Allen's work, which examined the tension between various types of organization design and the information needs in R&D organizations (Allen, November 1986). We also need to develop theories of how to manage and coordinate multiple interdependencies simultaneously and efficiently.

Gathering and analyzing data about interdependencies may, therefore, enable us to extend our thinking about some of the existing organizational design theories. The above comments suggest, in particular, an alternative approach to achieving congruence, one focused on identifying and minimizing instances of misfit not seeking fit. They also raise questions such as do there exist multiple kinds of fit (Drazin & Van de Ven, 1985), and how multiple structures become uncoupled over time (Gulati & Eppinger, May 28, 1996)

This viewpoint is supported by classic theories of design. For example, in Notes on the Synthesis of Form, an extensive treatise on the process of design, Alexander writes:

> Our conviction that there is such a thing as fit to be achieved is curiously flimsy and insubstantial. We are searching for some kind of harmony between two intangibles: a form which we have not yet designed and a context which we cannot properly describe. The only reason we have for thinking that there must be some kind of fit to be achieved between them is that we can detect incongruities or negative instances of it.

He continues:

> In practice, we see good fit only from a negative point of view... Even in everyday life, the concept of good fit, though positive in meaning, seems very largely to feed on negative instances; it is the aspects of our lives which are obsolete, incongruous, or out of tune that catch our attention...Misfits are the forces which must shape [design, and there is no mistaking them. Because they are expressed in negative form they are specific and tangible enough to talk about...

> I should like to recommend that we should always expect to see the process of achieving good fit between two entities as a negative process of neutralizing the incongruities or irritants and forces which cause misfit (Alexander, 1964).

5. Measuring and Assessing Interdependency

One of the most striking revelations coming out of this survey is the narrowness of the methodological and empirical approaches taken to investigate interdependence. As indicated by a quick glance at Tables 2, 3, and 4 and supported by further more detailed review, the vast majority of the research is either completely conceptual, case descriptive, or replicates early operational definitions (usually some variant of (Thompson, 1967) or (Van de Ven & Ferry, 1980)). There are virtually no inductive or qualitative studies of interdependence where, for example, a researcher attempted to understand interdependence as people experience it within an organization. This method bias has no doubt contributed to our narrow understanding of the concept and its implications. In other words, it is entirely possible that our definitions and understanding of interdependence are nothing more than a testimonial to our methods, in effect an artifact of using time and context independent measures (Weick, 1974).

For example, relying on questions such as "While doing your assigned tasks, how much do you have to depend on outside departments?" or "Please indicate how much of your work flows in an independent, sequential, or reciprocal manner" (Van de Ven & Ferry, 1980) to assess aspects of interdependency assumes that people know when they come across an interdependency and can reliably assess it (Weick, 1974). Such measures, therefore, obscure important details of work which have as one of their distinguishing properties the fact that people often do not even realize that problems exist for which they need solutions. Thus, to ask people about the pattern or level of

interdependency can miss or mislead us about key aspects of interdependence associated with newer, more complex work arrangements.

For instance, Weick notes that if one goes into an organization and watches which parts affect which other parts, one will predominately see the tightly coupled parts. Those parts that are interdependent slightly, infrequently, or periodically will, almost by definition, be less visible. Similarly, many organizational processes could exhibit a mixed quality of interdependence if, for example, they follow a reciprocal pattern early on but sequential pattern later. But that aspect will be altogether missed (and inappropriate coordination mechanisms invoked) if the observer extrapolates from early stages of the relationship (Weick, March 1976).

Relying on self-reports or survey responses also presents possible biases. Research in social psychology suggests that people tend to over-rationalize their activities and attribute greater meaning, predictability, and coupling among them than in fact exist (Katz & Kahn, 1966). Individuals are also prone to report unilateral causation as opposed to mutual causation insofar as the former supports a positive self concept. The tendency to describe situations in terms of causal arcs rather than loops may also reflect high levels of mobility or a variance in perception within firms. If people are highly mobile (both within and across organizations) they may not stay in a situation long enough to appreciate the feedback consequences of their actions (Weick, 1974). A marketer who operates in the fast-paced commercial world may define reciprocal interdependence as a loop occurring within a one week time frame; someone working in a research organization, on the other hand, would probably have a longer time horizon (Lawrence & Lorsch, 1967). Researchers also represent a potential source of bias through their modeling efforts (Athey & Stern, 1996).

6. A New Research Agenda

The previous sections looked to the past in describing three major interdependency perspectives. These paradigms represent continued areas of active research as indicated by the large number of sub-stream theories and variants generated within each category. This section sketches out some ideas coming out of this survey for a bolder agenda for interdependency research.

First, the agenda should begin by closely examining the concept of interdependency itself before proceeding to investigate and measure its impact on organizational outcomes. Most authors included in this review are not really studying interdependence, but rather how interdependence impacts something else, usually performance. We need a richer, more unified understanding of the interdependence variable itself before we proceed to build such models.

Second, while it is clear that each perspective on interdependency has its shortcomings, each also offers important insights. New research should, therefore, build upon this past work, guided by a goal of increased integration. The classic debates about predictability versus unpredictability or internal versus external are not very controversial anymore. Most scholars recognize (albeit perhaps reluctantly) that relationships are sometimes deterministic but often not and that organizations represent complex, evolving entities. It is likely that interdependencies are sometimes predictable in advance but often more emergent and that some forms of interdependency are harder to manage than others. It is equally apparent, however, that our understanding of the concept rests on isolated viewpoints, which tend to constrain the realism of interdependency research.

Third, as suggested in Section 5, future research on interdependency must exploit new methodological approaches. In particular, rather than starting with a pre-conceived definition (and operationalizing it in yet another way), researchers studying interdependency need to apply methods that both highlight and preserve rich details of context (Weick, March 1976) and enable us to make tractable theoretical and normative statements about variations. In fact, we may need to invent (or at least agree upon) a language or grammar about interdependence before further theoretical progress can be made (Salancik & Leblebici, 1988).

Yet certain pervasive shortcomings also become apparent as a result of this survey. In particular, although the sense-making perspective has a dynamic element to it, there is a general lack of consideration of the role of time in all of this research, undoubtedly reflecting the cross sectional nature of most of the research. (An exception is work by Adler (Adler, March-April 1995).) Theorists tend to portray firms as starting with a clean slate of interdependent tasks waiting to be structured and coordinated, yet we know that technology and environments can change very rapidly, leading organizations to continually structure and restructure themselves over time. This suggests that interdependency patterns and designs will also evolve and perhaps be shaped or constrained by their past form.

Finally, we need to develop a clearer thesis about the relationship between tasks and organizational design or structure. This survey revealed a considerable amount of confusion surrounding these two concepts.[7] The traditional viewpoint says that, given the existence of an interdependency, we can design organizational solutions to manage

[7] One possible source of this confusion, revealed in this survey, is the considerable variation across studies in all three paradigms as to the level of task execution. For example, we saw numerous cases where one author's 'interdependency' was conceptualized as a form of structure in other studies. Micro-level researchers tend to view group-level interdependencies as a structural variable whereas group scholars portray inter-group relations as a type of interdependency.

it. Recently, however, scholars have begun to modify this simple determinate model by depicting organizational structure as an intervening variable between tasks and interdependency (Eccles & Nohria, 1992). That is, interdependency is not inherent in the task (or environment) but rather an outcome of the organizational design and differentiation processes.

For example, Wagerman defines task interdependence as existing when "each member must take action for any other member to do any part of their work," but locates the source of such interdependence not in the task itself but rather in the "organizational structure, work instructions, and materials" (Wagerman, 1995). According to this interpretation, the same tasks could conceivably exhibit different types or degrees of interdependence in different organizational structures.

7. Conclusion

This paper builds upon a long history of research on interdependency. In particular, it presents a conceptual framework, which integrates interdependency research from three separate streams of theorizing in an attempt to develop a clearer understanding of both the similarities and important distinctions in theorists' approach to the concept.

The survey suggests that our understanding of interdependency is actually quite limited and dated. We are still primarily drawing upon the Thompsonian notions of pooled, sequential, and reciprocal forms of contingency. While that work contains some fundamental insights, it ignores some of the more recent approaches to theorizing about the nature of work in organizations and largely fails to reflect the complexity of work and work relationships in organizations today. On the one hand, we need to broaden our view of interdependence beyond that of simply a structured pattern of task

relationships. More content-based viewpoints likewise need to incorporate the importance of structure and pattern in their models. Although much additional theoretical and empirical work remain to be done, this survey represents an important first step in opening up a dialogue about a fundamental concept that has not been adequately developed in recent years.

APPENDIX A
Social Science Citation Index Analysis[8]

One question the literature survey does not address is the relative relationship among the three theoretical perspectives on interdependency. For example, can they be traced back to a common source article or do later perspectives represent branches off of an earlier line of research? How has the relative balance and influence of research within and across different perspectives varied across time? Such questions are beyond the scope of this research, but I present some preliminary evidence and suggest ways we might address them here.

Informal analysis and conversations with scholars suggested that people most often associate Thompson's 1967 article with the concept of interdependency. This conjecture is supported by data from this survey. I reviewed 93 interdependency references in total (54 information processing, 26 resource-based theories, and 13 sense-making theories).[9] Eighty-six of these were published after 1967 (49, 24, and 13, respectively), of which 31 (36%) referenced Thompson.

Next I conducted a forward search of references to Thompson using data from an electronic bibliographical index. The Social Science Citation Index (SSCI) is an electronic database of citations in journals across a broad span of the social sciences (e.g., business, management, political science, sociology, etc.). Source articles are available since 1972.[10] An electronic search of the database in March 1997 for all references to Thompson (1967) revealed 3145 'hits.' Figure A.1 shows how these citation references were distributed across the years 1972 (the year the database began) through 1996 (the last full year at the time of this study).

As seen in the histogram, the rate of citations has remained fairly steady since 1978, averaging about 130 per year during that interim. Figure A.2 shows how the 3145 references are distributed by journal subject category. Not too surprisingly, business and management journals account for the vast majority of the references (79%), but Thompson's work has also influenced other fields as diverse as sociology (9%), finance (4%), and computers (2%).

It is important to note some potential problems with this analysis. First, the database itself is far from perfect. Source articles only include original journal publications, not reprints. Nor can we be sure exactly how or why the reference is made, other than by going back to the original articles (the database only contains the reference citation and occasionally a brief abstract). In particular, Thompson's book

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[8] Thanks to MIT Sloan School Senior Associate Reference Librarian Kate Pittsley for valuable help in performing this search.

[9] Because the articles were not randomly selected, we cannot draw any conclusions or generalizations from this distribution.

[10] In a confusing bit of nomenclature, 'source article' refers to the journal publication that contains a reference to the target article, in this case (Thompson, 1967).

contained a number of other ideas that have been highly influential in management theory.

A more significant problem is the lack of a standard reference format. Some authors use two initials (J.D.) while others use only one (J.). The year (1967) is usually included but occasionally not, and misspellings are rampant. Thus, a single search may not reveal the full universe of source articles. Recognizing this, I performed the search on four major variants: Thompson-JD-1967-Org*, Thompson-J-1967-Org*, Thompson-1967-Org* and Thompson-Org*.

Another potential source of bias is the fact that the set of source journals in the database has not remained constant over the years (nor is it the full universe of potential journals). This bias would be reflected in Figure A.1 in the form of artificially high (low) peaks (valleys) as source journals enter (exit) the database. In Figure A.2 certain subject areas are likely to be under-represented due to the social science orientation of the database. For example, searching a scientific citation index like Applied Science and Technology (AST) would likely reveal many more computer science source references to Thompson (1967) than what was found here simply because AST accesses more computer science journals.

Despite these somewhat significant limitations, this citation analysis is useful in that it substantiates the fundamental impact of this key reference and, therefore, the centrality of the concept of interdependency.[11] It is also interesting that the reference rate has remained fairly constant over the years, suggesting that this is not some 'fad' but rather more of a perennial concept in organization theory.

One future approach would be to take the 3145 (or perhaps the subset of 2487 from business and management journals) and analyze the content of their abstracts or titles for key words. Such data could be used to confirm the existence of the three paradigms proposed here, analyze their distribution and evolution over time, or suggest alternative categorization schemes.[12]

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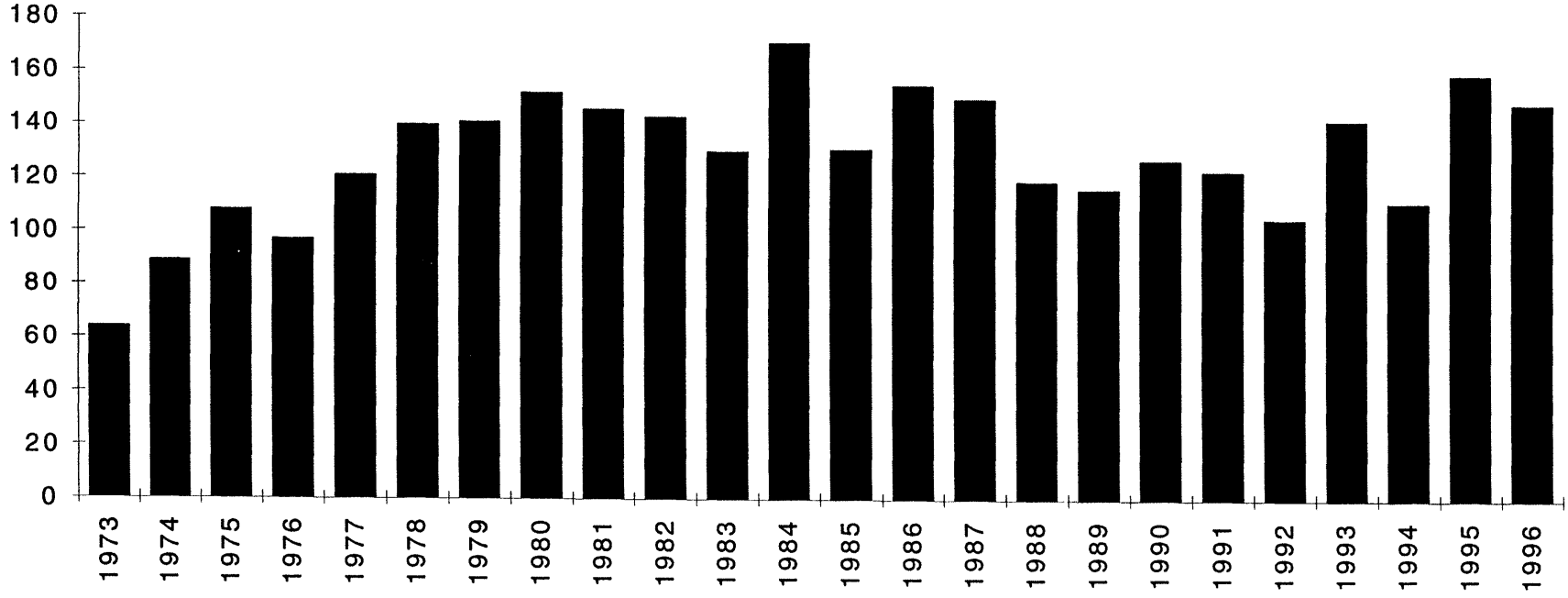
[11] The librarian who helped me perform this search, who has had extensive experience in this area, has never encountered anything close to this high of a hit rate.

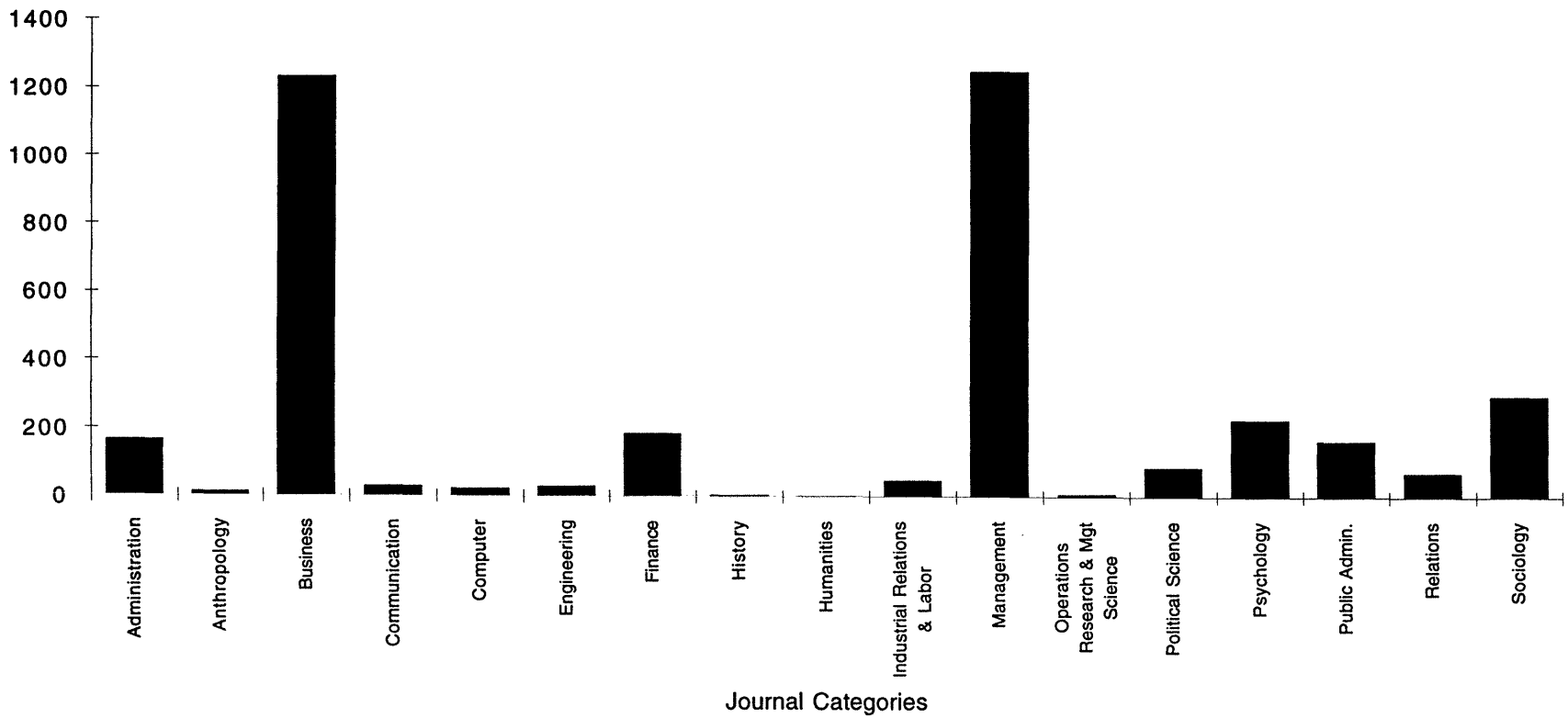
[12] Unfortunately, this was not possible in this study. The SSCI is extremely expensive to use for anything more than simple keyed-in requests; downloading all 3000+ articles would have been prohibitive. Instead, I collected a variety of references over several years and analyzed their content as described in chapter 2.

FIGURE A.1
REFERENCES TO THOMPSON (1967), 1972 - 1996



Source: Social Science Citation Index

FIGURE A.2
REFERENCES TO THOMPSON (1967) BY JOURNAL SUBJECT CATEGORY, 1972 - 199



Source: Social Science Citation Index

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