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KNOWLEDGE AS A CONTINGENCY FACTOR: ACHIEVING COORDINATION IN INTERORGANIZATIONAL SYSTEMS

by

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KNOWLEDGE AS A CONTINGENCY FACTOR: ACHIEVING COORDINATION IN INTERORGANIZATIONAL SYSTEMS

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ABSTRACT

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LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
C2	Command and Control
CDR	Commander
COA	Course of Action
COA DEV	Course of Action Development
CONOPS	Concept of Operations
COORD	Coordination
CPM	Critical Path Method
DF	Degrees of Freedom
DS	Direct Supervision
EK	Explicit Knowledge
FE	Functional Exceptions
FTE	Full Time Equivalent
HQ	Headquarters
LDR	Leader
MA	Mutual Adjustment
MA	Mission Analysis
MGR	Manager
MGT	Management
MOC	Maritime Operations Center
NATO	North Atlantic Treaty Organization
NEO	Non-combatant Evacuation Operations
OPT	Operational Planning Team
ORGCON	Organization Consultant
PE	Project Exceptions
POW-ER	Projects, Organizations and Work for Edge Research
PREP	Preparation
PROJ	Project
SD	Standard Deviation
SIG	Significance

TK	Tacit Knowledge
TM	Team
US	United States
USAID	United States Agency for International Development
VDT	Virtual Design Team

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I. INTRODUCTION

"Basic to the theory of organizations is the premise that all organizations need coordination. Coordination means integrating or linking together different parts of an organization to accomplish a collective set of tasks" (Van De Ven, Delbecq & Koenig 1976). This research employs a contingency theoretic lens to investigate the influence that group knowledge level has on the ability of independent organizations to coordinate mutually beneficial activities. This is a multi-method, meso-level organizational study that looks at the performance of boundary spanning groups employing the different coordination mechanisms of direct supervision and mutual adjustment.

A. CONTEXT

Large-scale disasters are significant events that tend to rapidly create a great deal of human suffering; major hurricanes and earthquakes, tsunamis, volcanic eruptions, and man-made disasters such as the terrorist attacks of 9–11 are examples of disaster phenomena. In the aftermath of these events and in some cases immediately prior to an event such as a hurricane, many diverse organizations act in response. Those organizations generally include governmental departments and agencies (e.g., local, state and federal), military forces, non-governmental organizations (e.g., relief agencies), businesses, and similar organizations from the international community. Often, these organizations have similar functions (e.g., providing medical assistance) and rapid deployment capabilities. These organizations generally share a broad, common goal—they want to relieve human suffering. They also face a common, highly complex environment. Many of these early responding organizations have a high degree of expertise and experience both in getting to and operating autonomously in a disaster area. Even with that degree of experience and common guiding goal, these organizations often face a host of challenges to putting their capabilities to use in a timely manner—and timely response is essential in mitigating many problems in the aftermath of a disaster. Some of those challenges include lack of familiarity with the local environment, novel problems created by the disaster, and inefficient interorganizational coordination (Wright

1976; Tierney 1985). With those particular challenges in mind, the theoretical frameworks brought to bear in this dissertation are discussed.

B. ORGANIZATION DESIGN THEORY

Organization research and the studies of disasters and disaster management found common ground in the 1960s with the emergence of interest in open system models for the study of organizations. Open system models promoted consideration of the effects of the external environment on an organization (Scott 2003). The external environment included such things as resources outside the control of an organization, other organizations, and the effects of environmental exigencies (Rogers & Whetten 1982). The development of the open systems models paved the way for the study of relationships between different organizations, and those relationships were highly applicable to the study of organizations that respond to a disaster.

One of the well-accepted open system models of organizations is the contingency model (Lawrence & Lorsch 1967). The contingency model is a rational systems perspective: components of an organization (e.g., its people and technology) are purposefully arranged to efficiently attain goals (Scott 2003). The contingency theory of organization design is based on the idea that while there are general forms (i.e., structural arrangements) that can be recognized in any organization, there is *no one best way to organize* to efficiently attain goals (Galbraith 1977; Donaldson 2001; Scott 2003). Instead, efficient attainment of goals is based on the fit between internal arrangements of organizational components and the demands of the environment (Donaldson 2001; Scott 2003).

An organization is defined as a socially constructed structure of people, processes, and material resources whose purpose is the efficient attainment of its goals (Blau & Scott 1962; Etzioni 1964; Leavitt et al. 1974; Mintzberg 1983). Organization is critical to enabling the efficient attainment of a firm's goals—so critical that organization theorists conceptualize it as central to the long-term success of the firm (Burns & Stalker 1961; Burton & Obel 2004; Child 1973). Indeed, over many decades, organizational research shows that mismatches between organizational design characteristics and well-understood contingency factors (e.g., task uncertainty and interdependence) lead to lower performance and potentially to an organization's obsolescence (for a review of Contingency Theory, see Donaldson 2001). Hence, understanding relevant contingency factors is critical to an organization's leadership for its role in managing structural adaptation, especially the type of adaptation that looms in the face of a crisis like a disaster event.

While classic contingency factors (e.g., size and task interdependence, for a review, see Donaldson 2001) and design responses (e.g., centralization and coordination mechanisms, for a review, see Daft 1998), are well understood, the emergence of the idea that *knowledge* can be viewed as a critical organizational resource (Drucker 1995, Grant 1996b; Nonaka 1995; von Krogh 1998) is prompting more attention in organization design research (Burton & Obel 1998). Research into the phenomenon of knowledge, particularly knowledge management, is gaining momentum in the broad field of Information Science (Alavi & Leidner 2001; Croasdell et al. 2003); however, organization design research that focuses on knowledge as a contingency factor remains sparse; for groundbreaking research into the idea that knowledge is an organization design contingency factor, see Becerra-Fernandez & Sabherwal (2001), Birkinshaw, Nobel & Ridderstrale (2002), and Ibrahim & Nissen (2006).

C. KNOWLEDGE FLOW THEORY

Knowledge in this context comes from the *tacit and explicit* construct articulated by Polanyi (1966). Tacit knowledge is the personal know-how and mental models developed through experiences. More importantly, it is tacit knowledge that, when combined with other resources (e.g., humans and machinery), enables action (e.g., producing products). A common characteristic of tacit knowledge is that it is not easily transferred from one place or person to another. Explicit knowledge, on the other hand, is articulated knowledge (e.g., formalized written procedures) that are easily stored and transferred.[1] A key aspect of explicit knowledge is that it cannot completely capture all

[1] Other taxonomic ideations regarding knowledge are discussed later in this work.

that is known tacitly. Nonaka (1995) theorizes that knowledge, especially tacit knowledge, is a powerful resource that firms use and create to positively affect performance.

Knowledge management and organizational learning theories suggest that there should be a purposeful balance between exploration and exploitation tasks—i.e., those tasks that contribute directly to knowledge creation and work respectively (March 1991, Nissen 2006). The dynamic theory of knowledge creation contends that organizational performance and long term competitive advantage can benefit as a result of improved knowledge flows throughout a firm, especially flows of tacit knowledge (Nissen 2006). The processes by which those flows occur are identified as socialization, externalization, combination, and internalization (Nonaka 1995; Nissen 2006). Knowledge creation and learning is conceptualized as a spiral sequence of flow through those four processes. If this sequence is not promoted, then knowledge tends to become isolated in distinct areas of a firm, i.e., it "clumps." Tacit knowledge is especially susceptible to clumping due to its nature of being highly personal and difficult to articulate. Tacit knowledge also can be thought of as having high viscosity (i.e., being "sticky"): it does not flow easily (von Hippel 1994; Nonaka 1995; Nissen 2006). Hence, it behooves managers to understand how organizational structures promote or inhibit knowledge flow.

D. INTERORGANIZATION KNOWLEDGE FLOW

Drawing on the idea that knowledge enables action, knowledge management and interorganizational knowledge flow are significant areas for research in disaster or crisis response situations that are marked by intense resource and time constraints (Chou 2007). In these situations, both knowledge exploitation and knowledge exploration are critical. There is generally a surplus of work for every responding organization; therefore, expertise resident within an organization is generally heavily exploited early in the response to enable immediate actions that begin to achieve the organization's goals. Additionally, the environment that these organizations interact with is marked by many novel conditions that require new combinations of actions and innovative use of available resources (i.e., knowledge exploration) to enable efficient responses and further attainment of those goals. From an open systems perspective, knowledge is a resource that is available, not only within the firm, but from the environment as well—especially from other organizations. This makes knowledge research paradigms an apropos lens through which to investigate interorganizational performance issues in the aftermath of disasters and crisis events (Chua, Kaynak & Foo 2007; Chua 2007).

Some organization research has highlighted the idea that organizations tend to prefer autonomy, especially in crisis situations (Levine & White 1961; Tierney 1985). This contributes to an insular approach to planning; in other words, planners responsible for charting an organization's course in the face of a crisis tend to look at the environment as if they are the only service provider (Dynes & Quarantelli 1976; Tierney 1985). This single-provider perspective is not a realistic condition in crisis events: generally, myriad organizations with varying degrees of skills and local knowledge converge in response to a crisis (Dynes & Quarantelli 1976; Neal & Phillips 1995; Chua 2007; Chua, Kaynak & Foo 2007; Becerra-Fernandez et al. 2008). Often an organization finds itself dealing with a host of other organizations that it may not have previous experience working with on a regular basis (Dynes & Quarantelli 1976; Tierney 1985; Becerra-Fernandez et al. 2008). Confusion and disagreement are prevalent byproducts of this lack of familiarity and often unclear interorganizational lines of authority (Quarantelli 1988; Suparamaniam & Dekker 2003). Tierney (1985) concluded that the main barriers to interorganizational effectiveness in crisis response were insufficient organization, education, and levels of awareness. To overcome those barriers, organizations must "…learn about themselves and disaster behavior…plan together and with other relevant community groups, and…give high priority to coordination of effort." (Tierney 1985 p. 83)

1. Interorganizational Coordination

Most researchers in the area of interorganizational studies have qualitatively looked at the antecedents of achieving interorganizational coordination (Whetten & Aldrich 1979; Rogers & Mulford 1982; Smith, Carroll & Ashford 1995; Kenis & Knoke 2002; Suparamaniam & Dekker 2003). Some have postulated that traditional contingency factors (e.g., task uncertainty and task interdependence) applicable to organization design (i.e., intraorganization design) provide a sound explanation regarding the type of coordination mechanisms (e.g., organic or mutual adjustment rather than bureaucratic or hierarchy with its direct supervision) that would exhibit the best fit for the temporary interorganizational structures that emerge when multiple organizations agree to start working together (Mulford & Rogers 1982; Ishida & Ohta 2001; Wright 1976). Others have proposed that hierarchical responses are the best mechanism for coordination in crisis response situations (Bigley & Roberts 2001; Moynihan 2006 and 2008; Gonzalez 2008). This dissertation research is undertaken to provide new insights into this debate.

It has been observed that cooperation and coordination between organizations have been an increasing organizational trend (Baker & Faulkner 2002). Just as there are a variety of ways to organize to achieve a firm's goals, there are multitudes of structural ways to facilitate interorganizational coordination to enable goal achievement (Smith, Carroll & Ashford 1995; Van de Ven & Walker 1984). Just as complex organizational structures (e.g., the matrix form) marked by lateral relationships and informal or weak ties (Granovetter 1973) have grown in popularity over the past decade (Scott 2003), networked or alliance interorganizational forms are appearing frequently in industry (Baker & Faulkner 2002; Scott 2003). Those forms appear to capitalize on the strength of loose coupling and weak ties—ties that are facilitated by the ubiquity of Internet and other communications channels (Kenis & Knoke 2002). Contingency theorists stress that these popular forms are no organization performance panacea, and recommend that organization managers look at structural aspects of their firm and various contingency factors (e.g., elements of their external environment or task interdependencies) to see if they are in fit (see Donaldson 2001; Burton & Obel 2004).

In the governmental sector, stalwart bureaucracies frequently are affected by various contingencies, especially when performance requires coordinated activities with other governmental organizations, both national and international. Points of friction are likely to emerge as these bureaucratic forms interact with each other while attempting to achieve related goals. Scholarly research (see Nissen, Jansen, Jones & Thomas 2004; Nissen 2005) and high profile reviews, such as the 9–11 Commission, reveal the friction that exists between and within bureaucracies and their difficulty in achieving goals in complex situations. Those studies show that key performance goals of those organizations were not successful, even with the availability of critical knowledge and ubiquity of communications technology. Increasing the layers of bureaucracy and changing information processing rules—like the actions taken to reorganize the U.S. National Intelligence community—are certainly alternative structures worthy of consideration, but these again are no panacea, especially when dealing with independent international partners. Achieving cooperative relationships between different organizations reflect the concept of an interorganizational system.

2. Interorganizational Systems

Interorganizational systems are defined as "planned and intentionally formed cooperative ventures between otherwise independent agents." (Kumar & van Dissel 1996) They are becoming more prevalent today largely because they can share costs, spread risk, and access complementary resources, especially knowledge, to help them succeed in the face of growing environmental complexity (Mowery, Oxley & Silverman 1996). While more firms are making the strategic decision to cooperate with other organizations, researchers have left unattended the mechanisms for how the practitioners should be organized to efficiently attain the desired goals. Practitioners, here, are those who have to generate the dynamic information flows between the partnering organizations (Schermerhorn 1979). Those people are referred to in organization literature as *boundary spanners* (Mintzberg 1979; Thompson 1967).

Interorganizational systems can include a variety of independent organizations that take on some role in a developing structure among the organizations. Often, deliberate planning and time are required for these organizations to become effective at achieving their interorganizational goals (Inkpen & Li 1999). There are, however, instances where time is not a luxury, such as during a crisis (e.g., natural disaster). Creating interorganizational action among government agencies in these extreme events often entails forming an entity that would resemble a joint venture (i.e., the resource contributions from two or more organizations that go to form a new organization that gets its goals from the parent firms, see Daft 1998). It can be argued that because those joint ventures emanated from bureaucratically structured organizations they tend to be likewise structured—i.e., that due to the strong acculturation process in many governmental organizations, familiarity with known structures were favored over the consideration of contingency factors and the concept of fit (Comfort 1985). While research has been done on knowledge flows in extreme organizations (see Nissen, Jansen, Jones & Thomas 2004; Nissen 2005), this research adds to the understanding of knowledge flows and organization design issues at the interorganizational level of analysis.

In either deliberate or crisis situations, forming interorganizational systems requires that some agents from each organization become involved in initiating the necessary structures (e.g., roles and processes) to achieve satisfactory interorganizational performance. Those initially involved agents fit the definition of a boundary spanner unit: an organizational unit that interfaces with the external environment (Mintzberg 1979; Thompson 1967). Early boundary spanning activity is postulated as critical to achieving the goals that drive the formation of an interorganization system (Schermerhorn 1979). Smith, Carroll and Ashford (1995) cited the need to provide managers insights into how to manage work teams operating in the challenging environment of interorganizational alliances.

E. RESEARCH QUESTION

This dissertation applies a contingency theoretic approach to investigating an important interorganizational performance issue. It expands the idea that knowledge is not only a critical resource, but also a contingency factor to be considered in organization design. It expands the understanding of performance implications of coordination mechanisms operating among boundary spanners during interorganizational system formation. And, this research provides further evidence of the efficacy of knowledge management research into the area of disaster response operations. The specific research question addressed in this dissertation is:

What are the organizational performance effects of different *types of knowledge* (i.e., tacit and explicit) interacting with organization design coordination mechanisms (e.g., direct supervision and mutual adjustment)?

F. RESEARCH APPROACH

This contingency theory research entails comparing organizational performance data resulting from the combination of different types of knowledge interacting with different types of coordination mechanisms. This kind of research lends itself to a two-by-two factorial design (Shadish, Cook & Campbell 2002). Table 1 depicts the two-by-two factorial design where tacit and explicit types of knowledge are juxtaposed with direct supervision and mutual adjustment coordination mechanisms to provide a framework for comparing performance data. There are, however, significant challenges of conducting contingency theory research on an interorganizational system emerging in response to a crisis event. Foremost among these challenges are the infrequent, unanticipated nature of crisis events and the highly unique nature of each event and the responding organizations. To ameliorate these challenges, this research uses a mixed methodology research approach (Tashakkori & Teddlie 1998; Kerlinger & Lee 2000; Mingers 2001).

		Coordination Mechanism	
		Direct Supervision	**Mutual Adjustment**
Knowledge Type	**Tacit**	Direct Supervision *Interacting with* Tacit Knowledge	Mutual Adjustment *Interacting with* Tacit Knowledge
	Explicit	Direct Supervision *Interacting with* Explicit Knowledge	Mutual Adjustment *Interacting with* Explicit Knowledge

Table 1. Factorial design

This mixed approach uses a combination of computational organization modeling (Levitt, Cohen, Kunz, Nass, Christiansen & Jin 1994) and participant observation (Spradley 1980). The qualitative participant observation phase focuses on collection of multiple sources of data to set the stage for triangulation: combining evidence from multiple sources to deepen confidence in explanations developed of organization science phenomenon, as well as to generate future research areas where the data shows incongruence (Burton 2003). Participant observation in a field research setting is conducted by observing networks of independent military headquarters as they simultaneously respond to the same crisis event. New knowledge is generated by observing how each boundary spanning team, in this case each headquarters' planning team, works to coordinate initial response actions with the other headquarters. Detailed observations of team structures, knowledge flows, and planning and coordination processes are used to develop an empirically grounded baseline computational model of the interorganizational system. From that model and informed by organization and knowledge flow theory, computational experimentation is conducted. The experiment consists of adjusting select model parameters and holding all other parameters constant, and then multiple simulation runs using Monte Carlo techniques are conducted to generate the data to support statistical analysis of this factorial design experiment (Burton & Obel 1995; Carley 2002; Nissen & Buettner 2004).

1. Multi-Method Research

This research builds on a continuing stream of research that employs computational organizational models that are grounded in organization theory (e.g., Galbraith 1974; Mintzberg 1979) to conduct computational experimentation (e.g., Nissen & Buettner 2004, Nissen 2005, and Looney & Nissen 2006). The results of those experiments allow for the analysis of a variety of organization forms, especially ones that are rare and temporary. The computational modeling tool used in this research comes from more than two decades of work in the Virtual Design Team (VDT) Research Program (VDT 2005). It is based on upon Galbraith's (1974) theory that organizations are information processing systems (Cohen 1992). An extension of this extensively validated agent-based model, the POW-ER application, is used in this research.

2. Field Research Structure

The research documented in this dissertation was conducted within the auspices of a large-scale multinational maritime field experiment. To investigate an interorganizational phenomenon during a crisis, a team of planners from six distinct, non-collocated, and co-equal maritime organizations (i.e., no two organizations had a superior-subordinate relationship in actuality or implied by military rank of its commander) were available to conduct a pilot study over a ten day period.

To generate the interorganizational dynamics that would ground the development of the computational model, the teams of planners were divided into two groups, each having three planning teams. Each group represented a *federation*, specifically a *coalition*: a federation formed by mutual agreement to cooperate and coordinate behavior (Warren 1967; Provan 1983). Each group was given a three day mock international crisis scenario based on a complex type of operation other than war (e.g., humanitarian assistance/disaster relief situation) along with similar objectives (i.e., common goals) and the common task to "coordinate" planning efforts and each team's individual plan with the other teams within the group. By virtue of the scenario, objectives and common task, the planning teams became *boundary spanning units* for their independent organizations.

On the surface, these independent organizations with reciprocal interdependencies may appear to be an atypical structure to a person familiar with the more traditional military command and control response to crises—i.e., the joint/coalition task force. Traditionally, a task force is commanded by an agreed upon leader and populated with personnel, equipment and/or logistics from each of the contributing organizations. From organization theory, this would be consistent with the creation of a divisional structure (Mintzberg 1979) to handle the increased information processing demands of the crisis environment (March & Simon 1958; Galbraith 1974). Drawing on Mintzberg's (1979) "five basic parts" of organizations, the perceived drawback to this approach is that while elements of the *operating core* are immediately available to respond, it takes time for the *technostructure, support staff*, and *middle line* to form and begin efficiently functioning to support the leader at the *strategic apex*. The delay can be partially attributable to travel time and the developmental time required for these organizational parts to coalesce into a high performing whole (Tuckman 1965).

While each organization's strategic apex and available operating core units are overwhelmed with decision making and work tasks respectively, the boundary spanning units perform planning (e.g., the act of developing alternative courses of action to solve a problem—see Cyert & March 1992, and Simon 1997). In this field environment, each boundary spanning unit had between 7 and 17 people participate in the scenario. The participants operated from their office buildings. Since these office buildings were not located in the same cities, the participants used Internet-based and telephone communications channels to exchange information. Passive participant observers (Spradley 1980) were assigned to each unit to monitor and make a record of both internal unit activities and inter-unit activities. Relevant data from these observations are used to develop a grounded baseline computational model of this interorganizational phenomenon.

G. ORGANIZATION OF WORK

In Chapter II, a literature review is conducted to cover the theoretic foundations that underpin this research, including organization design, structural contingency theory, knowledge dynamics, interorganizational coordination, disaster response research, and computational organization theory. In Chapter III, the research design is articulated. In Chapter IV, the analysis of the data is presented. Chapter V concludes this dissertation with a summary of the findings, discussion of limitations, and suggested future research.

II. BACKGROUND

This chapter presents a review of the structural contingency theory and the knowledge flow theory literatures regarding organization design and points to some unanswered questions regarding contingency factors and their affect on organization performance at the interorganizational level. The focus here is on interorganizational response at the early stages of a crisis or disaster event where virtual organizations may emerge. The chapter also includes a section on computational organization theory as it represents an effective means for investigating many organizational issues, especially when experimentation with real world organizations is costly or the opportunities are fleeting, such as in disaster response activities.

A. ORGANIZATION RESEARCH

Prior to the 1960s, organization research generally focused on the internal elements of an organization—i.e., it excluded the influences of the external environment. Management practitioners such as Fredrick Taylor (1911) and Henri Fayol (1949 translation) articulated theoretical models that became very popular during the burgeoning industrial era in the early 20th century (Scott 2003). Those models are classified as closed system models: they consider only the internal elements of a firm in their explanations of that firm's performance (Scott 2003). By the 1950s, a combination of societal changes and social science advancements prompted the development of new theories and models of organizations such as the currently prevalent open systems models. These new theories, in combination with the recognized "bewildering variety" (Scott 2001 p. 11) of organizations that exist in the world, contribute to the rich field of organization research as evident by its diversity of useful models (e.g., Bureaucracy, see Weber 1947 translation; M-Form and U-Form, see Chandler 1962; Markets and Hierarchies, see Alliances, see Clark 1965; Williamson 1975; Joint Venture, see Pfeffer & Nowak 1976; Networks see Miles & Snow 1978; Clans, see Ouchi 1981; Federation, see Provan 1983; High Reliability, see Roberts 1990; Virtual see Davidow & Malone 1992; Edge of Chaos, see Brown & Eisenhardt 1998). The following sections address the foundation of structural contingency theory of organization design and the foundation of emerging knowledge flow theory. It concludes with a section that describes interorganization theory and how structural contingency theory and knowledge flow theory converge and provide insightful lenses through with to investigate interorganizational responses to disaster situations.

1. Open System Model

The open system's perspective of organizations originated in the early 1950s as researchers started to appreciate the complexity that existed in these social systems. This perspective recognizes that organizations have multiple interacting elements that take inputs from the environment, execute some process or processes, and produce outputs back to the environment (Boulding 1956; Bertalanffy 1962; Katz & Kahn 1966). That perspective led researchers to appreciate the efficacy of viewing organizations as systems of coupled interdependent parts that exhibit dynamic behavior (Baum & Rowley 2002). This way of viewing organizations stands in stark contrast to the closed systems perspective where organizations are perceived as being similar to mechanical systems (i.e., severely constrained by rigid, formal structures such as rules and roles) with little flexibility (Scott 2003).

Organization theorists generally agree that the following elements are common to all organizations: goals, participants, technology, social structures, boundaries, and the environment (Leavitt, Pinfield & Webb 1974; Daft 1998; Baum & Rowley, 2002; Scott 2003). These elements are clearly depicted in Scott's 2008 version of the Leavitt Diamond Model of Organization (Leavitt 1965), see Figure 1, where they interact with and influence each other. In the figure, goals define the ends that participants in an organization collectively desire to achieve (Scott 2003). Technology represents the way goals are achieved by participants, and is typically recognized as the combination of processes and equipment employed by participants (Leavitt 1965; Scott 2003). Social structures refer to recurring patterns of interactions among participants (Scott 2003). It is these recurring patterns that, whether purposefully designed (e.g., job definitions), pre-existing (e.g., social norms), or emergent (e.g., informal social interactions), produce the coordination among participants that is necessary to achieve organization goals (Scott 2003). Boundaries identify the elements that are considered to be within the organization. Stemming from the open systems perspective, the organization boundary is depicted in Figure 1 as a dashed line to reflect the integral relationship between the elements of the organization and the environment, and the dynamic nature of the boundary.

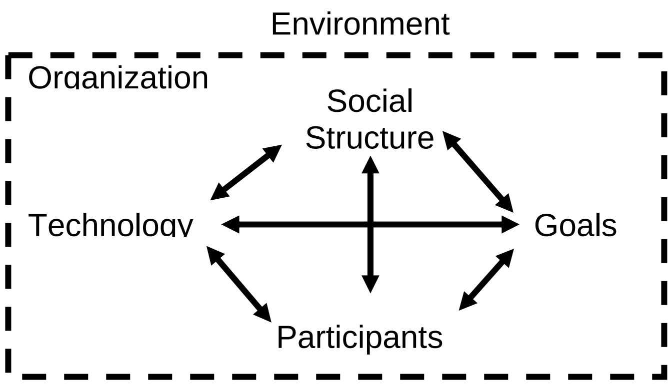

Figure 1. Leavitt’s Diamond Model of Organization (from Scott 2003)

Open systems models account for both the influence of the environment on a firm (e.g., a cybernetic system (Boulding 1956) perspective where feedback from the environment plays a crucial role in organizational performance), and the internal dynamics that occur within a firm (i.e., firms evolve over time by actually incorporating elements of the environment) (Leavitt, Pinfield & Webb 1974; Banner & Gange 1995). Open systems theorists view the environment as “the ultimate source of materials, energy and information.” (Scott 2003 p. 101) The environment, therefore, provides the resources and impetus that make organizational adaption possible and necessary.

Early organization theorists such as Taylor (1911) and Fayol (1949 translation) employed a rational perspective to explain organization structures. This rational perspective came from the idea that an organization’s structure (e.g., roles and rules) was deliberately designed to most efficiently achieve the organization’s goals. This dominant perspective was a significant foundation of the open systems research that emerged in the

1960s and continues today (Baum & Rowley 2002; Scott 2003). According to Scott's (2003) "Layered Model" for classifying organization theory development, *Contingency Theory* is one of the open systems, rational theories. Competing open systems models exist; some are rational and others are natural. A natural system perspective places emphasis on observing the behavioral aspect and goal incongruence of participants and how informal structures emerge that are not rationally designed. Transaction Cost (Williamson 1975) and Knowledge-based (Nonaka & Takeuchi 1995) models are rational open systems models, while Population Ecology (Hannan & Freeman 1977) and Institutional Theory (DiMaggio & Powell 1982) are natural open systems models.

The next section focuses on structural contingency theory and provides background information regarding organizational structure, a rubric for structural elements to consider when designing or investigating an organizations, and contingency factors relevant to this research.

2. Structural Contingency Theory

Contingency theory is the most widely used research approach in the field of organization design (Lawrence 1993; Donaldson 2001; Scott 2003). March and Simon (1958) sparked contingency theory research by articulating the idea that different decision-making methods seemed appropriate depending on environmental conditions (e.g., uncertainty). By the early 1960s, a contingency theory paradigm began to supersede the classical management school's pursuit of a universal theory of administration and its goal of uncovering the one true best way to organize (Pennings 1975; Lawrence 1993). While the term "contingency theory" was coined by Lawrence and Lorsch (1967), other organization researchers were already exploring the theory's central assumption (see Burns & Stalker 1961; Hage 1965; and Woodward 1965). Central to contingency theory is the assumption that *there is no one best way to organize* to obtain desired goals (Galbraith 1977; Lawrence 1993; Donaldson 2001; Scott 2003). It is a theory based on the concept that to achieve high performance (i.e., goal attainment), select structural elements of an organization must be in *fit* with relevant contingency factors (e.g., level of environmental uncertainty (Duncan 1979)).

A contingency factor is a "variable that moderates the effect of an organizational characteristic on organizational performance." (Donaldson 2001 p. 7) The preponderance of contingency theory research investigates the social structures of organizations, hence, the distinction *structural contingency theory*. The classic elements of organizational structures are the *division of labor* among participants, and the *methods of coordinating* the work performed (Child 1972; Galbraith 1977; Mintzberg 1979; Daft 1998; Scott 2003). Division of labor is traditionally depicted as an organizational chart where both vertical and horizontal differences in labor are readily distinguishable. The following sections address draw heavily on past organization theorists and specifically Mintzberg's seminal work on organizational structure and specific contingency factors relevant to this research, specifically task interdependence and uncertainty.

a. Organization Structure

Mintzberg (1979) developed a theoretically based and empirically sound typology of five organization archetypes (e.g., Simple Structure, Machine Bureaucracy, Professional Bureaucracy, Divisional Form, and Adhocracy) and five coordinating mechanisms—see Figure 2; 1) Direct Supervision (Fayol 1949 translation), 2) Standardization of Work (Taylor 1947 and Weber 1947 translation, March 1957), 3) Standardization of Skills (March 1957; March & Simon 1958), 4) Standardization of Outputs (March 1957; March & Simon 1958), and 5) Mutual Adjustment (March & Simon 1958; Thompson 1967; Galbraith 1973). Each archetype is distinguishable by its shape, which is based on the predominance of its parts (i.e., Strategic Apex, Middle Line, Operating Core, Technostructure, and Support Staff). As an example, the strategic apex (e.g., Company President and top-level managers) dominates how work is coordinated is a Simple Structure type organization. Coordination is achieved through pre-established, supervisor developed rules and roles, and by direct supervision where exception (i.e., conditions emerge that do not fit the established rules) handling is achieved through decision making by top-level personnel. Notice that in order to establish which organization part predominates, the dominate type of coordination mechanism must first be determined. In Mintzberg's own words, coordinating mechanisms "should be considered the most basic element of structure, the glue that holds organizations together." (Mintzberg 1979 p. 3)

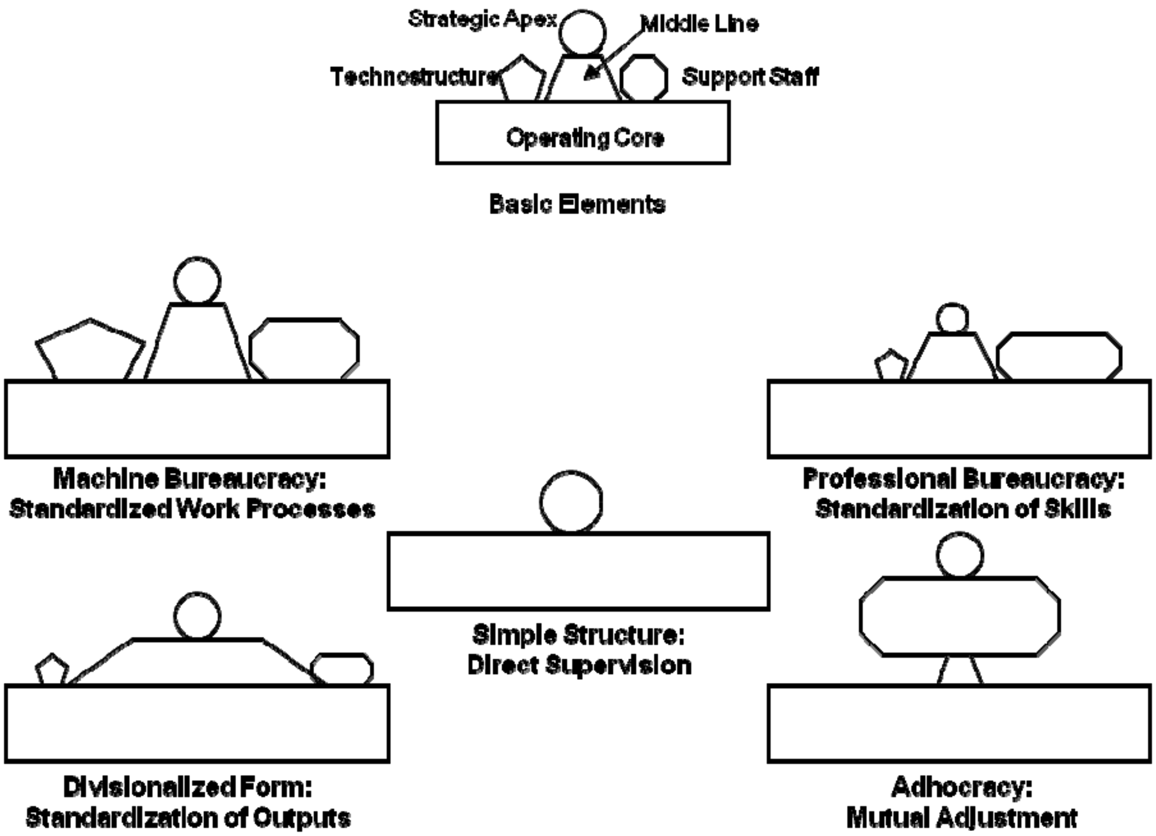

Figure 2. Organizational Elements and Archetypal Examples (adapted from Mintzberg 1979 and Nissen 2005)

Organization theorists tend to agree that there are different types of coordination mechanisms and a useful way of categorizing them regards their degree of complexity—see Figure 3 (Lawrence & Lorsch 1967; Thompson 1967; Galbraith 1973; Mintzberg 1979; Scott 2003). The degree of complexity for a coordination mechanism involves how workers in an organization handle the inevitable exceptions that arise during the conduct of their tasks. If a worker only has to look to his or her immediate supervisor to provide the answer regarding how to resolve an exception, then there is a low degree of complexity in that type of coordination mechanism called *direct* *supervision*. On the other hand, if each worker is supposed to resolve their exceptions as they arise, and in a way that has a beneficial result for attaining the organization's goals, then they would likely be obliged to consider alternative ways of handling the exception and the short and long-term implication of those alternatives on their task as well as the tasks that others in the organization perform. At the same time, the other workers may likewise be attempting to resolve a related or separate exception. That is an example of a highly complex (i.e., it requires consideration of many more conditions by many more workers) coordination mechanism called *mutual adjustment*.

A medium level of complexity in a coordination mechanism is one where standardization is imposed in some element of the tasks to be performed. This requires managers to design either, or more likely in combination, standardization of work (i.e., the tasks to be conducted), standardization of outputs (i.e., the products being delivered to other workers or customers meet specific specifications), or standardization of skills (i.e., the workers have similar abilities necessary to produce a coherent product). In each case, the worker is required to have a greater understanding of the rules to minimize the amount of conditions that rise to the level of an exception.

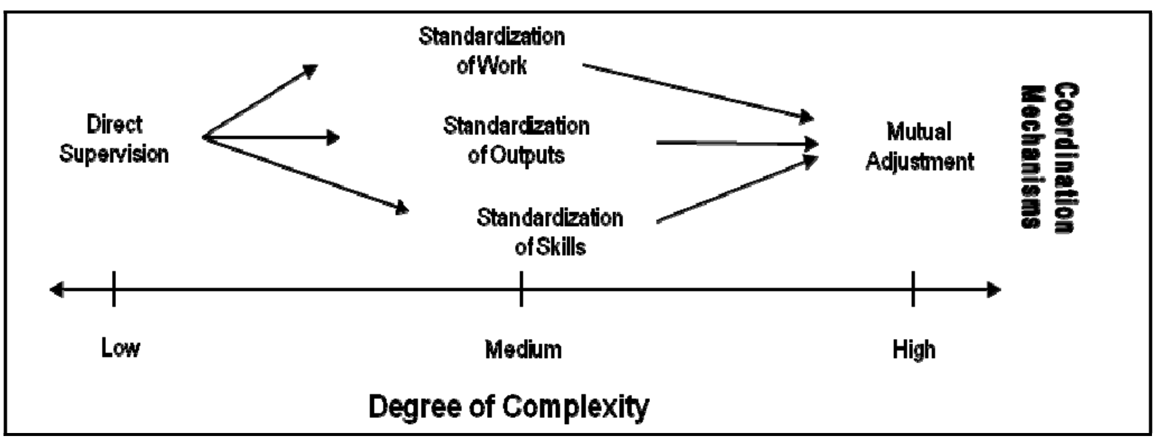

Figure 3. Coordination Mechanisms Along a Continuum of Complexity (from Mintzberg 1979)

b. Design Specifications

The final elements of Mintzberg's (1979) organizational treatise are the eight design parameters—1) Job Specialization, 2) Behavior Formalization, 3) Training and Indoctrination, 4) Unit Grouping, 5) Unit Size, 6) Planning and Control Systems, 7) Liaison Devices, and 8) Decentralization, both vertical and horizontal. These design parameters reflect the "discretion" to alter conditions within the organization that organization designers and managers have to produce some effect on "how materials, authority, information, and decision processes flow through it." (Mintzberg 1979 p. 65) As an example of the relationship of these design factors to contingency theory, consider an organization that expands (e.g., adds workers) and holds all other design parameters constant, performance is predicted to suffer until the members are reorganized into a new form—i.e., move from the previous form to a form that is a better fit (Blau 1970; Blau & Schoenherr 1971; Child 1973; Pugh & Hickson 1976; Pugh & Hinings 1976; Daft & Bradshaw 1980; Donaldson 1996). That example reflects just one of the myriad organization design rules that Mintzberg (1979) synthesizes. This combination of organization archetypes, coordination mechanisms, and design parameters constitutes "a rubric for classifying and analyzing a wide variety of organizational forms" (Nissen 2005). The relevance of this rubric to this dissertation is discussed in Section B of this chapter on computational organization experimentation.

c. Structural Contingency Factors

Donaldson (2001) organizes structural contingency theory research into two categories: (1) the *organic* theories that focus on how organizational effectiveness (i.e., the ability to attain goals) is moderated due to the fitness of micro-level structures (i.e., structures involving the relationships among the subunits of the organization) to the predominant contingencies of *task uncertainty* (see, Burns & Stalker 1961; Hage 1965; Lawrence & Lorsch 1967), *task interdependence* (see Thompson 1967; Lorsch & Lawrence 1972), and *technology* (see Woodward 1965; Perrow 1967; Thompson 1967; Galbraith 1973), and (2) the *bureaucracy* theories that focus on effectiveness due to fitness of macro-level structures primarily to the variables of *size* (see Chandler 1962;

Pugh et al. 1963; Blau 1970; Child 1973) and *age* (Starbuck 1965; Inkson et al. 1970; Samuel & Mannheim 1970). While the macro-level field has progressed to the point where analyzing organizational fitness is operationalized in an expert system (see Burton & Obel 2004), researchers continue to explore micro-level issues to identify other contingency factors (Lawrence 1993; Burton & Obel 2004). The next sections cover the relevant micro-level contingency factors associated with this research and specifically focuses on factors that relate to coordination within the organization and the level of complexity that organizations face, specifically task interdependence and task uncertainty.

(1) Task Interdependence. Interdependence is defined as the extent that one organizational subunit relies on a resource (e.g., information and material) from another subunit (Daft 1998). A subunit includes such entities as an individual, work group, or department. Thompson (1967) classified three types of interdependence: (1) pooled, (2) sequential, and (3) reciprocal. Pooled interdependence involves different subunits of the same organization that draw from common resources yet have no dependence on each other for the accomplishment of their work. For example, an aid organization such as the Salvation Army may have branch offices operating in different zones within a disaster area. As a part of their work to help relieve suffering through distribution of aid, each office may draw resources from a common regional pool of resources.

In sequential interdependence, the output of one subunit is the input to another subunit. A city's emergency operations organization in response to a terrorist attack involving hazardous chemicals may require its police forces to provide a certain level of security before its hazardous material/fire fighting teams can make the environment safe for rescue and emergency medicine teams to treat casualties.

Reciprocal interdependence involves subunits that both provide and are dependent on support from each other. As an example of reciprocal interdependence, consider a military organization responding to a humanitarian disaster; the organization would likely have transportation teams and logistics teams. Each team produces an input for the other. Specifically, transportation teams (e.g., helicopter detachments) move supplies to, and assist in distributing supplies from, forward operating bases. At these forward operating bases, logisticians not only manage the relief supply inventory, but they also sustain (e.g., provide fuel, food, and water) the transportation units to allow them to continue to move supplies.

Galbraith (1977) pointed out in his seminal book on information processing theory of organizations the correspondence between information processing requirements and Thompson's (1967) types of interdependence. In short, there is a correspondence between the types of interdependence and the intensity of interaction (i.e., information processing) between organizational subunits required to achieve coordination (Scott 2003). This is shown by putting interdependence on a categorical information processing scale from low to high; pooled is a low form of interdependence while reciprocal is a high form. Sequential interdependence falls in the middle as a medium form of interdependence. This parsimonious correspondence between information processing requirements and coordination mechanisms is not as simple as it appears, since vestiges of the less sophisticated coordination mechanisms remain while the more robust mechanisms emerge and take primacy for coordinating activities (Galbraith 1977; Galbraith & Nathanson 1978; Mintzberg 1979). Hence, this falls along a Guttman scale such that higher forms of interdependence are inclusive of the lesser forms of interdependence: within organizations, subunits that exhibit reciprocal interdependence also have instances of sequential and pooled interdependencies (Thompson 1967; Galbraith & Nathanson 1978; Mintzberg 1979). That Guttman scale is depicted in Figure 4. While the horizontal axis represents categories, one can see that categories exist within categories. The relative size of the categories within a category are mere abstractions and do not connote any relative values.

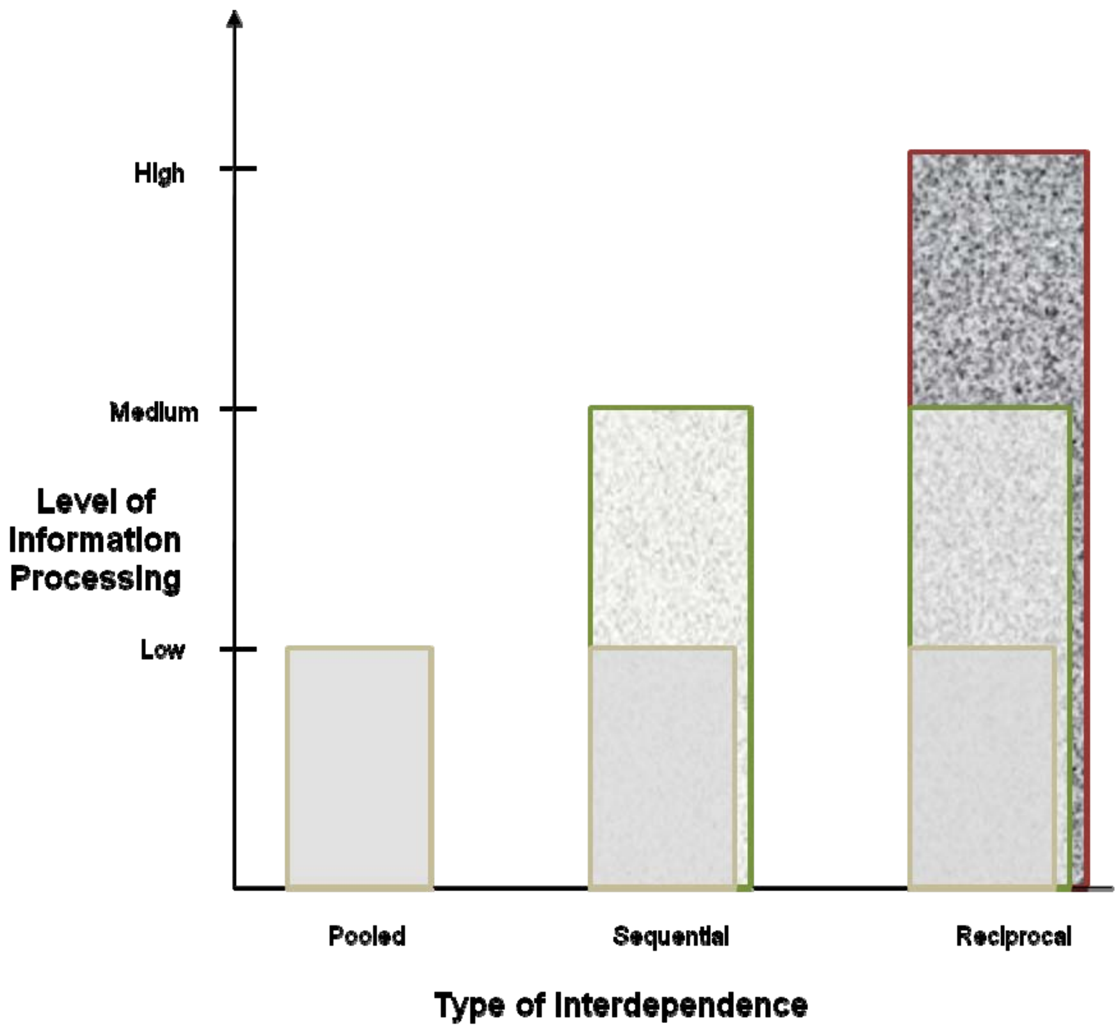

Figure 4. Types of Interdependence

Thompson (1967) identified a contingency relationship between an organization's performance and the type of coordination mechanism used between subunits: performance is dependent on fit between the level of interdependence and the level of sophistication of the coordination mechanism (i.e., rules and standard procedures, plans and schedules, and mutual adjustment) used. Galbraith (1973) and Mintzberg (1979) made similar conclusions about this fit relationship between the sophistication of coordination mechanisms and level of interdependence within organizations. These concepts are integrated here by tying them together based on the correspondence between level of complexity of coordination mechanisms and level of complexity associated with type of interdependence. Figure 5 depicts a useful synthesis of these theoretic contributions. In the figure, degrees of interdependence is substituted for the level of complexity that was shown in Figure 3, since both degree of interdependence and coordination mechanisms are associated with similar levels of complexity in the amount of information that is required to be exchanged to achieve coordination. Both mutual adjustment and reciprocal interdependence require high levels of information exchange and consideration of a greater amount of varied types of facts (e.g., resource and marketing information) by the workers. Hence, coordination mechanisms and types of interdependence correspond to the degree of complexity (i.e., high, medium, and low).

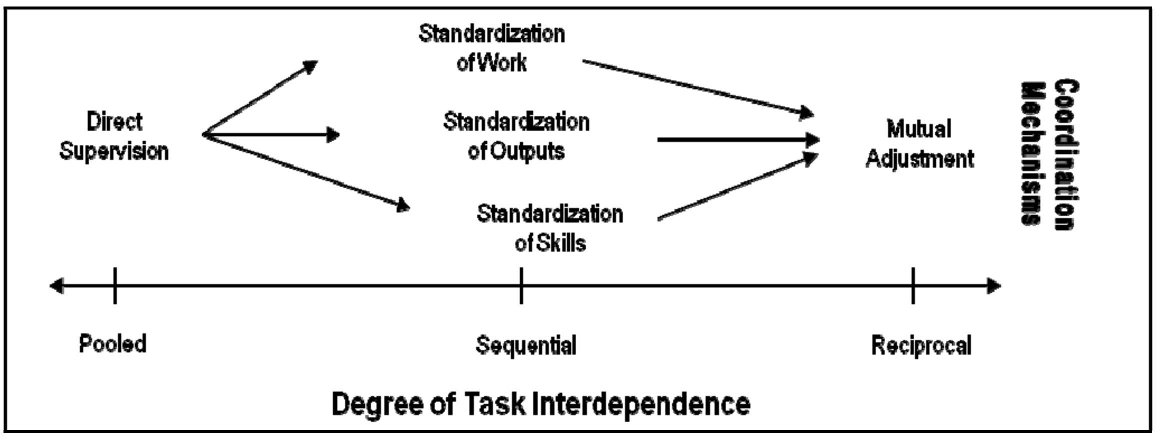

Figure 5. Continuum of Coordinating Mechanisms

(2) Task Uncertainty. Task uncertainty reflects the complexity that workers face in an organization (Donaldson 2001). The open systems model allows for this uncertainty to come from the task itself and from the environment. Burns and Stalker (1961) explored uncertainty as a useful construct to differentiate the types of environment that organizations face. They characterized the environment as stable or unstable depending on the rate of change of inputs (e.g., resources) and outputs (e.g., demand). Others explored similar constructs regarding the environment (homogeneous or heterogeneous, see Thompson 1967; Simple or Complex, see Duncan 1972; and Placid, Placid-clustered, Disturbed-reactive, or Turbulent, see Emery & Trist 1963; 1965; and Terreberry 1968) and concluded that the higher the variety of variables (e.g., how

many types of expertise are desired), or dynamics exhibited by an organization's environment meant that the organization faced higher uncertainty. Burns and Stalker (1961) identified a performance relationship between the level of environmental uncertainty and organization structure: performance depends on fit between the level of environmental uncertainty and the way firms organize to perform tasks. Mechanistic structures—i.e., structures that are characterized by hierarchical distribution of decision making, formalization of rules, and specialization of workers' roles—are fit with environments that exhibit low uncertainty (Burns & Stalker 1961; Hage 1965; Fry & Slocum 1984; Pennings 1992). Organic structures—i.e., structures that are marked by decentralized decision-making authority and flexible roles performed by broadly knowledgeable workers—are fit with high uncertainty environments (Burns & Stalker 1961; Hage 1965; Fry & Slocum 1984; Pennings 1992). These conclusions found support in many related studies (see Thompson 1967; Child 1975; Lawrence & Dyer 1983; Dess & Beard 1984). Related contingency research (see Hage 1965; Woodward 1965; Hage & Aiken 1970; Miles & Snow 1978; Gresov 1990) led some to conclude that *environmental uncertainty* and *task uncertainty* can be subsumed under the concept of a more encompassing notion of *task contingency* (Lawrence & Dyer 1983; Donaldson 2001; Scott 2003).

3. Knowledge Flow Theory

The emergence of knowledge as a critical organizational resource (Nonaka 1995; Grant 1996; Spender 1996; von Krogh 1998) prompted more attention in organization design research. While Burton and Obel (2004) incorporated much of the structural contingency research into their organizational diagnosis and design expert system Organizational Consultant (OrgCon®), they recognized the growing body of work in the field of knowledge flow theory (see Nonaka & Takeuchi 1995; Alavi & Leidner 2001; Nissen 2006b) and more specifically structural contingency theoretic studies that hypothesize knowledge as a contingency factor (see Rulke & Galaskiewicz 2000; Becerra-Fernandez & Sabherwal 2001; Birkinshaw, Nobel & Ridderstrale 2002; Postrel 2002; Ibrahim & Nissen 2003) and its potential to influence organizational design.

Currently, this body of contingency theory research is sparse and only shows "…partial support for the "fit" hypothesis in contingency theory." (Burton & Obel 2004 p. 10) This research furthers the argument that knowledge is a structural contingency factor.

The concept of knowledge has many facets: taxonomic work has produced frequent debate over descriptions of the various perspectives and types of knowledge (see Alavi & Leidner 2001). Here, knowledge is defined as a "justified true belief" that enables action (Nonaka 1994 p. 15). This definition accounts for the human process of justifying personal beliefs. For a person to take some action there must be some personal belief that the action will lead to a predicted result. Hence, knowledge enables action (Nissen 2006b). From an organizational performance perspective, it is this point that Nonaka (1994) stresses as critical for organizations to understand as opposed to the more "passive and static" (p,14) information processing theory (see Galbraith 1972). Knowledge flow theory focuses on the dynamic creation and transfer of knowledge in complex creative tasks such as problem solving and innovation (Nonaka 1994). Leweling (2007) shows convincing evidence that the performance of problem solving groups is enhanced when information and knowledge are shared as opposed to just when the groups only share information.

Many differing concepts of knowledge have been proffered (for a summary see Alavi & Leidner 2001 and Nissen 2006a); however, an epistemic distinction is made that classifies knowledge into two types: tacit and explicit (Polanyi 1966). Tacit knowledge is the personal know-how and mental models developed through experiences (e.g., the combination of developed feel for balance and balance correction techniques applicable to riding a bicycle enables one to ride—Polanyi 1966). A common characteristic of tacit knowledge is that it is not easily transferred from one place or person to another (i.e., it is sticky—von Hippel 1994; Nonaka 1995; Nissen 2006b). Explicit knowledge, on the other hand, is know-how that is codified (e.g., formalized written procedures, such as cooking recipes). This type of knowledge is more easily moved; however, a key aspect of explicit knowledge is that it cannot completely capture all that is known tacitly.

This epistemic distinction is used in this research because "the distinction between tacit and explicit knowledge…is the most enduring and prominent in a dynamic context." (Nissen 2006a p. 17) While knowledge creation and transfer (e.g., learning) are key dynamic aspects of knowledge, in an organizational context, knowledge must also be applied (i.e., put into action to achieve goals). It is theorized that knowledge, especially tacit, is a powerful resource that firms utilize and create to positively affect performance (Nonaka 1995; Grant 1996, von Krogh 1998; Nissen 2006a), but there is a tension between the knowledge work involving creation and application tasks. This is referred to as the "knowing-doing gap." (Pfeffer & Sutton 1999)

Knowledge management and organizational learning theories state that there should be a purposeful balance between exploration and exploitation tasks—i.e., those tasks that contribute directly to knowledge creation and work respectively (March 1991; Nissen 2006b). The dynamic theory of knowledge creation (Nonaka's 1994) contends that organizational performance will increase when explicit and especially tacit knowledge are able to broadly flow throughout an organization in support of both exploration and exploitation tasks (Nonaka 1995; Nissen 2005). Nonaka (1994) theorized that there were four modes of knowledge conversion that accounted for all flows; they are socialization, externalization, combination, and internalization—see Table 2. Socialization is the tacit-to-tacit flow of knowledge and is typically found in the close observation and "hands on" experience of doing something (e.g., an apprentice learning from a craftsman by observation, imitation and on-the-job training). Externalization is the transfer of tacit-to-explicit knowledge; typically, this takes the form of writing instructions after reflecting on how some action was performed. Combination is a process where knowledge is exchanged in its explicit form such as through face-to-face discussions in meetings and transferring written instructions by file transfer. Finally, internalization is the process of taking explicit knowledge such as a written or verbal set of instructions and coming to a personal understanding of them (e.g., learning the instructions) so that actions can be instinctively performed.

From \ To	Tacit Knowledge	Explicit Knowledge
Tacit Knowledge	Socialization	Externalization
Explicit Knowledge	Internalization	Combination

Table 2. Modes of Knowledge Creation
(from Nonaka 1994)

Knowledge creation and learning, which are essential to solving novel problems and improving task performance respectively, are theorized to "hinge on a dynamic interaction between the different modes of knowledge conversion." (Nonaka 1994 p. 19) This shifting between modes, although not required, is theorized to be most productive when it follows a cycle between tacit and explicit forms of knowledge. That cycle is represented as a spiral pattern of ever-increasing knowledge—see Figure 6 (Nonaka 1994). Nissen (2006b) extended that model to a useful four-dimensional model that facilitates better understanding of knowledge dynamics in the broader context of organizations.

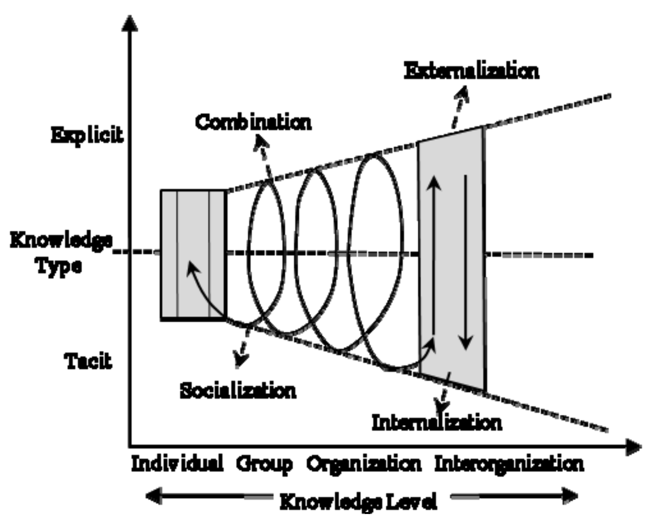

Figure 6. Spiral of Organization Knowledge Creation
(from Nonaka 1994)

The four dimensions of Nissen's (2006b) model (Figure 7) are epistemological (i.e., a dimension that classifies knowledge as either tacit or explicit), ontological (i.e., a dimension that distinguishes social levels such as individuals, groups, organization and interorganization), life cycle (i.e., an ontological dimension that distinguishes activities of knowledge, such as create and apply), and flow time (i.e., a temporal dimension representing the rate at which knowledge flows, for simplicity of representing this fourth dimension "fast" and "slow" are the two categories used) (Nissen 2006b). The temporal dimension is not shown in this generic figure, but it is represented by different thicknesses of the vectors that track the dynamic movement of knowledge through the other dimensions. Through use of this four-dimensional model, a manager can represent how knowledge is flowing and thereby identify knowledge gaps where resident knowledge is not broadly influencing performance—i.e., where tacit knowledge is isolated or "clumping" and not flowing. With the gaps revealed, the manager may target new ways to stimulate or trigger knowledge flows in productive ways that lead to increasing knowledge or enhancing task performance. These "ways" to stimulate knowledge flows can be viewed as a rational organization design choice; hence, a contingency theoretic perspective is apropos to investigating this management issue. The following sections review the burgeoning research on knowledge being an important contingency factor for consideration in organization design, and knowledge dynamics.

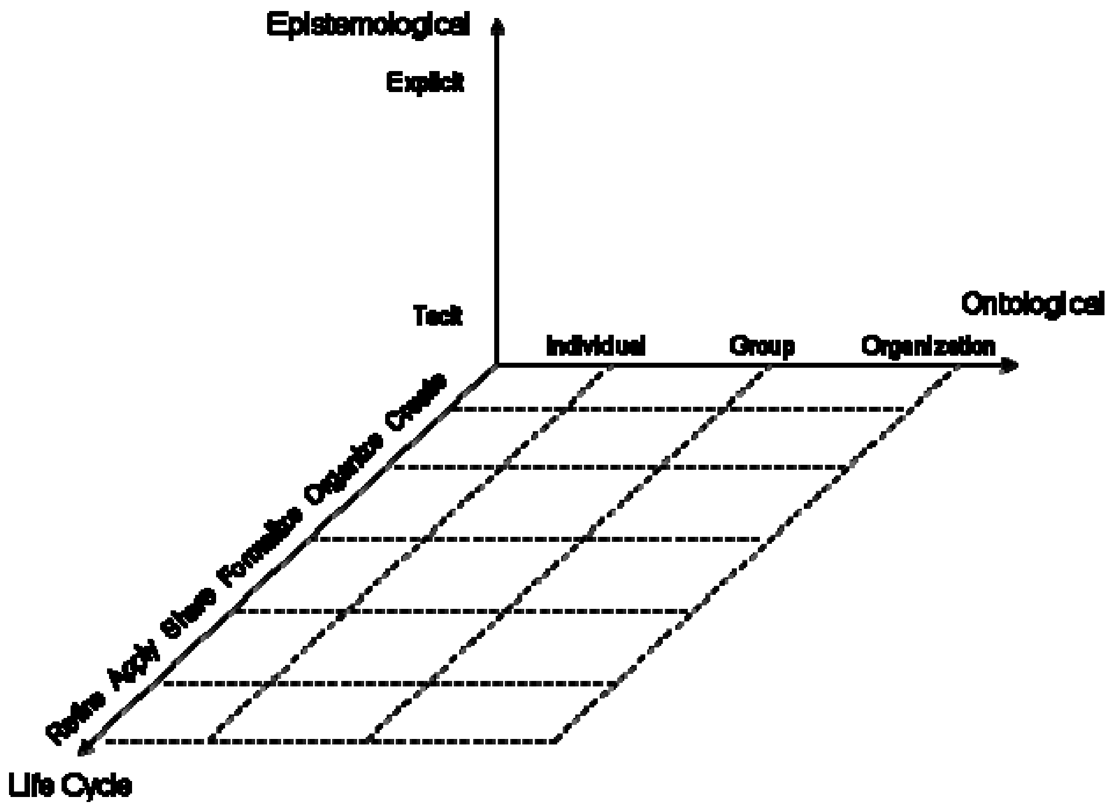

Figure 7. Knowledge Flow Life Cycle Model (from Nissen 2006b)

a. Knowledge as a Contingency Factor

While theoretical and empirical studies about knowledge creation and transfer are growing, the contingency theory work in this area remains sparse and focused on within team phenomena (Leweling 2007). Since 2001, researchers have been working to extend structural contingency theory to consider knowledge as a contingency factor when making organization design decisions (Rulke & Galaskiewicz 2000; Becerra-Fernandez & Sabherwal 2001; Birkinshaw, Nobel & Ridderstrale 2002; Postrel 2002; Ibrahim & Nissen 2003). Knowledge research regarding organization design is gaining momentum; however, it remains sparse and unfocused when compared to the extent of other contingency theory research. Becerra-Fernandez and Sabherwal's (2001) research focused on participants' perceived satisfaction with knowledge management as its performance factor, while Birkinshaw, Nobel and Ridderstrale's (2002) study did not address structural contingency factors, rather it focused solely on the effects that knowledge observibility (i.e., how easy is it to reverse engineer the knowledge used to produce the product from observing the final product—from Zander & Kogut 1995) interacting with system embeddedness (i.e., how tied is the product development process to a physical location—from Brown & Duguid (1991) and Tyre & von Hippel (1997)) contribute to the numbers of patents achieved as a performance measure.

Rulke and Galaskiewicz (2000) built on the small group performance literature (see Steiner 1972; Shaw 1981; McGrath 1984; Jackson 1992; Liang 1994; Stasser & Stewart 1992) which points to a "strong relationship between knowledge possessed by group members and performance." (Rulke & Galaskiewicz 2000 p. 612) In the condition where the problems faced by a team are complex, the contingent effects of structure (i.e., hierarchical or decentralized pattern of relationships among group members) interacting with different distributions of knowledge (i.e., teams made up of all generalists compared to all specialists and a mixture of specialists and generalists) are mostly consistent with classical structural contingency theory (see Burns & Stalker 1962; Thompson 1967; Duncan 1979; Shaw 1981; Argote et al. 1989; Donaldson 2001)—showing that decentralized structures perform better than centralized structures (Rulke & Galaskiewicz 2000; Powley & Nissen 2009). Their research showed one exception: teams comprised of generalists performed equally well in either group structure (Rulke & Galaskiewicz 2000).

One possible explanation for that universal finding is that only at the end of the two-year study, did Rulke and Galaskiewicz (2000) apply social network analysis principles to distinguish groups as either hierarchical or decentralized. This discounts other research findings that coordination mechanisms may change over time (Gulati & Singh 1998; Harris & Beyerlein 2003). In the Rulke and Galaskiewicz (2000) study, subjects were asked to report whose work they relied upon and who they thought relied upon their work throughout an experiment. This relates to the idea that organization structure is revealed through information flows (Galbraith 1977; Taylor & Van Every 2000). The social network approach, however, does not account for the degree of formalization (e.g., decision-making roles or information-processing rules) in the groups. In other words, although each group was prescribed a traditional hierarchical decision making and information processing structure (e.g., a team president, and three functional vice-presidents), no control over formalization was apparent so each group's social network structure could have evolved over time. Since sampling to assess social structure only occurred at the end of the two-year study, the accumulation of the performance over time compared to the determined structure at the end of the experiment may have masked the contribution of different structures that might have emerged and functioned along the way.

b. Related Knowledge Dynamics Research

The dynamic theory of knowledge, on the other hand, stresses the importance of knowledge flows, especially of tacit knowledge flows, to sustaining competitive advantage and high performance (Nonaka 1995; Nissen 2006b). As task uncertainty increases, agility is postulated as an important organizational characteristic (Postrel 2002; Mowshowitz 2002; Alberts & Hayes 2003). Agility connotes movement: the ability to modify or change—to enact other existing knowledge in the place of how something had been done (e.g., using a different procedure, or applying a different mental model to help understand a situation) or create new knowledge (e.g., developing a new problem solving strategy, or a novel solution to complex problems). Today, organizations generally have many knowledge acquisition options (e.g., hiring additional expertise, or partnering with another organization) to attain the requisite variety (Ashby 1958) necessary to perform well in the face of new complex, dynamic environments (Mowery, Oxley & Silverman 1996; Baker & Faulkner 2002; Scott 2003). During a crisis or disaster response situation, managers may not have a high degree of control over the availability of expertise (e.g., generalist or specialist) and experience from the organization on hand, or available in the short term, when initiating problem solving processes.

Nissen and Levitt (2004) employ computational agent-based organization modeling to explore the effects of knowledge flows on organizational performance. The research focuses on the potential contributions to organizational performance of knowledge flows associated with learning (e.g., through formal training courses), skill level development (e.g., through on the job training), and team experience (e.g., through individuals working together over time). The results highlight the potential counter intuitive cause and effect interactions associated with how a training course might be sequenced with work tasks (e.g., concurrently or prerequisite) and yield significantly different project outcomes in terms of cost, time and quality due to the effects of knowledge flows.

Other researchers have addressed different knowledge constructs and how they relate to performance. The theory of absorptive capacity (Cohen & Levinthal 1990) states that the more a person knows, the more they can learn, but it is silent on whether or not the effects are more or less pronounced in teams made up of generalist, specialist or a mix of both. Postrel (2002) addresses generalist (i.e., trans-specialist) and specialist team composition issues from a manufacturing organization perspective and concludes a contingency theoretic perspective that, "Industries where the process technology is mature and stable, but product innovation is high should display relatively high levels of trans-specialist understanding between design and manufacturing, while industries where process technology is dynamic but product innovation is slower should see relatively low trans-specialist understanding." (Postrel 2002 p. 315) That research leaves open for future investigation the management issues associated with how to "devise a structure of governance that will motivate the parties to cooperate." (Postrel 2002 p. 316) According to Krause (1984), cooperation produces a smoother meshing of endeavors (i.e., actions); hence, it strongly relates to knowledge flows.

Nissen et al. (2008) challenge some of Postrel's fundamental assumptions, especially that performance (i.e., expected payoff) is unidimensional; drawing on microeconomic and organization theory, they point out that "performance is a multifaceted, omnibus concept with many trade-offs between sub-dimensions such as cost, time, component quality and product integration quality (e.g., Smith & Reinerstan, 1991; Bayus, 1997)." (Nissen et al. 2008, p.126) Furthermore, they develop and test, using computational organization modeling techniques, a variety of theoretically sound hypotheses relevant to Postrel's specialist and trans-specialist construct. Of particular note is their use of computational organization theory to test the marginal value of transspecialists in the face of increasing modularity of the sub-parts of a company's product, component complexity, reciprocal interdependence, and centralization.

The theory of transactive memory (Wenger 1986) appears to support a contingency theoretic perspective regarding interdependence, and their relationship to knowledge flows and performance. Transactive memory theory suggests that the level of interdependence should inform managers about how best to organize (i.e., arrange the organization's meta-knowledge or who knows what knowledge). If the tasks that participants in the organization perform are largely independent vice interdependent, then an integrated transactive memory system where everyone has similar knowledge (e.g., a local police force) is appropriate. When tasks for participants are interdependent, then a differentiated transactive memory system, where special expertise resides in different people or groups and for the most part everyone knows the locations of the expertise (e.g., federal crime laboratory) is appropriate. This theory suggests that management should play a role in appropriately adjusting knowledge resources to facilitate flows that will enhance organization performance—hence, making management decisions to increase design fit.

These theories along with knowledge flow theory suggest that managers should consider the importance of knowledge as a contingency factor in organization design—especially as it relates to coordination mechanisms and their influence on knowledge flows that lead to high levels of performance. Complicating this organization design task for management is the nearly instant access to knowledge resources beyond the manager's traditional purview—i.e., beyond the firm's boundaries. That access is facilitated by the ubiquity of networks of communications channels (e.g., cellular telephones and the Internet), not only within an organization, but with other entities of the external environment. The following sections present background information on the subject of interorganizational entities.

4. Interorganizational Theory

The open system perspective for investigating organizational phenomena provides researchers the ability to probe cooperative and competitive relationships between organizations. Two main thrusts in interorganization research emerged over time, dyadic cooperative relationships between organizations (see Evan 1966; Aken & Hage 1968; Pfeffer & Nowak 1976, Molnar & Rogers 1979; Whetten & Leung 1979; and Van de Ven & Walker 1984) and networks of organizations (Provan 1983; Miles & Snow 1995; Kraatz 1998; Topper & Carley 1999; Kogut 2000). Networks can be viewed as exhibiting competitive or cooperative behavior. Organization ecology researchers investigate competitive behaviors and organization pathology issues (see Weick 1979; Carrol 1984). Interorganizational communities and interorganizational fields are two other categories of research that explore cooperative relationships among organizations (Scott 2003). Interorganizational community research developed from Hawley (1950) and Warren (1967); these researchers looked at symbiotic relationships between organizations that were interdependent due to geographic co-location (Scott 2003). Organizational field research, on the other hand, looks at organizations that are functionally interdependent and perhaps even isomorphic (i.e., have nearly identical structures such as military organizations) (Levine & White 1961; Schermerhorn 1979; DiMaggio 1986; Daft 1998; Scott 2003). This dissertation focuses within the organization field, where functionally similar organizations adapt and cooperate to meet the challenges of a dynamic environment.

In this dissertation, the organization field is the level of analysis because it limits the scope of interorganizational entities being considered, and is a logical stepping stone to future research at more complex levels of analysis. In the area of disaster response situations, there are relevant instances of functionally similar organization that respond to crisis events, so the finding of this research are generalizable and helpful in building a bridge to investigating even more complex interorganizational crisis management issues, such as when diverse organizations (e.g., military and non-governmental) come together in response to a disaster.

Due to the complex nature of interorganizational social systems, researchers often employ qualitative methods and investigate the antecedents of interorganizational relationship formation (e.g., the quest for complementary knowledge) and how those factors translate into governance structures (Whetten & Aldrich 1979; Mulford & Rogers

1982; Smith, Carroll & Ashford 1995; Kenis & Knoke 2002; Suparamaniam & Dekker 2003). This is especially prevalent in disaster research of interorganizational phenomena.

Warren's (1967) seminal work describes a continuum of interorganizational governance structures (see Figure 8) ranging from social choice to an independent unitary organization. Social choice is where autonomy in goal setting and decision making by each organization is paramount and coordination is achieved by what Granovetter (1973) refers to as weak ties and informal communications (Litwak & Hylton1962; Warren 1967). An example of this is the early stages of a new charity such as a community chest (see Andrews (1952) Corporation Giving) where independent benefactor organizations come together to mutually fulfill a community need (Litwak & Hylton 1962). A merger, on the other hand, is an instantiation of the independent unitary organization. It governs much like the strategic apex in a bureaucracy; hence, it can be viewed as an intraorganization phenomenon (Litwak & Hylton1962; Warren 1967). A unitary organization's leadership dictates its own structural coordination mechanisms (e.g., creation of a joint venture or a military combined joint task force). Between those extremes are coalitions and federations. A coalition's governance structure entails a strategic intent to work together (e.g., coordinate activities) made by each participating organization. This drives the formal requirement to coordinate some activities, but does not necessitate usage of formal information processing rules. Two examples of coalition activities are joint purchasing decisions (see Evan 1966) and major disaster relief efforts by multiple countries' militaries and non-governmental aid organizations (see case study examples regarding the December 2004 Asian Tsunami in Thailand (Weerawat 2007) and the August 2005 Hurricane Katrina (Beccera-Fernandez et al. 2008)), especially in the case where the disaster has overwhelmed the affected country's ability to coordinate activities.

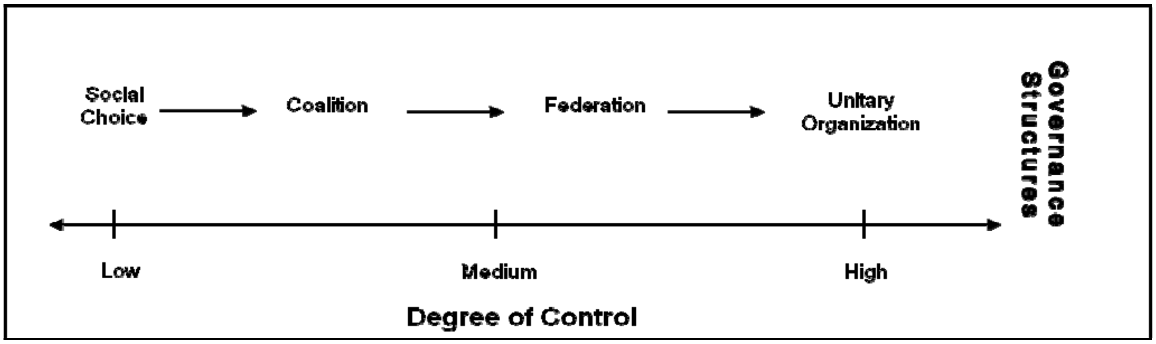

Figure 8. Continuum of Interorganizational Coordination Structures

Warren's (1967) final governance structure is the federation. It entails multiple organizations agreeing to formally allow a "third party" to coordinate their activities (e.g., a sports league and a United Nations Disaster Relief Coordinator or an Emergency Relief Coordinator—see Weiss & Campbell 1991 and Stephenson 2005). There is a significant difference in the degree of decision-making authority in the two examples of federations: the National Football League commissioner and his office generally have tighter control over coordinating the operations of the league than a United Nations Disaster Relief Coordinator has over the myriad governmental and non-governmental organizations that might respond to a crisis. "Tighter control" generally refers to having more formalized means to elicit desired performance (Etzioni 1965). A study of the humanitarian operations in the former Yugoslavia (see Minear 1994) or Operation Provide Comfort in Northern Iraq (see Weiss & Campbell 1991) are examples of the weaker form of federative control.

The federation and unitary organization are bureaucratic governance structures and the social choice and coalition are organic governance structures. These correspond well to degree of control from the intraorganization literature—specifically Mintzberg's (1979) design parameters of formalization and centralization. Some organization scholars have postulated that traditional contingency factors (e.g., task uncertainty and task interdependence) of organization design (i.e., intraorganization design) provide a sound explanation regarding the type of coordination mechanisms (e.g., organic with mutual adjustment mechanisms rather than bureaucratic with direct supervision mechanisms) that are in fit for the interorganizational structures that operate when multiple organizations start working together (Dynes & Aguirre 1976; Wright 1976; Mulford & Rogers 1982; Scott & Meyer 1991; Ishida & Ohta 2001).

In a disaster situation, organizations face high uncertainty and reciprocal interdependencies, hence, mutual adjustment mechanism are most fit (Dynes & Aguirre 1976; Comfort 1994; Harrald et al. 1994). Others propose that hierarchical responses are the best mechanism for interorganization coordination in crisis response situations (Pfeffer & Salancik 1978; Bigley & Roberts 2001; Moynihan 2006; Gonzalez 2008). The essence of the disagreement revolves around the assumption that interorganizational systems emerge to deal with increased environmental uncertainty and that the formation generally begets reciprocal resource interdependencies. Structural contingency theory research at the organization level suggests that organic structures are fit to meet the increased uncertainty and reciprocal interdependencies; however, Pfeffer and Nowak (1976), drawing on legacy data from large firms heavily engaged in research and development, claimed to find support for their hypothesis that the appropriate interorganizational structure is one that will reduce uncertainty between the organizations—i.e., a governance structure that is more bureaucratic and stresses formalizing patterns of interaction. Gonzales (2008) used case study research from multiple disaster response exercises, and found mediation (i.e., a hierarchical approach involving a leader that handles exceptions) to be the most prevalent and most effective coordination mechanism. Dekker and Suparamaniam (2005) pointed out that the choice of governance structure was frequently predicated on the parent companies' existing culture and structure.

Other researchers point to the structures employed during past collaborative interactions (Westphal, Gulati & Shortell 1997). These past familiar governance structures likely have at their root, the perception of requiring lower coordination costs (Lawrence & Lorsch 1967; Thompson 1967; Williamson 1975). Contingency theory research is a useful method for informing this debate, but the level of complexity in these interorganizational systems presents formidable challenges to the researcher, especially in the area of disaster events where the emergence of interorganizational systems is prevalent.

Disaster events generally include participation by governmental agencies. Since the government sector is flush with stalwart bureaucratic organizations, there is a high probability that the formation of interorganizational relationships in response to a disaster event will be affected by a natural desire to set up a familiar governance structure (Westphal, Gulati & Shortell 1997; Dekker & Suparamaniam 2005). Since no two organizations are identical, each organization that responds to a disaster will have different structural parameters. These different structures present challenges to coordinating activities, especially when cultural differences and varying degrees of trust exist between organizations (Suparamanian & Dekker 2003). Trust refers to one's (e.g., individual or organization) belief and expectation that its assets, while in some state of risk, are safe in the presence of others (Young 2003). A prime source of low trust stems from a lack of experience in operating together (Wright 1976). The following sections provide background information about interorganizational systems and specifically focuses on instances when organizations come together to operate in a virtual environment and form in the special circumstances during the early stages of a disaster response.

a. Interorganizational Systems

Interorganizational systems are defined as "planned and intentionally formed cooperative ventures between otherwise independent agents." (Kumar & van Dissel 1996) They are becoming more prevalent today largely because they can share costs, spread risk, and access complementary resources, especially knowledge, to help them succeed in growing environmental complexity (Mowery, Oxley & Silverman 1996). While more firms are making the strategic decision to cooperate with other organizations, researchers have left unattended the mechanisms for how the practitioners should be organized to attain the desired goals. Practitioners, here, are those who have to generate the dynamic knowledge flows between the partnering organizations (Schermerhorn 1979). Those people are referred to in organization literature as boundary spanners (Mintzberg 1979; Thompson 1967).

Interorganizational systems can include a variety of independent organizations that take on some role in a developing structure among the organizations. Often, deliberate planning and time are required for these organizations to become effective at achieving their interorganizational goals (Inkpen & Li 1999). There are, however, instances where time is not a luxury, such as during a crisis (e.g., natural disaster). Creating interorganization action among government agencies in these extreme events often entails forming an entity that would resemble a joint venture (i.e., the resource contributions from two or more organizations that go to form a new organization that gets its goals from the parent firms, see Daft 1998). It can be argued that because those joint ventures emanated from bureaucratically structured organizations they tend to be likewise structured—i.e., due to the strong acculturation process in many governmental organizations, familiarity with known structures are favored over the consideration of contingency factors and the concept of fit (Comfort 1985). While research has been done on knowledge flows in extreme organizations (see Nissen, Jansen, Jones & Thomas 2004; Nissen 2005), this research adds to the understanding of knowledge flows and organization design issues at the interorganizational level of analysis.

In either deliberate or crisis situations, forming interorganizational systems requires that some agents from each organization involve themselves in initiating the necessary structures (e.g., roles and processes) to achieve satisfactory interorganizational performance. Those initially involved agents fit the definition of a boundary spanner unit: an organizational unit that interfaces with the external environment (Mintzberg 1979; Thompson 1967). Early boundary spanning activity is postulated as critical to achieving the goals that drive the formation of an interorganization system (Schermerhorn 1979). Hence, the need to provide managers insights into how to manage their workers that conduct tasks through virtual environments and in the challenging arena of interorganizational alliances (Smith, Carroll & Ashford 1995; Alavi & Tiwana 2002).

b. Virtual Organizations

The desire for virtual products (i.e., a product instantaneously produced in response to a customer's demand) is considered a key driver in the creation of virtual organizations (Davidow & Malone 1992). "A virtual organization is a collection of geographically distributed, functionally and/or culturally diverse entities that are linked by electronic forms of communications and rely on lateral, dynamic relationships for coordination." (DeSanctis & Monge 1999, p. 693) Hence, virtual organizations "appear less a discrete enterprise and more an ever-varying cluster of common activities in the midst of a vast fabric of relationships." (Davidow & Malone 1992, p. 7) They are characterized as being highly flexible and adaptable and able to respond quickly to market demands (Grabowski & Roberts 1999). Those characteristics combined with the reduced costs of electronic communications and the growing ubiquity of Internet-based collaborative applications, especially those that have a high level of media richness (for examples see Daft & Lengel 1986), contribute to the growing efficacy of virtual organizations (Nohria & Berkley 1994; Hedberg et al. 1997; DeSanctis & Monge 1999; Wong & Burton 2000; Mowshowitz 2002).

In related work, Clancy (1994) defines the characteristics of a virtual team as being made of participants that are culturally diverse and employees of different organizations that are physically separated; this puts virtual teams squarely in the interorganizational system area of research and brings into focus the need to analyze the virtual teaming phenomenon and specifically investigate "how to best structure a virtual organization, when communication has to transcend the boundaries of space, time and culture, for efficient and effective coordination…." (Wong & Burton 2000, p. 340) This puts an increasing emphasis on understanding the contingency relationship of knowledge and organizational structures on the interaction between teams that span the boundary of their own organization to work coordination and problem solving tasks with the boundary spanning teams of partner organizations. A boundary spanning team is one "whose primary responsibility is to deal with parties outside the organization, such as clients, suppliers and research institutions." (Callahan & Salipante 1979 p. 26) In the context of this research, boundary spanners facilitate coordination and problem solving in the face of turbulent environments—i.e., these tasks involve both knowledge sharing and knowledge creation activities.

Wong and Burton (2000) investigated the phenomenon of virtual teams by constructing a theoretically grounded, agent-based computational discrete event simulation model as an experimentation platform. Their conceptualization of virtual teams in their agent-based model is theoretically grounded in the area of group performance. Their investigation, however, did not explore the impact that the virtual team members' knowledge characteristics had on team performance.

Organizations that work together through virtual teams are guided by a common purpose and interact through interdependent tasks (Lipnack & Stamps 1997; Wong & Burton 2000). Virtual teams are project-focused—they are formed when the need arises and disbanded when the task is complete (Grenier & Metes 1995; Simons 1995). Such dynamic teaming implies that there is not only little prior team history, but also that the work roles and responsibilities of team members change with each virtual team with which they are engaged. Those observations led to the development of three characteristics of team virtuality: (1) virtual team context; (2) virtual team composition; and (3) virtual team structure (Wong & Burton 2000).

The context under which virtual teams operate is generally marked by a low degree of experience working with other team members, facing novel tasks, and physical dispersion of members. Virtual teams are composed of people with heterogeneity in their organizational backgrounds and cultures. The structure of virtual teams is marked by a prevalence of lateral but weak ties. These lateral, weak ties are conducive to knowledge creation, but not knowledge sharing which is facilitated by strong ties (Alavi & Tiwana 2002). In the virtual team context, however, knowledge flows via strong ties must travel across the same communications channels (Wong & Burton 2000; Nissen et al. 2008). This may lead to performance problems especially when team members have a high degree of tacit knowledge to share. In the context of virtual teams, strong vertical ties can be achieved by structuring under a direct supervision coordination mechanism. The use of strong ties may be important where the tolerance for errors in the work to be coordinated is low (Wong & Burton 2000), and were a high degree of common knowledge in the early stages of a crisis is not available (Suparamaniam & Dekker 2003; Moynihan 2006).

Combining the issues raised with Rulke and Glaskiewicz's (2000) research with the work of Wong and Burton (2000), this research looks more deeply into the composition of the virtual teams based on the tacit and explicit knowledge distinction, and the type of coordination mechanisms that these groups often operate under during crisis situations. Drawing on Nissen et al. (2008), the following relevant organizational performance metrics are useful to explore as they present many tradeoffs between the sub-dimensions of organization performance: speed, component quality and product integration (e.g., Smith & Reinersten 1991; Bayus 1997). These metrics are associated with relevant hypotheses in the next section.

c. Interorganization Response to Disasters

Disaster events trigger the response of a large number of organizations (Emery & Trist 1965; Dynes 1970; Wright 1976; Quarantelli 1978), many of which begin to work together, hence, constituting an interorganizational entity. Sometimes the emergence of these entities is pre-planned, but often, even the pre-planned interorganizational system must interface with unforeseen organizations (Suparamaniam & Dekker 2003). Topper and Carley (1999) used qualitative methods and social network analysis techniques to investigate the emergent network of organizations that they call the integrated crisis management units (ICMU): a relevant and common instantiation of an interorganizational phenomenon in response to disasters. They draw into focus three competing theoretic perspectives that potentially explain the ICMUs, 1) the emergent coordinating group (e.g., see Dynes & Quarantelli 1968; Dynes 1978; Kreps 1978; Perrow 1984; Drabek 1986; Harrald et al. 1994), 2) the centralized system (e.g., see Meyer & Rowan 1977; Pfeffer & Salancik 1978; Staw et al. 1981; DiMaggio & Powell 1983), and 3) the distributed system (e.g., Dynes & Quarantelli 1968; Lawrence & Lorsch 1969; Galbraith 1973; Malone 1987; Comfort 1994; Harrald et al. 1994).

The emergent coordinating group perspective predicts that groups of organizations will “spontaneously coalesce during a crisis to help manage the interdependencies of individual responding organizations and to reduce conflict.” (Topper & Carley 1999 p. 69) The participants in this coordination group may have little experience or authority to perform the required tasks. In large-scale disasters that require extensive resources, the mutual adjustment coordination mechanism appears to be only “accidentally effective.” (Wright 1976 p. 82) Furthermore, for coordination by mutual adjustment to emerge, it seems to require a lack of available coordination expertise (Wright 1976). The general trend to the development over time of the emergent coordinating group is to start with mostly disconnected organizations and a few pre-planned coordination structures operating. This is followed by a phase of self-organizing behavior where new coordination structures between pairs of organizations emerge. Finally, a migration phase occurs where these paired coordination structures form into a central coordination group and every organization is connected to a central group of powerful organizations (Dynes & Quarantelli 1968; Topper & Carley 1999). Powerful generally refers to a preponderance of resources (Pfeffer & Nowak 1978) or the ability to confer legitimacy (e.g., governmental agencies) (DiMaggio & Powell 1983; Meyer & Rowan 1977).

The centralized system looks to a single organization to assume the dominate coordination role for the rest of the organizations in its affected area. It is often the case that pre-disaster contingency planning efforts seek to design this interorganizational coordination method into the response plan. This centralized coordination method—similar to direct supervision, seeks to capitalize on perceived vertical information processing efficiencies and reduction of uncertainty within the interorganizational system. This is attributable to a propensity of organizations to centralize, rigidify, and seek an external source of legitimacy in an effort to mitigate the uncertainty produced by the turbulent environmental conditions brought on by the disaster (Staw et al. 1981; Topper & Carley 1999). These ideations are supported by both resource dependency theory (Pfeffer & Salancik 1978) and institutionalism theory (DiMaggio & Powell 1983; Meyer & Rowan 1977). Wright (1976) drew on multiple disaster event case studies and identified an apparent contingency theoretic perspective that interorganization coordination through centralized control was more likely to be effective in smaller disasters where fewer resources were needed, so some resource slack was available, and actors with appropriate coordination expertise were available.

The development of this centralized coordination system begins with already well-formed relationships that are defined in pre-planned (i.e., formalized) structural relationships. As the disaster unfolds, centralization grows in response to growing complexity: other organizations not accounted for in the pre-planning join the coordination network. This centralized system is very similar to “military style” coordination network typically referred to as a command and control organization. This pre-planning and centralized control, however, has been maligned in other prominent disaster research studies (see Harrald et al. 1994, Dynes 1998, and Suparamaniam & Dekker 2003)

The distributed system draws on contingency and information processing theories. These theories explain that distributed team-like structures respond quickly and accurately to the turbulent environments found when responding to disasters (Carley & Lin 1997; Topper & Carley 1999). Others have corroborated these finding, pointing to organizational agility and lateral ties between subsystems being fit with turbulent environments (see Krackhardt & Stern 1988; Carley 1992; Harrald et al. 1994; Dekker 2005). A key aspect of this interorganizational structural fit is early identification and agreement on common goals, and a reliance on coordination through feedback rather than coordination via rigid pre-planned responses (Topper & Carley 1999). The emergence of the distributed system develops first from a few pre-planned interorganizational relationships, but as other organizations begin to enter the network of responders, the interorganizational system’s development is not mandated by some pre-planned response; rather its structural form is flexible. By feedback mechanisms and lateral, informal communications, the coordination structure is allowed to emerge and become distributed. As the disaster response moves along in time, this interorganizational system is agile enough to allow the organizations to effectively begin cooperating with local community entities, which is a key performance enhancement finding of Harrald et al. (1994).

The preceding sections highlight the debate regarding the effectiveness of different coordination mechanisms in achieving high performance in crisis response operations where interorganizational systems frequently operate in the face of high uncertainty. It has been shown that knowledge types (e.g., trans-specialist and specialist) within an organization produce varying performance results (Nissen et al. 2008). In this dissertation, two types of knowledge, tactic and explicit, are investigated to note their effects on performance of interorganizational systems that respond to disaster event. A group of boundary spanners that are highly experienced (i.e., have a high degree of tacit knowledge) in responding to crisis events, but thrust into the new role of collaborating in a virtual team environment will have performance differences based on the coordination mechanism employed to govern the boundary spanning activities (i.e., collaborating to produce mutually supporting plans of action—a framework for integrated action).

- Null Hypothesis H0: In the early stages of crisis response activities, there are no performance differences in virtual teams based on different types of knowledge resident within the teams and the coordination mechanisms used to manage the integration of activities.
    - Hypothesis 1: Virtual team performance with respect to the speed of integrating activities will be affected by the knowledge type composition of each team interacting with different coordination mechanisms.
    - Hypothesis 1a: Virtual team performance with respect to speed of integrating activities will be best (i.e., shortest time to project completion) when each team is comprised of individuals with high levels of tacit knowledge and operate under a mutual adjustment coordination mechanism.
    - Hypothesis 2: Virtual team performance with respect to the functional integration risk (i.e., risk to component quality) will be affected by the knowledge type composition of each team interacting with different coordination mechanisms.
    - Hypothesis 2a: Virtual team performance with respect to the functional integration risk of the planning actions will be best (i.e., risk to component quality will be lowest) when each team is comprised of individuals with high levels of tacit knowledge and operate under a mutual adjustment coordination mechanism.

- Hypothesis 3: Virtual team performance with respect to the project integration risk will be affected by the knowledge type composition of each team interacting with different coordination mechanism.
- Hypothesis 3a: Virtual team performance with respect to the project integration risk will be best (i.e., the quality of the overall project based on the integration of components will be lowest) when each team is made up of individuals with high levels of tacit knowledge and operate under a direct supervision coordination mechanism.
- Hypothesis 4: Virtual team performance with respect to communication risk (i.e., the ratio of missed or mishandled communications to the total amount of communications attempted between actors) will be affected by the knowledge type composition of each team interacting with different coordination mechanisms.
- Hypothesis 4a: Virtual team performance with respect to communication risk will be best (i.e., the ratio of missed or mishandled communications to the total amount of communications attempted between actors will be lowest) each team is made up of individuals with high levels of tacit knowledge and operate under a mutual adjustment coordination mechanism.

B. COMPUTATIONAL ORGANIZATION THEORY

Computational organization theory seeks to investigate organizational phenomena by employing computational tools (e.g., artificial intelligence and mathematical functions and relationships) that are grounded in well understood sociological theories such as organization theory, information processing theory, and contingency theory (Levitt, Orr & Nissen 2005). Similar to computer aided design and analysis of physical systems (e.g., bridges and new aircraft), computational organization theory supports building and analyzing executable models of theoretical or physical sociological systems such as organizations (e.g., see Carley & Lin 1997; Levitt et al, 1999; Burton & Lauridsen 2002; Looney & Nissen 2006). Those models can also be used to support computational experimentation through precise control of the design parameters that are used to build each model of the phenomenon: by holding certain design parameters constant while varying other select parameters, multiple Monte Carlo simulations are run on these executable models thereby enabling researchers to gain valuable insight into organization behaviors (Levitt 2004). Additionally, these simulation runs can be interrupted to gain insight into emergent conditions developing over time (Nissen & Levitt 2004). This research method is apropos to investigate the challenges of interorganizational disaster research because it offers the ability to test hypotheses regarding fleeting interorganizational relationships prevalent in disasters, and develop new theoretic insights of this complex environment.

Early work in computational modeling of organization behavior is traced to Cohen and Cyert (1965). The development of this method of organization research progresses alongside the development of software applications as evident in linear programming's optimization models that emulate pooled interdependencies and also critical path method (CPM) models for making explicit the representations of sequentially interdependent tasks (Jin & Levitt 1996). Carley and Prietula (1994) provide the foundation for the growth of computational organization theory into development of agent-based models (Cohen 1992; Kutz et al. 1999) which attempt to emulate the dynamic nature of organization behavior. The Virtual Design Team (VDT) program (VDT 2004) led by Stanford University researchers is an ongoing interdisciplinary research effort begun in the late 1980s to develop "new micro-organization theory and embedding it in software tools that can be used to design organizations in the same way that engineers design bridges, semiconductors or airplanes: through computational modeling, analysis, and evaluation of multiple alternate prototype systems." (Nissen & Levitt 2004 p. 172) The following sections present background information on a rich computational organization research stream led by Stanford University's Virtual Design Team and the modeling environment that it employs.

1. Background of Virtual Design Team Research

The VDT research is based on Galbraith's (1977) information processing theory of organizations, which has as its ontological foundation the belief that organizations are information processing entities. More details into the computational modeling environment that VDT and its extension called POW-ER (Projects, Organizations and Work for Edge Research—an environment for computational modeling of military command and control organizations and processes) employ are discussed in the next section. VDT research moves along two related tracks to meet its aforementioned goals. One track is the continuing effort to formalize (i.e., create non-numeric, symbolic) representations of well understood yet qualitative (i.e., informal, ambiguous, natural language) descriptions of organizational behavior, such as March and Simon's (1958) bounded rationality assumption, Thompson's (1967) task interdependence contingencies, and Galbraith's (1977) information processing abstraction (Nissen & Levitt 2004). "Once formalized through a computational model, the symbolic representation is 'executable,' meaning it can emulate the dynamics of organizational behavior." (Nissen & Levitt 2004 p. 172) While these symbolic representations are not as precise as the continuous variable-based physical science models of phenomena, these computational models are "semi-formal (e.g., people viewing the model can agree on what it describes), reliable (e.g., the same sets of organizational conditions and environmental factors generate the same sets of behaviors), and explicit (e.g., much ambiguity inherent in natural language is obviated)." (Nissen & Levitt 2004 p. 172) A limitation of this semi-formal modeling is that it must account for the non-deterministic behavior of social systems. There are, however, certain ways to mitigate that limitation, such as the fact that differences in individuals tend to average out when aggregated longitudinally or cross-sectionally. For example, workers are occasionally inattentive and make mistakes; this can be modeled stochastically to approximate collective behavior (Nissen & Levitt 2004). In other areas, various statistical distributions (e.g., normal) are used to account for ranges of possible behaviors, and Monte Carlo techniques are used to generate a range of expected to rare and exceptional behaviors of the organization model as a whole.

The other main track of VDT's research is in validating the modeling environment. Christiansen (1993) and Thomsen (1998) represent "extensive empirical validation projects…." (Nissen & Levitt 2004 p. 172) This effort continues in importance as researchers work to formalize additional well accepted micro-organizational theories and experiences. Following seminal works by Campbell and Stanley (1963) and Cook and Campbell (1976), the research team's focus is on reinforcing face validity (i.e., do the parameters and visual aspect of the model's representation of the phenomenon make sense to a subject matter expert), construct validity (i.e., are the operations of the underlying project elements accurate), internal validity (i.e., are only relevant concepts implemented and do they function correctly), and external validity (i.e., does the model allow for accurate representation of a variety of organizations structures).

A high degree of both internal and external validity exists in the VDT model. Its strong internal validity stems from extensive systematic testing processes using intentionally designed small projects to compare aggregate simulation results with contingency theory predictions (Jin & Levitt 1996). Its highly reputable external validity comes from three main modes: (1) emulation of real project teams through numerous retrospective case studies (Yin 2003) of diverse projects and organizations (i.e., over 20 case studies contribute details to enable back-casting calibration of micro-level behaviors to produce macro-level outcomes—see Christiansen (1993) and Thomsen et al. (1999)), (2) intellective experiments where researchers use the model as a virtual organization test bench to explore myriad organization questions and thereby gain new understanding of relevant phenomena (e.g., understanding performance effects of geographically distributed team members—see Wong & Burton 2000), and (3) cross-model docking (Axtel et al. 1996) where a comparison is made between the output of VDT and another model that uses a different modeling technique but similar inputs to represent the same phenomenon (e.g., docking comparison of ORGAHEAD and SimVision—see Louie et al. 2003) (Levitt, Orr & Nissen 2006).

2. Computational Modeling Environment

This section draws heavily from Jin & Levitt (1996) and Nissen and Levitt (2005). VDT is designed to explore complex but relatively routine tasks associated with many different industrial projects. In collaboration with Stanford University's Virtual Design Team research project, the Naval Postgraduate School's Center for Edge Power extends VDT into the computational modeling environment called POW-ER, which enables research into the military command and control (C2) domain. These similar computational modeling environments are based on the Galbraith's (1977) information processing theory that an organization processes and communicates information to coordinate and control its activities to produce some output (Jin & Levitt 1996). Processing and communicating information to achieve some organization goal generally requires humans to be involved in the activities. "These information processors send and receive messages along specific lines of communication (e.g., formal lines of authority) via communications tools with limited capacity (e.g., memos, voice mail, meetings)." (Jin & Levitt 1996) Table 3 describes the elements that make up the VDT and POW-ER computational modeling environment.

Tasks	Abstract representations of any work that consumes time, is required for project completion and can generate exceptions.
Actors	A person or a group of persons who perform work and process information.
Exceptions	Simulated situations where an actor needs additional information, requires a decision from a supervisor, or discovers an error that needs correcting.
Milestones	Points in a project where major business objectives are accomplished, but such markers neither represent tasks nor entail effort.
Successor links	Define an order in which tasks and milestones occur in a model, but they do not constrain these events to occur in a strict sequence. Tasks can also occur in parallel. These models offer three types of successor links: finish-start, start-start and finish-finish.
Rework links	Similar to successor links because they connect one task (called the *driver* task) with another (called the *dependent* task). However, rework links also indicate that the dependent task depends on the success of the driver task, and that the project's success is also in some way dependent on this. If the driver fails, some rework time is added to all dependent tasks linked to the driver task by rework links. The volume of rework is then associated with the project error probability settings.
Task assignments	Show which actors are responsible for completing direct and indirect work resulting from a task.
Supervision links	Show which actors supervise which subordinates. In these models, the supervision structure (also called the *exception-handling hierarchy*) represents a hierarchy of positions, defining who a subordinate would go to for information or to report an exception.

Table 3. VDT and POW-ER Model Elements and Element Descriptions (adapted from Looney & Nissen 2006)

Using those elements and guided by the information-processing theory foundation, organizational models are built by modeling the "knowledge work through interactions of *tasks* to be performed, *actors* communicating with one another and performing tasks, and an *organizational structure* that defines actors' roles and constrains their behaviors. In essence, this amounts to overlaying the task structure on the organization structure and to developing computational agents with various capabilities to emulate the behaviors of organizational actors performing work." (Nissen & Levitt 2004 p. 173) An illustration of how these elements interrelate is exhibited in Figure 9. As suggested by the figure, the organization structure models networks of reporting links. Those links can capture theoretically described micro-behaviors such as bounded rationality (March & Simon 1958) through a manager's limits on span of control, attention span, and empowerment. Task structures are represented as a separate network of activities that define expected work duration, complexity and required skills to complete. Within the organization structure, roles (e.g., manage and planner) can capture organization attributes such as skills possessed, level of experience, and task familiarity. Within the task structure, various sequencing constraints, interdependencies and rework loops are modeled to imbue the organization with considerable variety regarding how knowledge work is organized and accomplished.

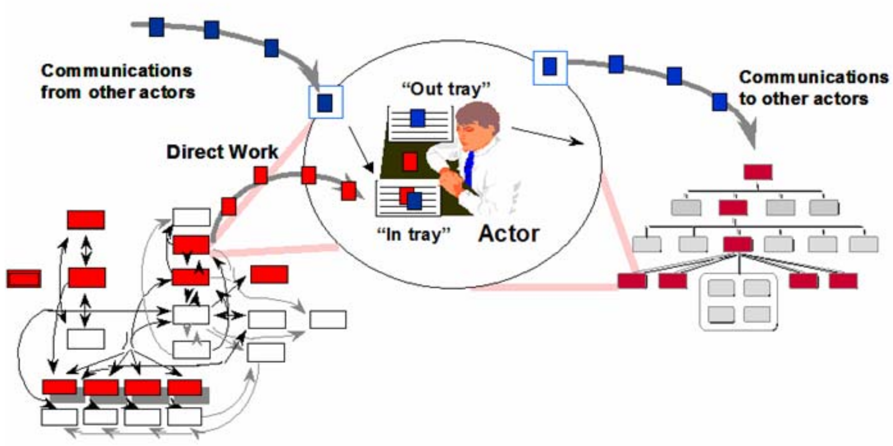

Figure 9. Information Processing View of Knowledge Work (from Gateau et al. 2007)

As also suggested by the figure, each actor has a queue of information tasks to perform (e.g., receiving messages, doing work, and attending meetings) and a queue of information outputs (e.g., completed work products, request for assistance, and communications to other actors). The performance of those tasks is affected by, (1) each actor's skill level at performing each task, (2) interruptions that occur which divert the actor's attention, (3) the relative priority that the task is given, and (4) the actor's backlog (i.e., queue length). A task is constrained by the number of actors assigned to each task, the magnitude of the task, and both scheduled (e.g., work breaks and ends of shifts), and unscheduled (e.g., awaiting information such as decisions from leaders and inputs from actors performing rework) downtime.

The preceding prose focuses on the ontological foundation of the computational modeling environment. The computational implications of the modeling environment involve calculations based on both direct work (e.g., planning and managing) and coordination work (e.g., group tasks and joint problem solving) which are modeled as *work volume*. This construct is used to represent a unit of work (e.g., associated with a task, or a meeting) within the task structure. In addition to symbolic execution of the VDT and POW-ER models (e.g., qualitatively assessing the skill mismatches and task concurrency challenges) through micro-behaviors derived from organization theory, the discrete event simulation engine enables process performance to be assessed (e.g., quantitatively projecting task duration, cost, rework, and functional and overall process quality).

This background information sets the stage for Chapter III's in-depth descriptions of the research methods. Within the research methods chapter, detailed descriptions of the parameters used to set up the baseline model and the necessary adjustments to the relevant dependent variables are provided.

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III. RESEARCH DESIGN

The literature review summarizes and combines the three main theoretical traditions informing this dissertation—structural contingency theory, knowledge flow theory, and computational organization design theory. This chapter presents the research design. The plan for this research is based on a mixed methodology research approach (Tashakkori & Teddlie 1998; Kerlinger & Lee 2000; Mingers 2001) where qualitative methods (e.g., case study—see Jin 2003, participant observation—see Spradley 1980, and grounded theory—see Glaser & Strauss 1967) precede the use of quantitative methods (e.g., scientific experimentation—see Shadish, Cook & Campbell 2002). In this dissertation, the plan is to conduct *case study research* to inform the building of a valid baseline agent-based computational organization model, which in turn is the venue for a two-factorial *computational experiment.* The controlled manipulation of select parameters of the baseline computational model are theory driven, and made to support testing of the structural contingency theory hypotheses that are articulated in the literature review.

This chapter first discusses the plan for conducting the qualitative research necessary to generate a representative computational organizational model of the observed phenomenon. It then presents the analytical method associated with the quantitative method, specifically Monte Carlo driven computational experiments that supports a two-factorial experiment construct and analysis of variance (ANOVA) statistical techniques.

A. QUALITATIVE METHODS

The research employs teams of researchers to simultaneously conduct qualitative field research at multiple high-level military headquarters during a major military field event. Each headquarters represents a maritime (i.e., naval) component of their respective country or standing political/military alliance (e.g., the North Atlantic Treaty Organization (NATO)). Each headquarters occupies a similar position in the traditional military hierarchy (i.e., chain of command)—see Figure 10. Each is responsible for similar organizational functions such as coordinating the naval operations for assigned forces over a large geographic area of responsibility. By virtue of having similar military and western maritime cultures and traditions, these headquarters have many common characteristics, which are discussed in the next chapter. This degree of homogeneity should facilitate similar preparations for the members of the research team employed to perform this immersive field research.

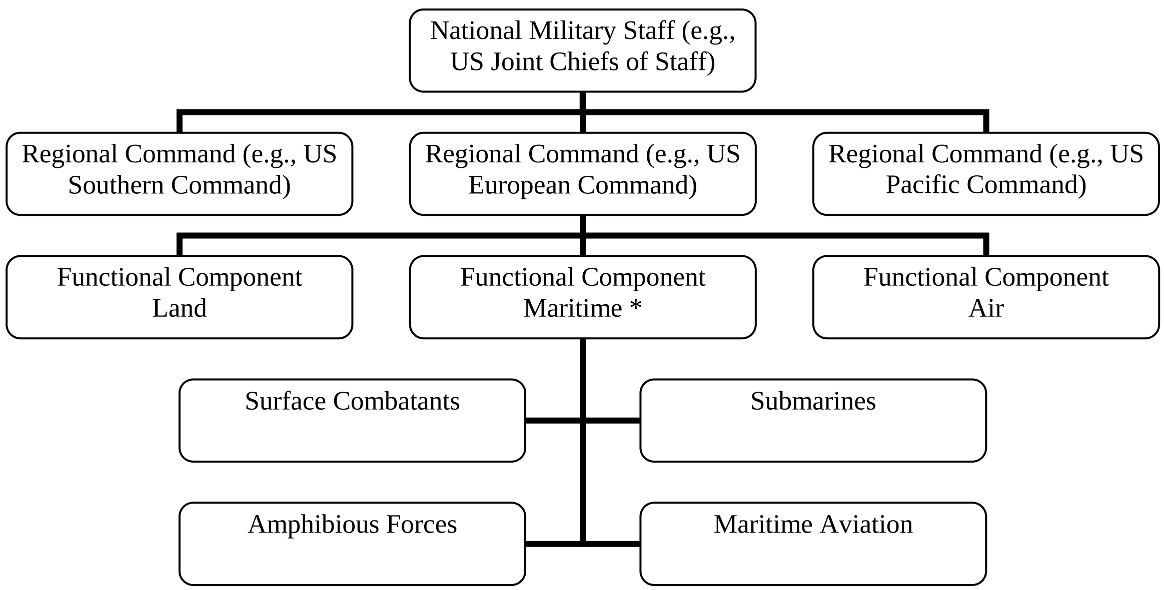

Figure 10. Generic Military Hierarchy (* Indicates Focal Level for this Research)

A driving objective agreed to by all of the participating headquarters was to explore collaboration between maritime headquarters as they attempted to develop plans that not only coordinated the activities of their own subordinate forces, but also achieved a high degree of coordination between their forces as they all faced the same emerging crisis. This qualitative fieldwork focuses on answering the following multi-part question: How do these organizations collaborate with one another to (1) coordinate problem-solving activities, (2) coordinate planned actions of subordinate forces, and (3) create new knowledge or share existing knowledge?

Each of these maritime headquarters is structured in a way that closely resembles Mintzberg's machine bureaucracy archetype (see Figure 11); therefore, it is their *techno-*

structure that is responsible for planning. The planning tasks accomplished by the techno-structure are designed to develop governing plans that coordinate the activities of their operating core. The participating headquarters each agree that it is their planning teams (i.e., techno-structure) that are responsible for developing this internal coordination (e.g., detailed plans), and have a primary role in the boundary spanning activities necessary to coordinate the activities of each organization's relevant operating core (e.g., tactical military forces). The *unit of analysis* in this qualitative phase is the maritime headquarters planning team. This focus is inclusive of the participants, the social structure, the goals, and the technology (Leavitt 1965; Scott 2003) of each headquarters' planning team. This level of analysis allows for the observation of formalized, vertical internal coordination mechanisms with emerging external, horizontal coordination requirements. The boundary spanning activities between the participating organizations enable this research to investigate organization performance (e.g., degree of coordination achieved) at the interorganizational *level of analysis*.

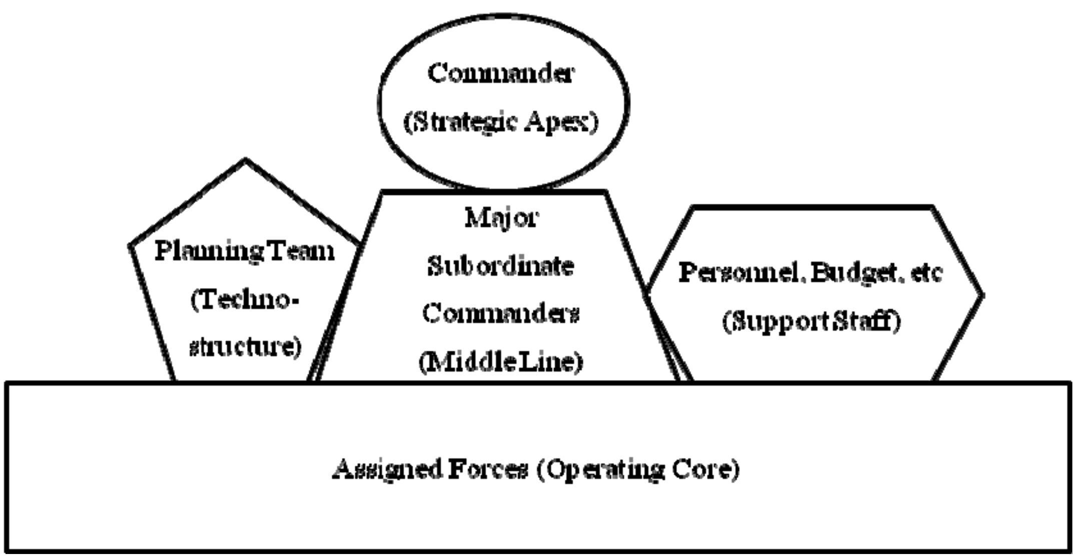

Figure 11. Generic Maritime Headquarters Depicted as a Machine Bureaucracy (adapted from Mintzberg 1979 & Nissen 2005)

The plan is to conduct this qualitative research following a *case study* method (Benbasat, Goldstein & Mead 1987; Yin 2003). The situations that these participating organizations agreed to explore represent a *unique case* (Yin 2003). The participating countries all agree that it is worthwhile to investigate the interorganizational coordinating activities enabled by highly connected communications networks when independent allied maritime headquarters each respond to the same emerging crisis. Figure 12 depicts each maritime headquarters dispatching a crisis response task force (e.g., a cross-functional task force assembled from its tactical maritime assets such as surface combatants and maritime aviation forces) to the affected area (i.e., crisis) and the coordination links between these independent headquarters that are relevant to this research. The participating headquarters each recognize that this type of crisis response relationship does happen (e.g., Non-combatant Evacuation Operations (NEO) and disaster relief operations), and they also agree that there is no doctrine or procedures written to help them achieve successful interorganizational coordination of activities.

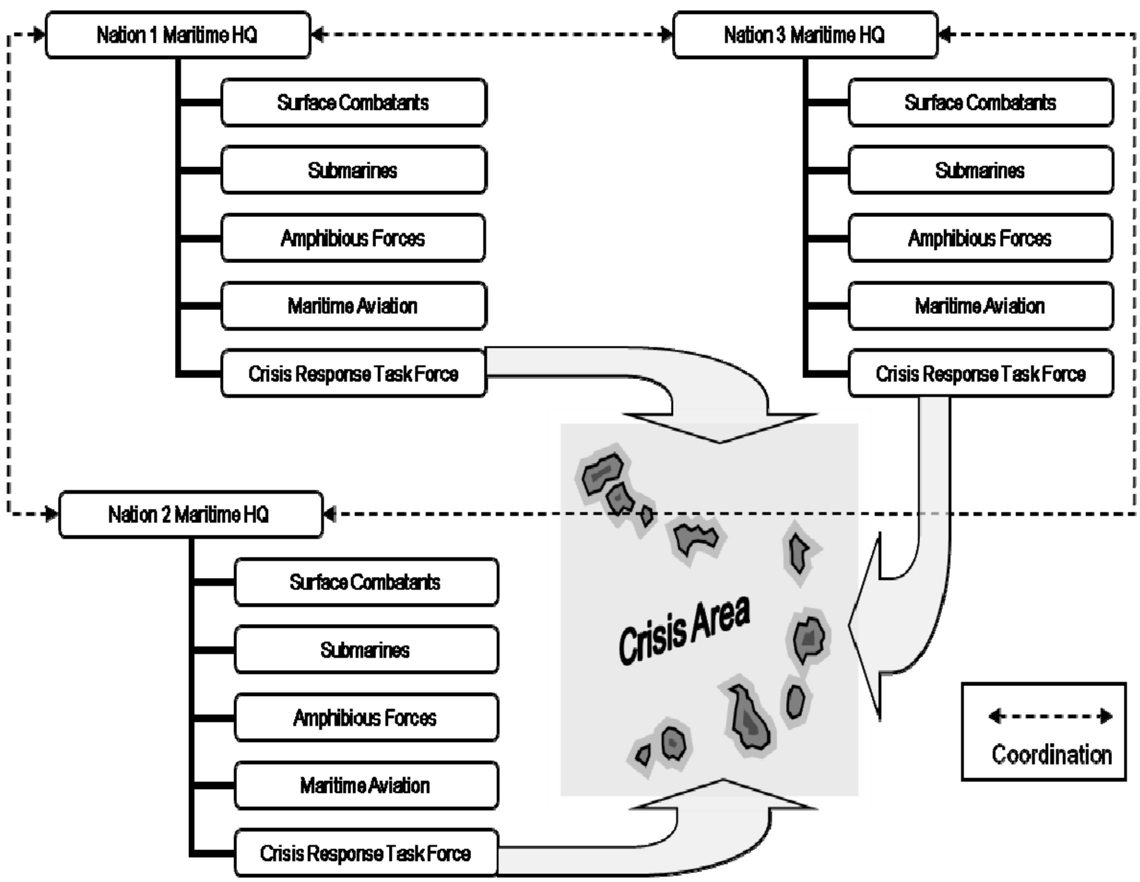

Figure 12. Multiple Independent Responses to a Maritime Crisis

From a qualitative research perspective, these participating headquarters also recognize that it is impractical to gain embedded access to observe and collect qualitative data during actual crisis events because the events are relatively rare, emerge rapidly, and there are administrative challenges to gaining embedded access for observers (e.g., security access to observe inside of workspaces where nationally classified information is used). Finally, the plan for the design of the scenario that these organizations face focuses on a situation that all agree is highly *representative* (Yin 2003) of a typical complex maritime crisis event where each country would likely respond with maritime forces.

1. Data Collection

The plan for data collection is driven by the desire to obtain data from multiple sources. With multiple sources of data, *data triangulation* can emerge during analysis. Data triangulation entails seeking convergence of multiple sources of evidence on the same finding or fact; hence, it enhances the *construct validity* of the study (Jick 1979; Yin 2003). Beyond data triangulation, this study is further enhanced by the convergence of multiple perspectives contributed by the individual members of each team of participant observers. This is known as *investigator triangulation* (Yin 2003), which enhances the *reliability* of the case study.

a. Preliminary Stage

The first stage of the data collection plan consists of acquiring *archival data* from the participating organizations. Archival data that articulates each organization's designed structure and procedures for coordinating the activities of subordinates is important to this research because it helps in preparing the data collection plan, and helps orient the observers prior to being immersed in the environment for ethnographic data collection work (Yin 2003). This orientation assists in documenting actions with some precision (e.g., correct spelling and phrasing). Additionally, architecture diagrams of the existing communications networks are of interest. The plan is to acquire, catalog and review this data prior to the field experiment. Not only is this information useful for developing the collection plan (e.g., surveys and interview instruments), it is informative during the analysis phase because it provides an objective source of data that is comparable to the observed structures and procedures from the field experiment.

b. Immersive Field Research Stage

The second stage of the data collection plan is focused on the *participant observers* (Spradley 1980). The plan is to have a team that consists of two or three observers immerse within each maritime headquarters and act as *moderate participants*. Spradley (1980) describes moderate participants as observers that "loiter" alongside the participants, and may use the same systems that the participants use. These participant observers collect ethnographic data such as condensed field notes. Based on *grounded theory* research techniques, they develop, analyze and interpret their observations to facilitate the mapping of the observed processes (Glaser & Strauss 1967; Charmaz & Mitchell 2001). These participant observation techniques go along with the case study method requirements to collect *documents* that the participants use or generate during the course of events.

Finally, the plan is to conduct periodic *interviews* with key participants and administer some *survey instruments*. Beyond the rich ethnographic descriptions (e.g., *grand tour* observation), the observers also pay particular attention to examples of knowledge flows, both *within* each organization and *between* the organizations. As these observations are critical to building the baseline computational model of this crisis response planning project, it is important that accurate direct observations of events are made (e.g., daily schedules of meetings including the start and end times of activities).

Coordination within and between the organizations is assessed based largely on written products developed by the participants. The plan for collecting documents entails using the observers' network access to all of the online workspaces that the participants use to store and transfer documents. The observers are to identify the relevant documents created throughout the field experiment, and collect and catalog them for analysis. The observers also have to manually copy and catalog any non-online written or drawn work for analysis. All on-line workspaces are archived to support qualitative analysis—this is in addition to the condensed collection of documents that the observer teams note as relevant to the *within* and *between group* coordination activities.

Conducting *open-ended interviews* with key participants are also a part of the data collection plan. Interview instrument development is guided by Rubin and Rubin (1995). Finally, questionnaires are used for additional data collection. These questionnaires collect demographic information as an efficient way (i.e., more efficient compared to conducting face-to-face interviews) of documenting the professional histories of the participants. Additionally, some open-ended questionnaires are planned to solicit opinions from the participants regarding the events experienced during the field experiment. This data is another piece of potential corroborating evidence for the observation data taken by the participant observers.

2. Qualitative Analysis

The plan is to analyze the multiple data sources of this case study research following the methods described by Yin (2003) and Glaser and Strauss (1967). Since the primary focus of the qualitative phase of this research is to develop a baseline computational organizational model, a *case description* methodology is applicable (Yin 2003). To facilitate the development of the baseline model, the key aspects that need to emerge from the case study are (1) process steps (i.e., tasks), (2) their associated time frames, and (3) the participants (i.e., actors) involved in each step. This places emphasis on developing *chronologies* (Yin 2003). The plan is for each team of observers to develop a chronology for their organization during the field experiment. They associate their field notes and interview data with these chronologies, especially incorporating instances of knowledge flows and any other interesting phenomena that they observe.

After the field experiment is complete, the plan is for the observer teams to come together and build a comprehensive chronology, and conduct *pattern matching* analysis of the phenomena observed based on grounded theory methods (Glaser & Strauss 1967; Atkinson et al. 2001; Yin 2003). During this phase of the analysis, it is important to determine where interdependencies (Thompson 1967) exist among the tasks performed.

To enhance the determination of interdependencies, a later review of the products developed and reworked throughout the chronology is conducted.

Once those analysis tasks are complete, the chronology and pattern matching analysis then compares that with the archival data and other documents collected, especially the formal organizational structures and procedures. Where designed and observed tasks, sequences, and actors align, triangulation enhances the construct validity of the data going into the baseline computational model development. Where there are differences, between the observed and formalized processes—as is expected—a review of the findings by key participants is planned, as well as a face validity check of the baseline computational model by select participants. The comparison and integration of these different sources of data help strengthen the construct validity of this phase of the research, which is important as this drives the development of the baseline computational organizational model.

B. QUANTITATIVE METHODS

The baseline computational model is developed using the POW-ER system.[2] The details of this baseline model are discussed in the next chapter. This section describes the plan for using the model to conduct and analyze the computational experimentation phase of this research. The experiment design and statistical analysis methods planned are presented next.

This hypotheses testing experiment involves a two factorial design—see Table 4. The factorial design accounts for manipulating two dichotomous independent variables—organization coordination mechanism (i.e., direct supervision and mutual adjustment) and knowledge type (i.e., tacit and explicit). The different coordination mechanisms are made manifest within the computational model by variations of select design parameters (e.g., *centralization* and *matrix strength*) and organizational structural relationships (e.g., supervisor-subordinate relationships between agents in the POW-ER models). The knowledge-type variables are made manifest by varying application experience and skill

[2] POW-ER is modeling environment that is based on nearly two decades of extensive and rigorous empirical validation conducted by the Virtual Design Team (VDT) research program established at Stanford University —see VDT 2005.

level assigned to actors in the models, and by variations to the *formalization* design parameter. The interactive results of these manipulations are measured by the dependent organizational performance variables of time, project risk, functional risk, and communication risk. This factorial design is a familiar contingency theory design (Donaldson 2001). A two-way factorial analysis of variance is planned to analyze the independent and interactive effects of the independent variables on the dependent variables (Kerlinger & Lee 2000).

<table>
<tr><td colspan="2" rowspan="2"></td><th colspan="2">Coordination Mechanism</th></tr>
<tr><td>Direct Supervision</td><td>Mutual Adjustment</td></tr>
<tr><td rowspan="2">Knowledge Type</td><td>Tacit</td><td>Centralization – Medium
Matrix Strength - Medium
Skill Level – High
Application Experience – High
Formalization – Low</td><td>Centralization – Low
Matrix strength - High
Skill Level – High
Application Experience – High
Formalization – Low</td></tr>
<tr><td>Explicit</td><td>Centralization – Medium
Matrix Strength - Medium
Skill Level – Low
Application Experience - Low
Formalization – Medium</td><td>Centralization – Low
Matrix Strength - High
Skill Level – Low
Application Experience - Low
Formalization – Medium</td></tr>
</table>

Table 4. Factorial Design

The plan for conducting the computational experiments starts with making select modifications to the baseline model's characteristics. The baseline model represents one of the four quadrants of the two-factorial experiment design. These select modifications are informed by organization design and knowledge flow theories, and the rationale for each are discussed in the next chapter. Once the model for each quadrant is created, the computational experiment is conducted using Monte Carlo techniques to simulate 30 iterations of the model. Means and variances are computed for empirically derived statistical distributions (Jin & Levitt 1996; Levitt et al. 2005; Nissen et al. 2008). Each hypothesis is tested against a 0.05 level of significance; this assessment is based on the *F*-ratio.

C. SUMMARY

This research uses a mixed method research design where qualitative methods precede and then inform the quantitative methods. The qualitative phase consists of immersive case study field research during a quasi-experiment that is specifically designed to set the conditions to view the unique and fleeting phenomenon of interest—i.e., initial coordination of interorganizational systems performed by boundary spanning teams. Using this qualitative data and analysis, a baseline computational agent-based organizational model is created. That model is used to create other theoretically based models that are representative of the interaction conditions within each quadrant of the two-factorial research design. Computational experiments are then run using Monte Carlo simulations. From those results, two-way ANOVA techniques are used to test the hypotheses developed in Chapter II.

IV. RESEARCH RESULTS

This chapter first presents the qualitative case study research that informs the development of the baseline computational organization model. The details of the baseline model are described followed by the theory-informed manipulations of the baseline model to enable the computational experimentation. The last section of the chapter presents the quantitative results of the Monte Carlo simulation driven computational experiment, a two-factorial experiment—as described in Chapter III—using analysis of variance (ANOVA) statistical techniques.

A. CASE STUDY

The case study involved observing a planning team at each of six independent military maritime headquarters. These headquarters set aside time and personnel to explore interorganizational collaboration in a virtual environment (i.e., synchronous and asynchronous information exchanges over Internet protocol-based applications and networks).[3] The military organizations that participated consider themselves representative of a Maritime Operations Center (MOC)[4]—i.e., a senior-level headquarters responsible for command and control of the full panoply of maritime assets.

The case study encompasses activities that took place over an eleven-day period where planning teams from these MOCs collaborated with each other while each one worked to build a plan of action to respond to a developing crisis scenario. The eleven

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[3] The event leveraged the infrastructure (e.g., networks and collaboration applications) of an annual multinational military field experiment.

[4] A MOC is a subpart of a maritime headquarters. Its role is generally similar to an organization's technostructure (Mintzberg 1979): it provides support to the commander (i.e., strategic apex) for planning and coordinating operations of the subordinate commanders and their assigned forces (i.e., middle line and operating core respectively). While some expertise from the support staff is typically available as needed (e.g., legal advise), the MOC generally does not include the administrative sub-parts of a maritime headquarters (e.g., personnel/human resources or training/education functions). For more details on MOCs, see Maritime Headquarters with Maritime Operations Center Concept of Operations (CONOPS). Although "MOC" is a U.S. Navy acronym, the other countries and Allied organizations involved in this event agree that their participating entities generally meet the U.S. Navy's definition of a MOC. The acronym MOC is used through the rest of this work to refer to these entities.

day field event constituted the single case; however, it is broken down into three separate periods, each driven by a unique synthetic crisis scenario (i.e., vignette)—see Figure 13.

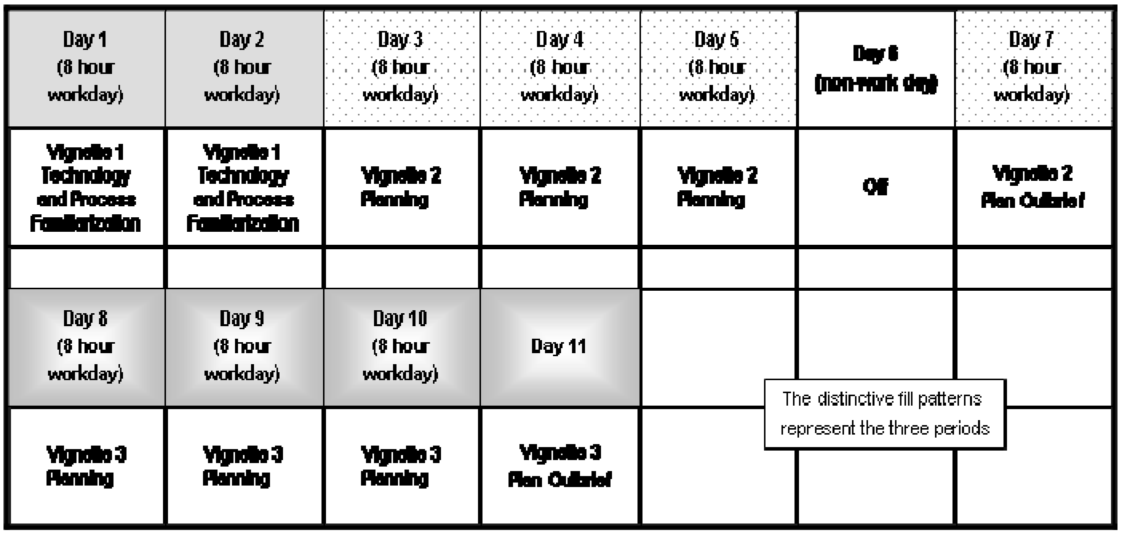

Figure 13. Pilot Study Schedule

There was an initial two-day familiarization event (Vignette 1), where the participants quickly work through their planning process in response to a synthetic crisis scenario. The purpose of this event was to familiarize the participants with:

- The technology (i.e., collaboration applications available to everyone),
- Their MOC's problem solving process (i.e., the within team process),
- The concept of coordinating their problem solving activities (i.e., the processes) with co-equal MOCs, and
- The concept of coordinating the problem solving processes' outputs (i.e., plans for the activities of subordinates assigned to each MOC's commander).

"Day 3" (see Figure 13) began the first of a three-day crisis response problem-solving vignette. During those days, each MOC's planning team worked to develop a recommendation to their commander regarding (1) how their subordinates' activities should be coordinated in response to the crisis, and (2) how their subordinate's activities should be coordinated with the activities of the other responding MOCs (i.e., the activities of their subordinates). Figure 12 in the previous chapter depicts this phenomenon of the subordinates from multiple MOC responding to a crisis event. After a non-workday (i.e., Sunday), Day 7 began as an out-briefing day. On this day, each MOC briefed its plan to its commander. These briefings were conducted separately so that there was no exchange of information between the teams. Day 8 began another three-day crisis response problem-solving vignette, Vignette 3, which was followed on day four with the final out-briefing to the commander. Of note, no non-workday was interspersed in this last vignette.

1. Participants

The participants in the case study consisted of military personnel that were assigned to one of the six participating MOCs. Each participant was either a full-time or part-time (i.e., collateral duty) member of his or her MOC's team of planners. Of the six MOCs, there were three different countries and a multi-national alliance represented. The participants all shared English as a common language, but for some of the participants at MOC5 and MOC6, that common language was not their first language. Throughout this document, the MOCs are generally referred to as:

- "MOC1" from Country A
- "MOC2" from Country A
- "MOC3" from Country B
- "MOC4" from Country C
- "MOC5" from Multi-national Alliance D
- "MOC6" from Multi-national Alliance D

Each MOC had a commander, a planning team leader, and at least a six member planning team. Of the 38 participants that provided anonymous demographic data, 81% reported having more than 15 years of military service. Based on the demographics and observer reports, none of the participants had less than five years of service. Over 60% of the demographic survey respondents reported that they had attended a formal planning course, and each MOC had at least one participant with significant planning experience. Based on observer reports, four of the six MOCs (MOC2, MOC3, MOC5 and MOC6) were made up a cohesive team of planners that routinely worked together. Of note, these figures exclude data about each MOC's commander: their position as a senior military decision-maker at a MOC is generally predicated on their years of knowledge and experience at decision-making, so they are not required to have detailed knowledge of the planning process.

The commanders ("Cdr") were not part of the daily planning activities nor the MOC-to-MOC collaboration, but they were available to receive daily updates, make decisions, and provide guidance regarding the mission and forces assigned. The planning team leaders, hereafter referred to as "Plan Managers," all had attended a formal planning course and had expertise at planning and managing planning activities of an operational planning team ("OPT"). Of note, none of them considered themselves experienced in synchronous collaborative crisis response planning activities with another co-equal headquarters. [5]

Each MOC was staffed by a team of cross-functional personnel (e.g., personnel with different specialization areas such as surface ship, maritime aviation, or medical operations). The teams generally consisted of between six and eight planners that were actively involved in tasks related to developing the planning products and collaborating with other MOCs. Four of the six MOCs contributed an experienced team of planners (i.e., worked together on planning projects as their primary duty, and had formal training in their planning process) to the field event. The other two MOCs (MOC1 and MOC4) contributed participants that generally had not worked together on planning projects as a primary duty. Of note, the participants were subject to the influences of real-world events, so on any given day, the number of active participants could have be different and in some cases, the same peopled did not participate in all of the vignettes.

2. Case Study Environment

The observations took place in six different locations, four in Europe and two in North America. The participants at each MOC operated from within their respective headquarters location (i.e., similar to a corporation's divisional headquarters). From

[5] Actors, such as "Cdr," are represented in this document in quotes to readily distinguish them from the task names and abbreviations that are distinguishable by starting with capital letters.

those locations, the participants had access to the equipment, people, and information sources that they wished to draw upon to support their work tasks. One notable difference existed from the way that these organizations generally operate during a developing crisis: the participating organizations limited their participants to an eight-hour workday during these vignettes, whereas during an actual crisis event, these organizations would likely implement extended work hours and adjust schedules to maximize the time available for planning.

Since the MOCs were physically separated, no face-to-face communications between the participants at different MOCs took place; therefore, knowledge flow activities between MOCs required virtual communications channels. During this case study, the communications channels were supported by a variety of electronic communications technologies (e.g., virtual meeting applications, web-based information exchange portals, email and telephone, etc.). The idea behind having a wide variety of communications media available to the participants was to not unduly influence or give a communications media familiarity advantage to any one MOC. In other words, each MOC was allowed to explore and select the specific channel or channels to use while simultaneously developing the procedures for how they would attempt to create coordination among their plans.

Four of the six MOCs worked out of their traditional work areas that were designed to support planning activities. Of the remaining two MOCs, MOC3 worked out of a classroom that was temporarily set up to support planning. It was located in a building adjacent to their normal office spaces due to communications network access restrictions imposed within their normal offices building. MOC4's participants worked out of a conference room away from their normal planning workspaces because of concerns over having the OPT participants working on a synthetic crisis event while working alongside other personnel handling real-world operation. The only difficulty of this arrangement was that MOC4's "OPT" participants did not have computer network connectivity from within their conference room work area. This required them to leave their workspace to conduct synchronous collaborations or post and download asynchronous collaborations at a dedicated workstation elsewhere in the building.

In general, the planning workspaces had computers, telephones, and network access. Additionally, each workspace had either whiteboard or butcher-block paper available for internal planning activities and space where the entire planning team could gather around for group face-to-face meetings.

3. Conduct of the Case Study

Three vignettes were conducted over the course of this case study. Each vignette provided the MOCs a trigger event to initiate their respective crisis action planning process. This trigger came in the form of a warning order from each MOC's higher headquarters and a common scene-setter information package describing details of the synthetic developing crisis.[6] The warning orders were very similar, but not exactly the same. Table 5 provides information about these trigger events.

Vignette 1	Vignette 2	Vignette 3
Developing piracy problem on the high seas	Terrorist threat to a high profile international public event located in an archipelagic environment	Maritime response to a potential pandemic outbreak in an archipelagic environment

Table 5. Theme of Vignettes

a. Vignette 1: Practice and Piracy Problem

As described in Chapter III, Vignette 1 was a brief crisis planning to give the participants the opportunity to practice using the various information technologies tools available to them (e.g., telephone conference calling, video teleconference, asynchronous file sharing and bulletin board applications, and robust online meeting applications with synchronous application and screen sharing, text and audio chat, and whiteboard functions) come to understand this idea of synchronous collaborative

6 A multi-national team of military and government contractors with real world planning and training expertise developed the vignettes and worked as field event controllers (commonly referred to in military exercises as "White Cell" or "Exercise Control") to provide participants realistic, dynamic sources of external information (e.g., if a participant had a question to ask of a higher headquarters or subordinate command, the controllers would provide realistic feedback). During the conduct of this case study, the team was headed up by an active duty military flag officer with extensive multinational experience.

planning among co-equal maritime headquarters. The participants were told that they should de-emphasize the quality of the products produced during this vignette in lieu of getting through all phases of the planning process and building familiarity with the various information technologies available.

In general, the participants worked quickly through each step of the planning process to build a plan that would put their available military forces into a position to thwart an outbreak of piracy on the high seas. Intra-MOC collaboration was common, but there were few instances where, during the course of planning, any inter-MOC collaboration took place until the end when each MOC's "Plan Manager" presented its plan. In essence, this was independent teams, each with insufficient resources, working on their own solution to the same problem, and then comparing those solutions near the end of the planning process. At that comparison point, it was assessed that one grouping of MOCs had come up with three separate levels of military plans. One MOC developed a very high-level strategic description of guidance and broad objectives that its forces should adhere to while countering the piracy situation. Another MOC developed a very tactical plan that essentially advised subordinates on how to take actions to stop individual pirate attacks, and what actions should be avoided. The third MOC developed a more operational-level plan to allow for sustained and focused operations of its forces and intermediate objectives that those forces should be seeking to accomplish. When these three different plans were shared by the participants at the end of Vignette 1, it was apparent to the participants and the observers that while three planning products were produced, they only fit together under a *levels of operations* construct (i.e., strategic, operational, and tactical levels of operations). The products did not appear to fit what the participants or the observers would agree were mutually supporting plans.

Through discussion amongst the "Plan Managers," the observers were able to note that there was general agreement that periodic collaborations needed to occur throughout the planning process. The "Plan Managers" agreed to conduct a collaboration meeting early during Vignette 2 to discuss milestones where the planning products being developed could be compared and refined in an effort to achieve a coordinated set of individual plans. The exercise control team also provided guidance that these plans should represent an operational-level focus instead of the more abstract strategic level or the overly specific tactical level.

b. Vignette 2: Terrorism Threat to an International Event Held in a Archipelagic Environment

The idea for the themes behind this particular vignette came about from the desire to use real-world, unclassified, and accessible data for the planners to draw upon when assessing the situation. A major World Cup sports tournament (e.g., Soccer World Cup) was scheduled during the exact time that this field event was scheduled. It also happened to occur on a variety of islands in a part of the world that was of national interest to three of the nations whose MOCs were participating, MOC1, MOC3 and MOC4 (note: only MOC3 represents a cohesive team of experienced planners). With a few embellishments (e.g., reporting that high level dignitaries from each country were visiting, and that most teams would be ferried to their different island matches) and disclosing synthetic intelligence assessments that certain terrorist groups were seeking to conduct attacks against teams and dignitaries, this set the stage for a robust maritime mission. The short notice mission was to assist the host nations with the protection of participants, dignitaries and spectators in the maritime environment (e.g., protect ferries shuttling people). Furthermore, if required, plan for evacuation of nationals from the three countries whose MOCs were participating. That mission is traditionally called non-combatant evacuation operations (NEO). This vignette and its three MOCs constitute Vignette 2A.

Since the other three participating MOCs did not traditionally operate in the aforementioned area of the world as the sporting event, details from a recently completed international political summit were harvested from news accounts and some experts that had participated in the security operations for the event. This summit occurred in an archipelagic area that was of interest to these other three MOCs, MOC2, MOC5 and MOC6. Similar to the preceding descriptions, some facts behind the real event were embellished and select synthetic disclosures were made to create a similar set of missions for which these MOCs were to develop plan. This vignette and its three cohesive and experienced MOCs constitute Vignette 2B—the primary event for establishing the baseline computational model.

A lead MOC was designated for Vignette 2B. This lead MOC gave directions for each MOC to conduct a mission analysis and then a mission analysis coordination meeting would take place using one of the collaboration applications. Each MOC joined this collaboration session with most all of their respective OPT members sitting in on the conversations. One of the MOCs (note: not the lead MOC) presented a highly detailed and complete mission analysis product and various discussions emerged to refine and clarify parts of this product. After the discussions concluded and each MOC had an appreciation of the similarities and what differences existed between their products, and more importantly why those differences could not be reconciled, the lead MOC's "Plans Manager" stated his opinion that the time that it took to conduct this meeting was not conducive to achieving future milestones on the way to the planning deadline on the third day of this event. The other two MOC "Plans Managers," in a separate discussion disagreed with the lead MOC's assessment, stating that they felt the Mission Analysis Coordination meeting was very productive and truly a new and unexpected form of interorganizational collaboration. The opinion of these two non-lead MOC "Plans Managers" did not get reported back to the lead MOC.

The lead MOC "Plans Manager" proceeded to divvy up the work tasks for the next phases of the planning process and have each MOC report only its designated products to the inter-MOC planning coordination meetings. No other rich, all-participant idea exchanges occurred during subsequent coordination meetings, as the lead MOC took the posted products and essentially built a lead-MOC plan that would achieve a high degree of interorganizational coordination. In organization theory terms, the lead MOC was attempting to *standardize the outputs*: achieve coordination by building one common plan for all to use. While this ran askew to the intent of the field experiment and directions (i.e., each MOC was to develop its own unique plan) given to the participants at the beginning, an overriding theme of the field event was to not impinge on how the participants accomplished coordination. In fact, one of the non-lead MOCs in Vignette

2B adhered to the intent that it should have its own country unique plan to present to its commander. This essentially led to two of the three MOCs having a very similar plan, and the third MOC having some differences that were largely unbeknownst to the other two.

In the other grouping of MOCs that constituted Vignette 2A, there was no designated lead MOC at the start; however, a leader emerged after the Mission Analysis coordination phase. This mutually agreed upon leader did not dictate processes or standardization of inputs, processes or outputs, rather it appeared that this leadership role served two purposes, 1) to alleviate the discussions regarding when products and coordination meetings should occur, and 2) perhaps adjudicate any potential disagreements that might emerge in the future. Similar to the other grouping of MOCs, this grouping conducted a Mission Analysis Coordination meeting after completing each one's internal analysis of the mission at hand. There were many discussions, refinements, and agreements to disagree over the mission details. Throughout the vignette, the discussions and disagreements remained very civil, with the appearance that each MOC appreciated the co-equal status of the other MOCs in the group.

During the conduct of this vignette, the leader of the highly experienced MOC shared with the other MOCs that one of the "OPT" members had actually called an official event security person to gain unclassified insight into how his nation was actually poised to handle security issues at the event. This was a prime example of sharing tacit knowledge, albeit in an explicit form. Through the course of this vignette, many discussions emerged between MOC "Plans Managers." During these discussions, they shared reasons and mental models regarding how elements of their planning products were developed. At one point, a "Plans Manager" stopped looking at another MOC's planning briefing in order to concentrate on the other "Plans Manager's" words. When asked, he said that it was more important for him to understand the meaning behind the presentation then to simply digest the few words and diagrams that showed up on the power point slides.

The final interesting activity that occurred during this group's planning regarded the development of multiple courses of action. The agreed upon lead MOC directed that each MOC produce one course of action to bring to a combined analysis session the next day. When the next day arrived, the lead MOC began discussing with one of the MOCs that their two courses of action were very similar and would not likely yield much of a comparison during the analysis and decision phase. The third MOC of the group had not pre-disclosed it course of action in the file sharing application, so there was some angst emerging from the lead MOC that the next phase could have problems. Once the third MOC entered the collaborative course of action analysis session, it was apparent that all would be well because that MOC's "Plans Manager" ignored the leader's direction to create one course of action and had his "OPT" follow their own planning process policies and create multiple, different courses of action. This work by the third MOC certainly facilitated a collaborative analysis of multiple courses of action, which provided each MOC with more confidence for making recommendations to their commander regarding the merits of each course of action.

Through discussions with the participants after this vignette, the participants agreed that, to their surprise, mutual adjustment seemed to work quite well. The only drawback was that it appeared to be "quite chatty." The observes took this to mean that discussions sometimes strayed off the point and sometimes went on longer than was generally regarded as typical in a fast-paced, crisis planning event.

c. Vignette 3: Containing a Pandemic in a Archipelagic Environment

The grouping of MOCs from Vignettes 2A and 2B remain the same for Vignettes 3A and 3B. Both of the groupings of MOCs received the exact same scenario since the focal archipelagic environment for this crisis was in or very near each MOC's area of interest. The three driving factors of this scenario were to develop plans to contain the spread of an emerging pandemic disease via restricting boat travel (e.g., set up and monitor a maritime exclusion zone), facilitate humanitarian assistance, and protect all forces from contracting the disease. Similar to the other vignettes, no one MOC had enough assets to effectively do this mission alone.

For Vignette 3A, the "Plans Manager" for the designated lead MOC, stated up front that because he recognized the co-equal status of each MOC, he did not intend to be very directive towards the other MOCs during the planning process. Both of the other MOCs' "Plans Managers" responded by saying that they disagreed and expected the lead MOC to be directive. This was the same grouping of MOCs that operated without a designated lead MOC in Vignette 2A. Soon after the Mission Analysis Coordination event completed, a real-world crisis event emerged for one of the MOCs. This required it to withdrawal its participants from the field event. In lieu of their participation, a single planner from the same country who happened to be operating in a support role in the exercise control cell picked up the planning duties to allow for continued three party collaborative coordination session to continue for the remaining two days of the vignette. His role was less about building planning products, and more about providing that third country perspective and planning expertise during coordination sessions.

Throughout the course of Vignette 3A, intra-MOC processes and inter-MOC collaborations appeared to operate similarly to the previous vignette. Some of the dialog between the MOCs was assessed to have a bit more sternness in tone during disagreements over details. It appeared that the two non-lead MOCs worked together to try and move the lead MOC's "Plan Manager" off of certain details, especially during the course of action analysis phase. Ultimately, a compromise was either reached, or all parties at least had a fairly clear understanding of the differences in each MOC's plans, and more importantly the rationale behind the differences.

The other grouping of MOCs constituted Vignette 3B. They seemed to suffer from the experiences that occurred during Vignette 2B where early highly collaborative work sessions were dismissed by the lead MOC as being too time consuming and not of great value. Again, although two MOCs did not share that opinion, one of them resigned itself to working its internal processes and only sharing what was asked for and not gaining much from the lead MOC's attempt to standardized the outputs (i.e., a common plan for all to submit). In Vignette 3B, however, where disagreements occurred, such as what the *center of gravity*[7] was for the crisis (e.g., what is the most powerful item working against your mission success), these disagreements were not dwelt upon; rather they were noted in each MOC's plan so that each commander could be aware that there was some item that remained uncoordinated.

In general, there was no real consensus opinion to emerge from this grouping of MOCs regarding which was the preferred way for co-equal MOCs to achieve coordination in plans. Two of these three MOCs were of the opinion that there was efficacy in both the no-lead situation and the designated lead situation. While one MOC was adamant that the designated lead MOC situation was not conducive to achieving coordination among co-equal MOCs during collaborative planning.

4. Process Details

Archival research of each MOC's planning doctrine shows strong similarity of the general steps involved. MOC4, MOC5 and MOC6 have identical process steps, while MOC1 and MOC2's identical process steps are very similar to MOC3's. Table 6 juxtaposes these doctrinal processes. Field observations strongly support the idea that these processes and the products associated with the process steps correspond well. This correspondence leads to a generalization that the process can be grouped into four phases; Mission Analysis, Course of Action (COA) Development, COA Analysis, and COA Decision. These phases are discussed next.

[7] Center of Gravity is a term coined by the Clausewitz, an eminent military scholar. It is a concept typically used to assess vital power possessed by friendly forces and vital power being wielded by an enemy during a clash of wills.

MOC4, MOC5 & MOC6	MOC1 & MOC2	MOC3	Generalized Process Steps
1. Initiation 2. Orientation	1. Initiation 2. Mission Analysis	1. Review of Situation 2. Identify & Analyze Problem	Mission Analysis
3. COA Development	3. COA Development	3. Formulate COAs	COA Development
	4. COA Analysis & Wargaming 5. COA Comparison	4. Develop & Validate COAs 5. Evaluate COAs	COA Analysis
4. Plan Development 5. Plan Review	6. COA Approval 7. Order Development	6. Cdr's Decision & Development of the Plan	COA Decision

Table 6. Comparison of Various Planning Processes

a. Phase One – Mission Analysis

The first generalizable phase of the planning process is Mission Analysis. Participants review and analyze warning orders and the situation provided, as well as the current situation based on the MOC's real-world operations. The purpose of this phase is to promote a general common understanding among all members within an "OPT." Specifically, the "OPT" needs to frame the problem in terms of task to be accomplished to successfully accomplish the assigned mission contained in the warning order. The common understanding also includes any limitations to possible actions that they might choose from, such as treaty requirements or rules of engagement. This phase consisted primarily of each "OPT" conducting an independent task to develop the mission analysis product—i.e., a PowerPoint briefing. This was followed by an internal face-to-face meeting between the "Plan Manager" and the "OPT." This allowed the "Plan Managers" to provide feedback to their "OPT" to refine the mission analysis product. It also gave the "Plan Managers" a product, which they put forward as an entering position for a collaborative coordination session with the other MOC "Plan Managers."

This collaborative mission analysis session with other MOCs was not reflected in any of the planning doctrines that governed the activities of these MOCs.

After Vignette 1, it appeared to the observers and was confirmed in interviews that the "Plan Managers" came to the realization that completely independent (i.e., no collaboration between MOCs during planning) planning based on a common mission and situation did not produce a very well coordinated set of COAs to be enacted by each MOC's subordinates. What emerged for Vignettes 2 and 3 was a preliminary discussion among the "Plan Managers" about the general timeline that the planning process should take including times when collaborative sessions to compare and coordinate intermediate products would take place. A mission analysis coordination meeting between "Plan Managers" emerged as a new step in the planning process. It was scheduled and completed prior to the traditional last step of the planning process—the commander's mission analysis decision step. Both the mission analysis coordination and mission analysis decision task provide additional feedback to refine the mission analysis product.

b. COA Development

COA Development is the second phase. It does not officially begin until the commander approves the mission analysis product and provides planning guidance. The primary task of this phase involves the "OPT" sketching out in words and pictures possible ways to sequence activities to accomplish the mission. Once the "OPT" has developed a draft version of each COA, the "Plan Managers" meet with the "OPT" to review these products and provide feedback. These COAs are then used as basis for a coordination session between the "Plan Managers." This event is similar to the coordination session used during the mission analysis phase. The inter-MOC COA coordination session was followed by each MOC "Cdr's" review of their MOC's developed COA drafts. During this task, the commander provides feedback and guidance regarding which COAs to analyze during the next phase.

c. COA Analysis

COA Analysis is the third general phase of the MOC planning process. The major tasks of this phase include the "OPT" conducting an analysis of each COA by basically describing in detail what each functional area activity is being performed, where and when in space and time, and which subordinates are performing those activities. This is done using words and diagrams to mentally walk through a COA to refine its level of details and coordination among those details. Generally, the activities proposed are challenged by some member of the "OPT" that is asked to raise potential environmental (e.g., bad weather) or adversary (e.g., attacks) challenges. This task covers many details. Upon completion of the COA analysis, the "OPTs" formulate their respective recommendation regarding which COA best meets the "Cdr's" mission and guidance. During this task, the "OPT" makes estimates of the advantages and disadvantages of each proposed COA. With these two tasks complete, the "OPTs" met with their respective "Plan Manager" to refine the products.

d. COA Recommendation

The "Plan Managers" then took element of their analysis and estimate products to a virtual coordination session with the each other. This session led to final refinement of each MOC's COA analysis phase products. This phase and the overall project finished with each "Cdr" independently reviewing the COAs and staff estimates, and ultimately approving one of the COAs.

B. COMPUTATIONAL MODELS

This section describes the computational modeling done to support this research. The first section outlines the baseline model design and parameters which are based on the qualitative research phase. It then reports the performance results from simulation runs of the baseline model. The next section describes the design and parameter changes to the baseline model to instantiate a model that can represent the performance outputs for each of the remaining cells in the two-factorial research design.

1. Baseline MOC-to-MOC Collaborative Planning Process Model

Figure 14 is a screen capture of the POW-ER model for the MOC-to-MOC collaborative planning process that takes place during the initial phase of an operation other than war crisis situation (e.g., humanitarian assistance and disaster relief operations) that calls for maritime assets from multiple countries to respond. The project entails three co-equal (i.e., each is responsible for preparing a course of action plan for its own assets) teams of planners working through their crisis action planning process to produce a decision briefing for their respective commanders. The observations point to a baseline model where the direct supervision and high tacit knowledge conditions exist.

The project tasks are represented in Figure 14 by yellow rectangular boxes. Pale yellow (light shaded box if viewing in black and white) boxes represent the tasks that are performed by each organization's commander (e.g., Cdr A). Yellow (medium shaded) boxes are tasks performed by each organization's plan managers (e.g., Plan Mgr B). Dark yellow (dark shaded) boxes are tasks performed by the respective operational planning teams (e.g., OPT C). A blue (light) colored one-way arrow connects actors to a task that they perform.

Black one-way arrows connect to the sides of task boxes represent the flow of work over the course of the project. Red arrows (one-way arrows that connect task boxes from the upper side) represent *rework* links. Rework links are important to account for exceptions or problems that occur during a task that compels rework of a related task to occur. Green arrows (two-way arrows that connect task boxes at the bottom side) represent reciprocally interdependent tasks where it is important for informal communications to occur.

Finally, a blue hexagon represents a milestone in the process flow of tasks. Milestones act to ensure that all predecessor tasks are complete before any of the next set of tasks can begin. Milestones in the diagram also help the reader perceive the start and completion of project phases. Table 7 shows a legend to assist the reader in understanding the POW-ER model screen capture.

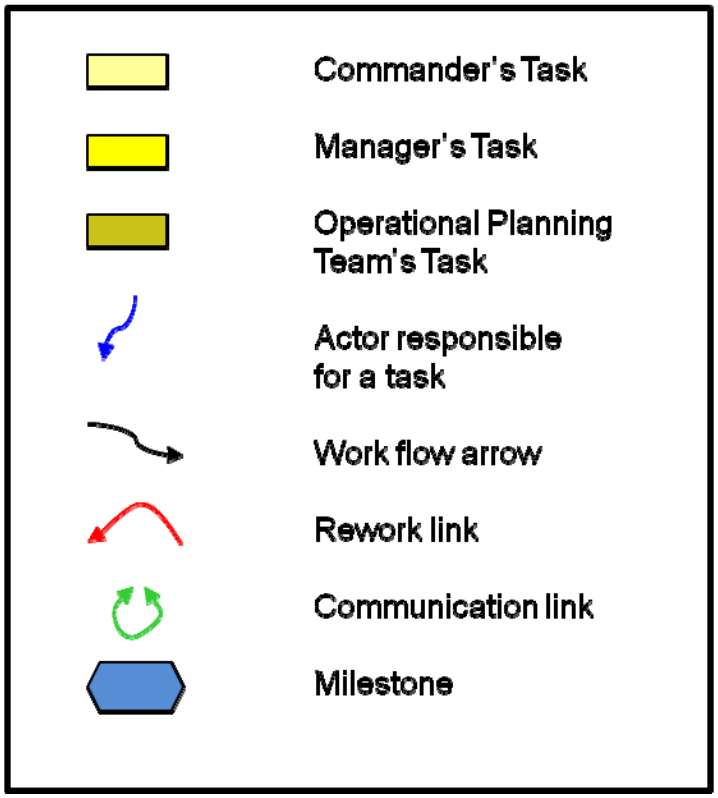

Table 7. POW-ER model legend

The project has four phases: (1) mission analysis, (2) course of action development (COA Dev), (3) course of action analysis (COA Analysis), and (4) course of action decision (COA Decision). To make the POW-ER model easier to view, each MOC's tasks stack on top of one another; in other words there are three layers of similar task boxes (e.g., Plan Prep C is in the foreground and partially covering the Plan Prep A and Plan Prep B task boxes). The only connections between the three layers are the green communications links that connect similar task boxes between each MOC's processes.

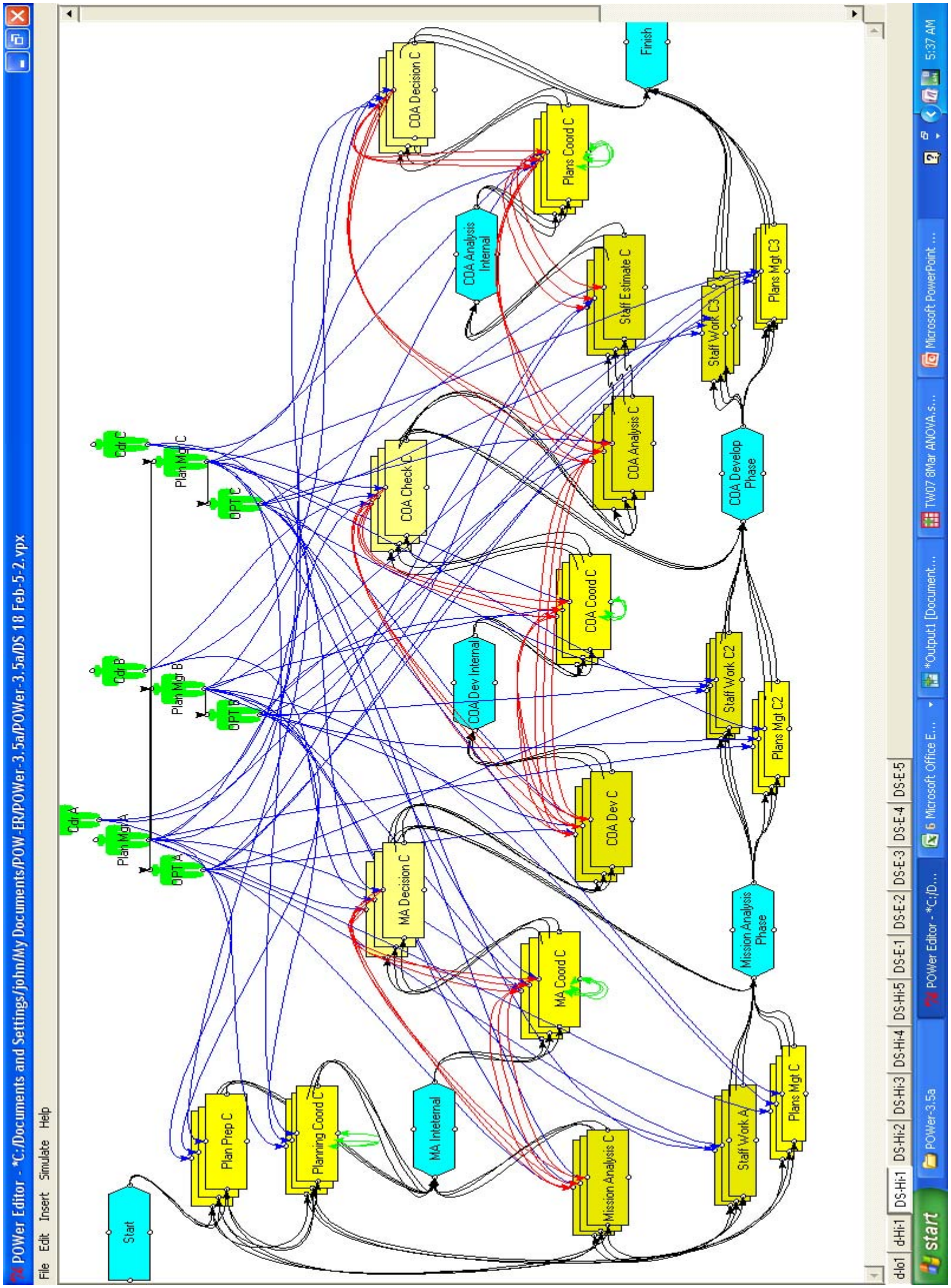

Figure 14. POW-ER Baseline Model of Direct Supervision Coordination Mechanism for Planning in an Interorganization System

a. Mission Analysis

The mission analysis phase includes tasks for the “Plan Mgrs” and “OPTs.” The “Cdr” actors do not have a direct task in this phase until the very end where they receive the mission analysis briefing, review it, provide feedback, and ultimately approve it. The “Cdrs” certainly work throughout the project, but they are instantiated in the model with only a 0.15 full time equivalent (FTE) setting, which translates into these actors only being available for the interaction with the planning process for around an hour each day. This matches the general observations throughout the vignettes where the “Cdrs” received briefings and gave guidance necessary for revisions and initiation of the next phase of the planning process.

The mission analysis tasks for the “Plan Mgrs” include: (1) planning preparation (Plan Prep), (2) planning coordination (Plan Coord), and (3) plans management (Plans Mgt). During Plan Prep, the “Plan Mgrs” read tasking messages, gather initial awareness of the operating environment, and formulate their initial ideas regarding the mission and how to execute the planning process (e.g., stipulating product deliverables and individuals or teams to prepare the products). In light of the common goal to collaborate with other MOCs to build coordination among the plans, the “Plan Mgrs” also have a short initial Plan Coord task where the designated leader shares his or her thoughts and directions with the other “Plan Mgrs.” These tasks are connected by green (light) bi-directional communications links (i.e., two-way green arrow connecting tasks) that signify a high level of communications needs to happen between these reciprocally interdependent tasks. Even though there is a leader that can designate when and what collaboration happens during the project, the other “Plan Mgrs” still represent co-equal MOCs that have a foremost responsibility to meet their commander’s unique requirements. Hence, the process and products that these other two MOCs execute and develop are reciprocally interdependent with the designated lead MOC. Finally, the “Plan Mgrs” each have a Plans Mgt task which accounts for a steady workload that is commensurate with their role as a mid-level MOC staff officer. In other words, their "inbox" is never empty (e.g., other plans need updating and daily situation briefings and policy meetings take up time). This task allows the "Plan Mgrs" to be modeled with an FTE of 1.0.

The "OPTs" have the primary task in each but the last phase of the project. They are responsible for performing the Mission Analysis activities that populate a briefing to their "Cdr." While there are many sub-parts within this task (e.g., Task Analysis, Priority Information Requests, etc.), it is sufficient for this research to represent mission analysis as a single task being performed by each "OPT." Due to the nature of the many sub-parts involved in this task (e.g., one doctrinal publication lists as many as 17 different processes to accomplish in mission analysis), the *requirements complexity* setting for this task is "high." Of note, there are no green communications links between these tasks because the teams performed these tasks generally without any substantive communications between "OPTs." Time is spent after completion of Mission Analysis in a meeting to review an "OPT's" product with their "Plan Mgr" before the product could be shared with another MOC. While a meeting is able to be represented in POW-ER, it has a significant impact on POW-ER outputs, especially relating to the coordination that occurs through communication in POW-ER. Since a meeting is designed in POW-ER to represent face-to-face communications, this could only affect coordination internal to a MOC, but that affect would add to overall project coordination and be unnecessarily reflected in the dependent variable *project risk*. To account for the time where internal MOC meetings occur, a lag time is added to the *successor link* (i.e., the black (dark) uni-directional arrow connecting two tasks) that emanates from the project *milestone* (hexagonal blue box) named MA Internal. If a meeting takes 90 minutes, a "lag of 1.5" is added to the *successor link*, which causes the next task to start after 1.5 hours. Time spent in meetings is accounted for in the "OPTs'" other task of Staff Work. Staff Work is similar to the "Plan Mgrs'" Plan Mgt task discussed in the preceding paragraph: it accounts for other daily activities that the OPT members perform (e.g., replying to correspondence such as electronic mail).

The Mission Analysis Coordination (MA Coord) task is the responsibility of the "Plan Mgr." This task involves the "Plan Mgrs" collaborating in a synchronous mode (e.g., telephone conference call or online meeting application) to review, discuss, and coordinate relevant details of their individual mission analysis products. This virtual collaboration event is modeled similarly to the Plan Coord task discussed above, where three MA Coord tasks are connected by green communications links signifying the intensity of communications between these reciprocally interdependent tasks. The significant difference between this task and both the Plan Coord and Mission Analysis tasks is that the MA Coord task's *solution complexity* is set to "high" because this task accounts for the majority of project coordination that occurs between the MOCs. Also, because a majority of the products within Mission Analysis are reviewed, the *requirement complexity* is set to "high." Finally, MA Coordination generates rework, signified by uni-directional red links (i.e., one-way red arrow connecting tasks). When an exception occurs in this task, rework is generated for the preceding Mission Analysis task. In other words, as the "Plan Mgrs" discuss and coordinate their respective Mission Analysis products, omissions, errors or new ideas could cause the "OPT" to modify aspects of its Mission Analysis product.

The final task of this mission analysis phase is the Mission Analysis Decision (MA Decision) by the "Cdr." This is briefly discussed in this section's first paragraph. During this task, any exceptions generate rework for the preceding tasks of the "Plan Mgr's" MA Coord and the "OPT's" Mission Analysis. Upon the "Cdr's" approval of the mission analysis, the "OPT" begins the COA Development phase.

b. COA Development

During the COA Dev task, the "OPTs" devise general activities for their available forces (i.e., those that they are authorized to plan for) to perform. Typically two or three different COAs are sketched out. The goal of this task is to articulate at least one feasible way to accomplish the mission. Once the requisite number of COAs are finished, there is again an internal review or meeting with of the "OPT" and the "Plan Mgr." This meeting is represented by a 1.0 hour lag in the *sequence* link between the *milestone* COA Dev Internal and the subsequent COA Coord task.

The COA Coord task is another synchronous virtual collaboration session to discuss the COAs that each MOC develops. The scope of this task does not involve the level of details that occur during the MA Coord task. Hence, it has no special task setting and is one of the tasks with the shortest *effort* assigned at 0.5 hours. Exceptions generated during this task cause rework to the "OPT's" COA Dev task.

The final task of the COA Development phase is the "Cdr's" COA Check. This review of the COAs developed elicits feedback from the "Cdr" regarding any modifications desired to the COAs and which COAs to carry forward into the COA Analysis phase. The feedback generates rework for both the "Plan Mgr's" COA Coord and "OPT's" COA Dev tasks.

c. COA Analysis

The "OPT" has two tasks associated with this phase, the COA Analysis task and the Staff Estimate task. The COA Analysis task is another example of a complex task because of the amount of internal requirements to satisfy. Each functional area (e.g., logistics, civil engineering, and force protection) of maritime operations is considered as the participants are led through a facilitated dynamic simulation (e.g., a two-sided game model) of the sequence of activities arranged in a COA. The task generally considers activities played out against dynamic external variables such as weather and other social systems (e.g., refugees and terrorist groups). This tasks helps ensure that activities are synchronized and all types of capabilities resident in the maritime force are considered. Since maritime assets typically have a wide range of capabilities (i.e., are multi-mission capable), this analysis task's *requirement complexity* characteristic is set to "high." Exceptions that occur in this analysis task generate rework in the COA Dev task.

The "OPT's" Staff Estimate task requires the actors to consider the functional areas investigated during the previous COA Analysis task. This consideration leads to an evaluation of the COA based, usually based on some objective criteria. The objective evaluation is developed and forwarded along with the its associated COAs to the "Plan Mgr" for coordination with the other MOCs in the Plan Recommendation task, and finally on to the "Cdr's" COA Decision task.

The Plan Recommendation task is the final synchronization task between the MOCs. Again, it is conducted after an internal meeting involving the "OPT" and "Plan Mgr," which is modeled as a 1.0 hour lag in the *successor* link following the COA Analysis Internal milestone hexagonal box. The Plan Recommendation task is conducted in a synchronous virtual collaboration session where details of multiple COAs along with the staff estimates, specifically those that are being recommended to a Cdr, are reviewed and refined as necessary. Due to myriad details and contribution to project coordination considered in this task, both the *requirement complexity* and *solution complexity* are set to "high." Exceptions occurring in this task generate rework in the COA Analysis task.

The final task in the process is the "Cdr's" COA Decision task. The "Cdr" takes the input for this task from the output of the "Plan Mgr's" Plan Recommendation task. Exceptions occurring in this task generate rework for both the Plan Recommendation and COA Analysis tasks. Once complete, this concludes the planning project, which is designed to formulate guidance that would be delivered to subordinate assets of a MOC as they commence the actual operations in response to the crisis event.

d. General Model Parameters

Each object in the figure has a number of model parameters that are set to guide the behavior of the agent-based model (Looney & Nissen 2006). These parameter settings reflect empirical observations from the immersive fieldwork phase, empirically determined "normal" levels for organizations in general (see Jin & Levitt 1996; Levitt et al. 1999; Nissen & Levitt 2004), or draw on prior related research (see Wong & Burton 2001; Looney & Nissen 2006). Table 8 summarizes the baseline model's parameters. The following brief description of the model parameters is drawn from the SimVision User Guide.

The first three parameters represent the organization design specifications. *Centralization* describes the degree to which communication flows and decision making are hierarchical. In the baseline model, *centralization* is set to "medium" to reflect the interorganizational alliance nature of the case: although one of the "Plan Mgrs" is designated to lead the collaborative planning project, each organization represents an independent maritime organization and will not defer exclusively to the lead manager. *Formalization* describes the degree to which communication flows and work tasks follow formal routines and documented standardized procedures. This parameter is set to "low" to reflect the propensity of highly experienced planners to not rigidly follow the defined steps of their planning process and do their best to equally respond to both formal and informal communications. *Matrix strength* represents the degree that managers supervise subordinates and are relied upon to handle exception situations that occur during tasks. This parameter is set to "medium" to reflect the combined nature of some designated supervision along with the necessary informal communication that take place during interorganizational coordination activities.

The next four parameters reflect probabilities for *communications*, *noise*, *functional exceptions* (FE), and *project exceptions* (PE). The intensity of communications and the frequency of interruptions (e.g., misunderstanding in what was communicated) are governed by the *communications* and *noise* probability settings. In this model of virtual interorganizational collaboration, these parameter settings, 0.7 and 0.5 respectively, are guided by Wong and Burton (2001) and supported by the empirical observations of this case study. Likewise, the FE and PE settings of 0.05 and 0.1 respectively are guided by Looney and Nissen (2006) and supported by the empirical observations of this case study. FE represents the probability that an exception occurs in a task, and that the exception will only affect the quality of that task. PE represents the probability that an exception occurs in a task, and that the exception will affect any related tasks (i.e., tasks connected by red *rework* links).

The next three parameters reflect the experience and knowledge available in the project. *Team experience* reflects the experience level of all the actors facing the problem at hand (i.e., the project). Both the unique nature of crisis events and the interorganizational collaborative planning situation drive this parameter setting to "low." *Planning skill* and *application experience* are parameters associated with each actor.

Planning skill accounts for the competency of the actor at performing the planning tasks of the project. In this case, the "Plan Mgrs" and "OPTs" are determined to have a "high" level of planning skill. The "Cdr" position is responsible for general decision making and review tasks, hence, the default "generic" skill setting of "medium" is applied. The *application experience* setting is "high" for the "OPTs," since they were generally shielded from direct communications with other MOCs and their tasks remained grounded in their standard planning process. For the "Cdrs" and the "Plan Mgrs," the *application experience* is set to "low;" this accounts for the unfamiliar work of virtual simultaneous interorganizational collaboration coupled with the unfamiliar concept of co-equal military organizations must coordinating operations without the typical military hierarchy in place providing strict unity of command.

Finally, the actors in each organization are arranged in a familiar three level hierarchal configuration. The "Cdr" is designate a *project manager*, the "Plan Mgr" is designated a *subteam leader* and the "OPT" is designated as a *subteam*. These settings affect the speed and type of exception handling that occurs in the project. "Project managers" tend to handle exceptions quickly and thoroughly, while "subteam" actors take longer to decide and tend to ignore or only partially handle exceptions. The unique aspect of this baseline model is that the commanders are not connected directly to their subordinates as is the case in typical hierarchical organizations. The POW-ER model as currently designed allows for only one supervisor per actor; therefore, to create the situation where one "Plan Mgr" is designated to lead the collaborative planning effort, the other "Plan Mgrs" have the lead "Plan Mgr" as their supervisor. That precludes the ability to connect the non-designated "Plan Mgrs" to their respective "Cdr."

Parameter	Setting
Centralization	Medium
Formalization	Low
Matrix strength	Medium
Communication probability	0.7
Noise probability	0.5
Functional exception probability	0.05
Project exception probability	0.10
Team experience	Low
Planning skill	High
Application experience	
-Cdr & Plan Mgr	Low
-OPT	High
Role	
-Cdr	Project Manager
-Plan Mgr	Subteam Leader
-OPT	Subteam

Table 8. Baseline POW-ER Model Parameter Settings

e. Baseline Performance Results

The POW-ER modeling environment is used to emulate the behavior and performance of the baseline model just described. The baseline model as described above meets the requirements for *face validity* based on reviews by an observation team member, planning experts, and organizational modeling experts. The following performance results are presented to demonstrate that the baseline model corresponds to the behaviors and performance of the observed organization in the field. With that element of external validity, there is confidence that this model is suitable for developing and running computational experiments for hypothesis testing.

Table 9 summarizes the observed performance of all the groups, the targeted run time for each major task, the simulated run time for each major task, and the critical path method (CPM) setting for each major task. All numbers represent hours to complete a task. The asterisked columns constitute the primary input for the task duration specifications of the baseline model since the MOCs grouped together in these vignettes clearly represented the tacit knowledge group (i.e., cohesive teams of experienced planners). The “Target” column generally averages the observed durations in the two asterisked columns. The shaded column represents performance outputs of the Monte Carlo simulations for the baseline model. The performance outputs in the “Run Time” column are based on the mean of 30 cases conducted with unique seed values (i.e., 1-30) and a total of 50 trials per case. Finally, the “CPM Duration” column lists the hour value assigned to the “effort” parameter of each task. The “effort” parameter reflects only the direct work associated with a task: this is how long a task would take to accomplish in a perfect situation such as where no exceptions or communications were required during the performance of the task.

The “Run Time” quantities correspond well to the observed task durations in the “Target” column. At this point, the baseline model has achieved both face validity and internal validity based on the accepted structure depicted in Figure 13, and the performance of the model listed in Table 9. With these two conditions and the strong construct validity of associated with Stanford’s years of Virtual Design Team research, there is substantial confidence that the baseline computational model can be used to support the computational experimentation necessary to answer the research question raised in this dissertation.

Process Step	Vignette 2A	Vignette 3A	Vignette 2B*	Vignette 3B*	Target	Run Time	CPM Duration
Mission Analysis	5.0	4.5	3.5	4.0	3.7	3.6	3.0
Mission Analysis Coordination	2.5	1.5	3.5	2.0	2.8	2.8	1.5
COA Development	4.5	4.0	2.5	4.0	3.3	3.3	3.0
COA Coordination	1.0	0.5	1.0	2.0	0.5	0.7	0.5
COA Analysis	2.0	1.0	2.0	2.0	1.0	0.8	1.0
Staff Estimate	2.0	1.5	2.0	2.0	1.0	1.2	1.0
Plan Coordination	3.0	2.5	3.0	3.5	3.3	3.3	2.0
subtotal					15.3	15.7	12.0
Cdr's Tasks	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Delays for Meetings	4.0	4.5	4.0	3.5	3.7	3.5	3.5
Parallel Tasks	~ 3 hrs/day	~ 3 hrs/day	~ 3 hrs/day	~ 3 hrs/day	3.5	3.9	3.0
Total	30	26	27.5	29	25.5	25.6	18.5

Table 9. Baseline POW-ER Model Output Details

2. Model Manipulations for Computational Experimentation

Using the baseline model described above, manipulations informed by theory and field observations were made to create three new models to generate data for each of the three remaining cells in the two factorial experiment design—coordination mechanism and knowledge type. The parameters for these models are listed in Table 10. The parameter settings for the baseline direct supervision-tacit knowledge (DS-TK) are listed in the second column and have been explained in the previous section. The last three columns present the modification to the baseline model in **bold** font, and the column heading underscores the treatment modification from the baseline—i.e., direct supervision-explicit knowledge (DS-EK), mutual adjustment-tacit knowledge (MA-TK), and mutual adjustment-explicit knowledge (MA-EK).

a. Explicit Knowledge Manipulation

The third column, DS-EK has the same hierarchical structure and tasks as the baseline model. In other words, a screen capture of this DS-EK model is identical to the baseline model, DS-TK (see Figure 14 above). All of the manipulations to create the DS-EK model are made to the model parameter settings. The first parameter manipulation to create differentiation between groups on the condition of knowledge type, *tacit* versus *explicit*, is the formalization parameter. This parameter governs the communications flows between all tasks. A *formalization* setting of "low" (see baseline settings for DS-TK) indicates that the actors are less likely to follow the formal process steps of a task, and engage in more informal task-related communications while performing the each task. Multiple field observations support this setting; observers at MOC5 and MOC6 both noted that the cohesive teams of highly experienced planners preferred to move quickly and flexibly through the process steps—appearing to operate "almost instinctively." Observers at MOC3 noted that the "OPT" closely but flexibly performed tasks—treating the doctrinal process as a guide rather than a prescriptive process to be exactingly adhered to. Hence, the setting to create the EK condition alters the baseline's *formalization* setting of "low" to "medium." This modification is further supported by field observations and interviews. At MOC1, it was noted that the "OPT" members were given a template for the planning products that they were responsible for completing. The planners generally stepped through each section of the template in order. A "Plan Manager" of a less experienced "OPT" was observed to have a deep conviction about being deliberate in reviewing each detail of a product in the doctrinally prescribed order. His discussion of these products in collaboration sessions was also deliberate and time consuming. Although this strict following of prescribed procedures may seem highly formal, the informal communications that occur between "Plan Mgrs" during review and coordination tasks in this virtual team interorganizational system precludes the *formalization* parameter being set to "high."

The settings of *application experience* and *skill level* are the remaining two parameters that help instantiate the EK condition. Knowledge flow theory describes tacit knowledge as highly personal know-how acquired largely by the experience of performing actions—e.g., on the job training and apprenticeship. A team of people that have very little experience in performing the steps of the doctrine, especially in the fast-paced instance of planning in response to a crisis, are deemed to have a parameter setting of "low" for *application experience*. Furthermore, maritime headquarters' planning familiarization events generally focus on planning for conventional military combat operations as opposed to disaster response operations.

The most obvious difference between a TK and EK condition regards the *skill level*. Knowledge flow theory clearly considers people with a high degree of tacit knowledge to be highly skilled—hence, the "OPTs" of the TK condition and all "Plan Mgrs" have a *planning skill* level set to "high." For the EK condition, the "OPTs" are supplied with written doctrine and planning product templates, and generally have some familiarity with the both, so their "planning skill" level is set to "medium" instead of "low."

Parameter	DS-TK	DS-EK	MA-TK	MA-EK
Centralization	Medium	**Medium**	**Low**	**Low**
Formalization	Low	**Medium**	Low	**Medium**
Matrix strength	Medium	Medium	**High**	**High**
Communication probability	0.7	0.7	0.7	0.7
Noise probability	0.5	0.5	0.5	0.5
Functional exception probability	0.05	0.05	0.05	0.05
Project exception probability	0.10	0.10	0.10	0.10
Team experience	Low	Low	Low	Low
Planning skill	High	**Medium**	High	**Medium**
Application experience -Cdr & Plan Mgr -OPT	 Low High	 Low **Low**	 Low High	 Low **Low**
Role -Cdr -Plan Mgr -OPT	 Proj Mgr SubTm Ldr Subteam	 Proj Mgr SubTm Ldr Subteam	 Proj Mgr SubTm Ldr Subteam	 Proj Mgr SubTm Ldr Subteam

Table 10. POW-ER Model Manipulations for Experimentation

b. Mutual Adjustment Manipulation

A direct supervision coordination mechanism is characterized by centralized decision making (e.g., exception handling). Were the baseline model to represent an intra-organizational system, the *centralization* parameter would likely have been set to “high,” but in this interorganizational case, it is set to “medium.” The mutual adjustment coordination mechanism has a *centralization* setting of “low” to reflect the idea that each MOC is independent and does not look to any centralized decision maker. Each “Plan Manager” makes his or her own decisions regarding their MOC’s plans.

Matrix strength is the other parameter that helps instantiate the mutual adjustment condition. The mutual adjustment condition supports the idea that actors in an organization or between organizations in an interorganizational system are highly connected and, hence, have a greater propensity to informally communicate amongst one another. The *matrix strength* parameter is changed to “high” in the case where a mutual adjustment coordination mechanism is present. But that is not enough to fully capture in the POW-ER model the activities of an interorganizational system operating by a mutual adjustment coordination mechanism: structural, process and communications entities need to be addressed; hence, the visual display of the baseline model is changed to fully instantiate the mutual adjustment condition.

The first difference to discuss is the hierarchical relationship amongst the actors presented in the baseline model (see Figure 14 above). Figure 15 shows that no single “Plan Mgr” has a supervisory link to another “Plan Mgr.” In other words, the MOCs do not have any hierarchical coordination mechanism present. The next change to note is that the tasks that the “OPTs” perform are now linked by green *communication links*. These links show that the actors conducting these tasks communicate regarding the interdependencies of elements within the tasks. For example, during a mission analysis task, an “OPT” would likely share its products, rationale for the products, and ideas with another MOC.

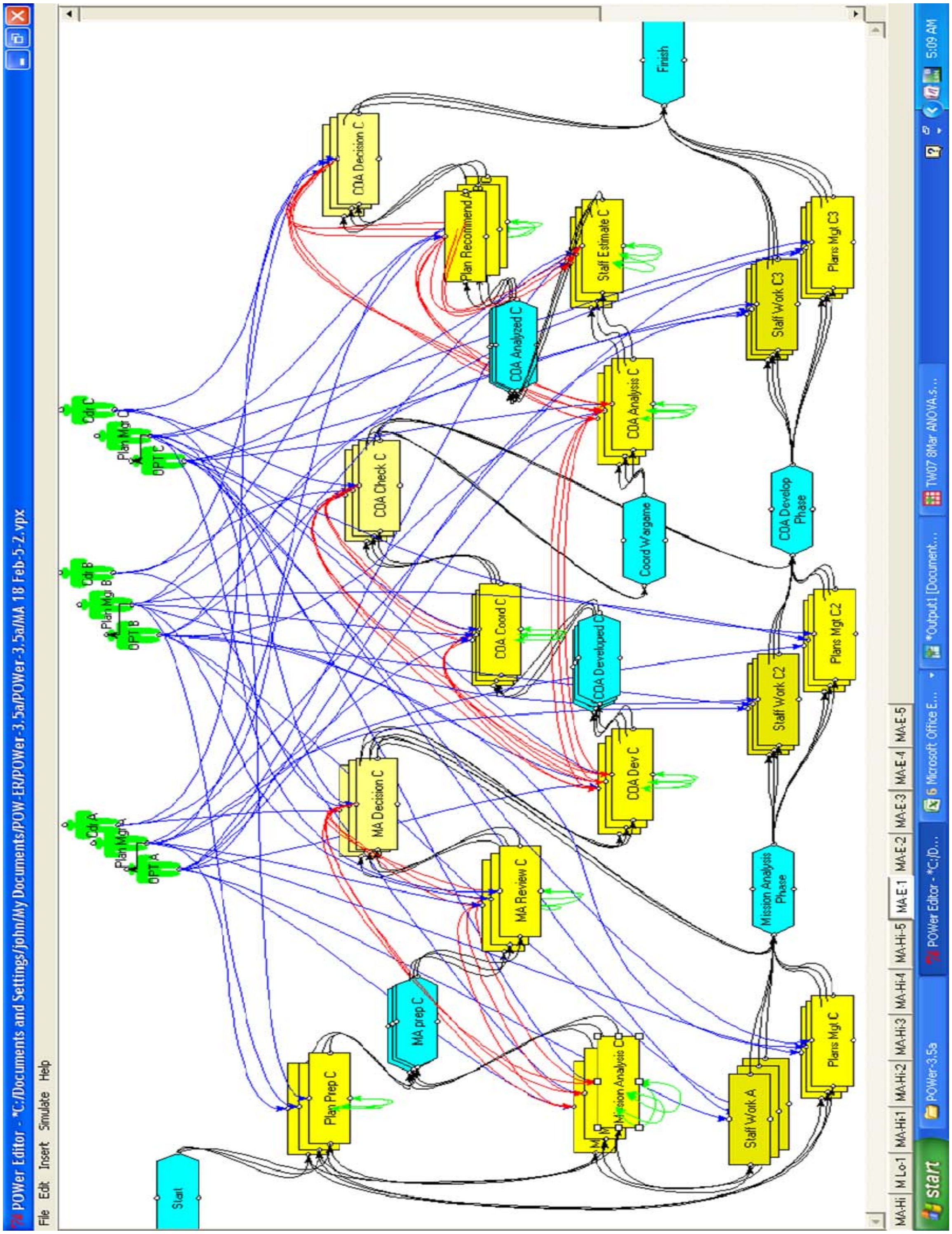

Figure 15. POW-ER Model of Mutual Adjustment Coordination Mechanism for Collaborative Interorganization Planning Coordination Using Mutual Adjustment Coordination Mechanism in a Virtual Environment Model

Regarding the "Plan Managers," no longer would they need to perform the two separate tasks of Plan Preparation (Plan Prep scheduled for two hours with no green communication links) and Planning Coordination (Plan Coord scheduled for 15 minutes with communication links) depicted in the baseline model. The details collaborated on during the Planning Coordination task could be developed during a collaborative Plan Preparation task. Instead of the direct supervision models' two task parallel sequence, the mutual adjustment condition allows for the Plan Preparation and Planning Coordination tasks to be combined into one Plan Preparation task (scheduled for two hours) with green communication links connecting each MOC's similarly named task. Of note, the green *communication links* add time to the simulated duration of each task, so deleting the 15 minutes of collaborative communications between the baseline model's Planning Coordination is accounted for in the communications growth and concomitant growth in simulation duration of the Plan Preparation task.

The *milestone* markers in the baseline are set as single entities. This is because the coordination meetings are supervised by the *lead* "Plan Manager." In other words, the task Mission Analysis Coordination (MA Coord depicted in the baseline model) cannot begin until everyone is ready (i.e., finished their predecessor tasks. In the mutual adjustment model, the *milestones* are represented by three independent boxes, as MOCs can theoretically proceed at their own pace. The only difference to this generalization occurs prior to the COA Analysis task. The nature of the COA Analysis step is to synchronize all functional areas relevant to the mission at hand. Disjointed (i.e., tasks not conducted at the same time) work on this plan synchronization task would likely be less productive than simultaneous completion of this synchronization task. In light of this, a single *milestone* precedes the three COA Analysis tasks that are now connected by green *communication* links in the mutual adjustment models.

The final difference between the direct supervision and mutual adjustment conditions is the parameters of the coordination tasks (e.g., MA Coord and COA Coord depicted in the baseline model). In the direct supervision condition, the "OPTs" do not collaborate during their tasks. All collaboration between the MOCs is handled by "Plan Managers." This puts the entire coordination burden on them. The collaboration is conducted entirely during the coordination tasks. To account for the large amount of detail that has to be covered and the sole responsibility to accomplish this coordination falls to the “Plan Managers,” the *requirement complexity* and *solution complexity* parameters of the “Plan Manager’s” MA Coord and Plan Coord tasks are set to “high” in the direct supervision models. Because the OPTs in the mutual adjustment conditions informally communicate during the major development tasks of each phase, it is assumed that less detail review and coordination challenges will be faced by the “Plan Managers” during the coordination tasks. To instantiate this assumption, the *requirement complexity* and *solution complexity* parameters of the “Plan Manager’s” coordination tasks (depicted as MA Review and COA Review in the mutual adjustment models) are both set to “medium” in the mutual adjustment models. Additionally, the duration setting of these tasks is also likely to be less due to the need to only address those issues that could not be resolved during the collaborations performed by the “OPTs.” In light of this, 30 minutes is decremented from the post-MA Internal and post-COA Dev Internal milestone review tasks (formerly Coord task depicted in the baseline model) of the mutual adjustment condition.

C. QUANTITATIVE RESULTS

1. Characteristics of the Dependent Variables

Each of the four models is run 30 times using a seed value sequenced from 1 to 30 to initialize the Monte Carlo simulations. Each time a model is run, a total of 50 trials for that seed value are conducted. The dependent variables of *speed*, *functional risk* and *project risk* are checked to ascertain that they meet the assumptions for performing parametric statistical analysis techniques (e.g., ANOVA) so that there is confidence in the reliability of the results (Kerlinger & Lee 2000; Field 2005). Normality and homoscedasticity are the assumptions for parametric techniques and they are checked for using the Kolmogorov-Smirnov test for normality and Levene’s test for homoscedasticity (Field 2005). Over the entire data set (120 runs), the dependent variable of *speed* ranges from 22.85 to 37.30 hours (m = 29.73, s = 5.61). *Functional risk* ranged from 0.2401 to 0.4729 (m = 0.3434, s = 0.0543), *project risk* ranges from 0.2866 to 0.5551 (m = 0.4452, s = 0.0466), and *communication risk* from 0.4221 to 0.5515 (m = 0.4951, s = 0.0373). Using the Kolmogorov-Smirnov test for normality, each dependent variable is determined ($p < 0.05$) to come from a normal distribution, as shown in Table 11. Using Levene's Test for equality of variance, most of the dependent variables are determined ($p < 0.05$) to meet the homoscedasticity assumption as shown in Table 12. The dependent variable of *speed* has an F-statistic of 3.859 which corresponds to a 0.011 level of significance that does not meet the $p < 0.05$ test; however, "In terms of violations of the assumptions of homogeneity of variance, ANOVA is fairly robust when sample sizes are equal." (Field 2005 p. 324) Since the majority of the parametric technique assumptions are met and for the one exception, it has been shown that the ANOVA is robust when sample sizes are equal as in this computational experiment, the parametric ANOVA technique is applicable as the basis for this analysis of the data.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Speed DS-EK	.100	30	.200*	.968	30	.498
Functional Risk DS-EK	.144	30	.117	.946	30	.128
Project Risk DS-EK	.078	30	.200*	.984	30	.924
Communication Risk DS-EK	.111	30	.200*	.982	30	.874
Speed DS-TK	.122	30	.200*	.953	30	.204
Functional Risk DS-TK	.100	30	.200*	.976	30	.726
Project Risk DS-TK	.120	30	.200*	.948	30	.147
Communication Risk DS-TK	.097	30	.200*	.966	30	.426
Speed MA-EK	.064	30	.200*	.986	30	.953
Functional Risk MA-EK	.090	30	.200*	.950	30	.164
Project Risk MA-EK	.110	30	.200*	.957	30	.263
Communication Risk MA-EK	.122	30	.200*	.959	30	.298
Speed MA-TK	.109	30	.200*	.964	30	.388
Functional Risk MA-TK	.101	30	.200*	.959	30	.285
Project Risk MA-TK	.118	30	.200*	.963	30	.369
Communication Risk MA-TK	.070	30	.200*	.989	30	.986

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Table 11. Test for Normality

	Levene's Test			
	F Statistic	**df1**	**df2**	**Sig.**
Speed	**3.859**	**3**	**116**	**.011**
Functional Risk	**.093**	**3**	**116**	**.964**
Project Risk	**1.928**	**3**	**116**	**.129**
Communication Risk	**.984**	**3**	**116**	**.403**

Table 12. Test for Homoscedasticity

a. Speed

The first hypothesis test regards the speed that it takes for the project to be completed. *Hypothesis 1* predicts that knowledge types interacting with coordination mechanisms will have a statistically significant impact on the speed at which a virtual team completes the project. The ANOVA test finds significant main effects at $p < 0.05$ for both the knowledge type ($F(1, 116) = 93518.575$, $p < 0.001$, $w^2 = 0.922$) and the coordination mechanism ($F(1, 116) = 7502.847$, $p < 0.001$, $w^2 = 0.074$). There is also an interaction effect between coordination mechanism and knowledge type ($F(1, 116) = 201.483$, $p < 0.001$, $w^2 = 0.002$)—see Table 13. Figure 16 graphically shows the relationship between the dependent variable of speed and the four conditions of the 2-factorial design.

Source	Sum of Squares	df	Mean Square	F	Sig.	Effect Size ω^2
Coordination Mechanism	277.287	1	277.287	7502.847	.000	0.074
Knowledge Type	3456.224	1	3456.224	93518.575	.000	0.922
Coordination Mechanism * Knowledge Type	7.446	1	7.446	201.483	.000	0.002
Error	4.287	116	.037			
Total	109774.886	120				

Table 13. Tests Between-subjects Effects on the Dependent Variable: Speed.

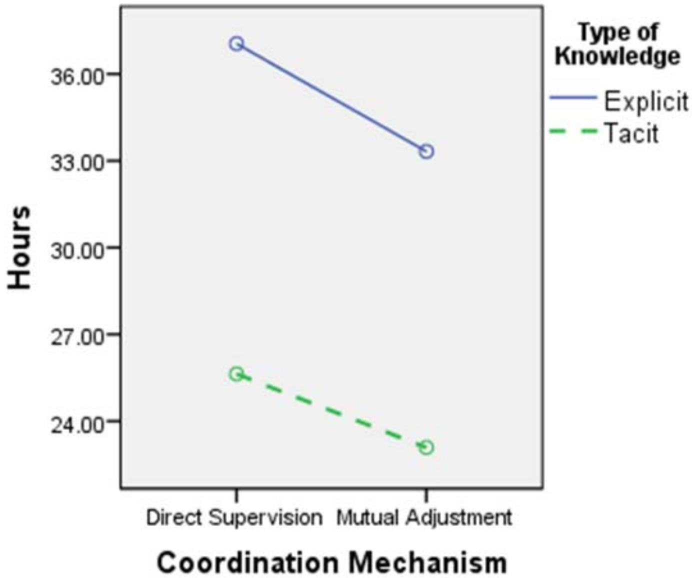

Figure 16. Plot of ANOVA Test for Speed of Project Completion

Based on the results of the Factorial ANOVA test, an independent *t*-test is conducted to evaluate *hypothesis 1a* which predicts that teams made up of individuals with high tacit knowledge working under a mutual adjustment coordination mechanism will perform their tasks in the shortest amount of time ($M_{\text{ma-tk}}$ = 23.09, *SE* = 0.0247 compared to $M_{ds\text{-tk}}$ = 25.63, *SE* = 0.0352)—see Table 14 for details of the *t*-test. The effect size (ω^2 = 0.919) for the ANOVA and the effect size (*r* = 0.99) shows that the knowledge type has a very large affect on the speed at which project completion is achieved (Frey 2006).[8] As is common with very large effect sizes, this result is not surprising: a group made up of highly experienced teams will in general solve difficult problems more rapidly than a group of lesser experienced teams. Based on the *t*-test and large effects size, the mutual adjustment coordination mechanism appears to be the best fit for virtual teams to quickly complete planning problems for crisis events.

Based on the ANOVA F-test, the effect size (ω^2 = 0.074) for the main effect coordination mechanism does not quite meet Frey's (2006) threshold for a medium affect on the speed of project completion. This small effect size leads to the conclusion

[8] Frey (2006) lays out *effect size standards* as: small = 0.01, medium = 0.09 and large = 0.25.

that managers should consider the differences in performance of the mutual adjustment coordination mechanism and the direct supervision coordination mechanism—i.e., that in an interorganizational collaboration among groups of boundary spanners, the mutual adjustment coordination mechanism will likely speed up the completion of initial planning activities.

	N	Mean	Std. Deviation	Std. Error Mean	*t*	*df*	Sig. (2-tailed)	Effect Size *r*
DS-tK	30	25.63	.1928	.0352				
MA-TK	30	23.09	.1352	.0247				
t-test					59.139	58	< .001	.99

Table 14. Results of *t*-test for DS-TK and MA-TK Conditions for Speed of Project Completion

Finally, while the interaction effect does not occur by chance (i.e., the coordination mechanism interacting with knowledge type was statistically significant with $p < 0.001$), the effect size ($w^2 = 0.002$) is so small that managers should be foremost concerned with knowledge type and coordination mechanism independently. There is not much value to considering the interaction effect of those independent variables when it comes to considering the speed at which the project will be completed.

b. Functional Risk

Hypothesis 2 considers the effects on functional risk from the different coordination mechanisms and knowledge types. The ANOVA results find significant main effects at $p < 0.05$ for knowledge type ($F(1, 116) = 231.671$, $p < 0.001$, $w^2 = 0.667$); however, there is a non-significant main effect for the coordination mechanism ($F(1, 116) = 1.305$, $p = 0.256$, $w^2 < 0.001$)—see Table 15. The interaction effect between coordination mechanism and knowledge type is also not significant ($F(1, 116) = 1.149$, $p = 0.286$, $w^2 = 0.001$).

Source	Sum of Squares	df	Mean Square	F	Sig.	Effect Size ω^2
Coordination Mechanism	.001	1	.001	1.305	.256	< 0.001
Knowledge Type	.232	1	.232	231.671	.000	0.667
Coordination Mechanism * Knowledge Type	.001	1	.001	1.149	.286	< 0.001
Error	.116	116	.001			
Total	14.500	120				

Table 15. Tests Between-subjects Effects on the Dependent Variable: Functional Risk

The ANOVA results do not support *hypothesis 2a*. Individuals with high tacit knowledge operating under the mutual adjustment coordination mechanism ($m_{ma\text{-}tk}$ = .2996, s = 0.0313) do not perform statistically different from individuals with high tacit knowledge operating under a direct supervision coordination mechanism ($m_{ds\text{-}tk}$ = .2992, s = 0.0306). There is no statistically significant difference between levels of functional risk where teams of individuals with high explicit knowledge operate under either coordination mechanism ($m_{ds\text{-}ek}$ = .3810, s = 0.0340, compared to $m_{ma\text{-}ek}$ = .3938, s = 0.0306). Figure 17 shows the relationship between the dependent variable of functional risk and the four conditions of the 2-factorial design.

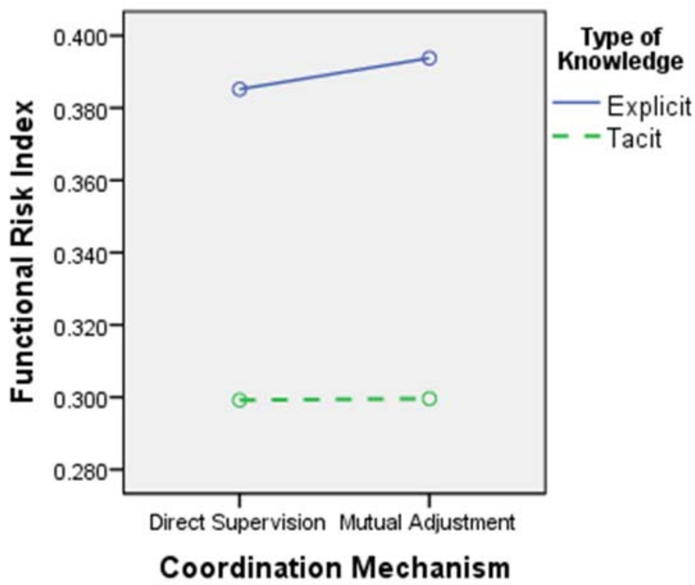

Figure 17. Plot of ANOVA Results for Functional Risk

c. Project Risk

Hypothesis 3 considers the effects on project risk from the different coordination mechanisms and knowledge types. The ANOVA results find significant main effects at $p < 0.05$ for knowledge type ($F(1, 116) = 28.262$, $p < 0.001$, $w^2 < 0.165$). There is a non-significant main effect based on coordination mechanism ($F(1, 116) = 2.733$, $p = 0.101$, $w^2 < 0.012$), and a non-significant interaction effect between coordination mechanism and knowledge type ($F(1, 116) = 1.129$, $p = 0.290$, $w^2 < 0.001$)—see Table 16.

Source	Sum of Squares	df	Mean Square	F	Sig.	Effect Size ω^2
Coordination Mechanism	.005	1	.005	2.733	.101	0.012
Knowledge Type	.049	1	.049	28.262	.000	0.165
Coordination Mechanism * Knowledge Type	.002	1	.002	1.129	.290	< 0.001
Error	.203	116	.002			
Total	24.041	120				

Table 16. Tests Between-subjects Effects on the Dependent Variable: Project Risk

The ANOVA results do not support *hypothesis 3a* as there is no statistically significant project risk performance difference between the tacit knowledge teams operating under the different coordination mechanisms (m_{ds-tk} = .4353, s = 0.0413 and m_{ma-tk} = .4145, s = 0.0526). This also applies to the explicit knowledge teams (m_{ds-ek} = .4677, s=0.0318 compared to m_{ma-ek} = .4632, s = 0.0387). Regarding knowledge type as a contingency factor, the effect size (w^2 = 0.165) for this finding is moderate, and leads to the assessment that there is a moderately strong relationship between the independent variable knowledge type and the dependent variable project risk. Regarding the relationship between coordination mechanism and project risk, the results do not reveal statistical significance at the $p < 0.05$ level; however, the results are close and the effect size is small. Since the number of trials in this ANOVA was determined by a power calculation based on detecting a large effect size, perhaps future research should look at this effect being of a moderate size. That would lead to more trials being conducted for this relationship and perhaps a finding of statistical significance (i.e., conducting this ANOVA with 80 runs may detect a statistically significant difference for coordination mechanism). Figure 18 shows a graphical representation of the relationships.

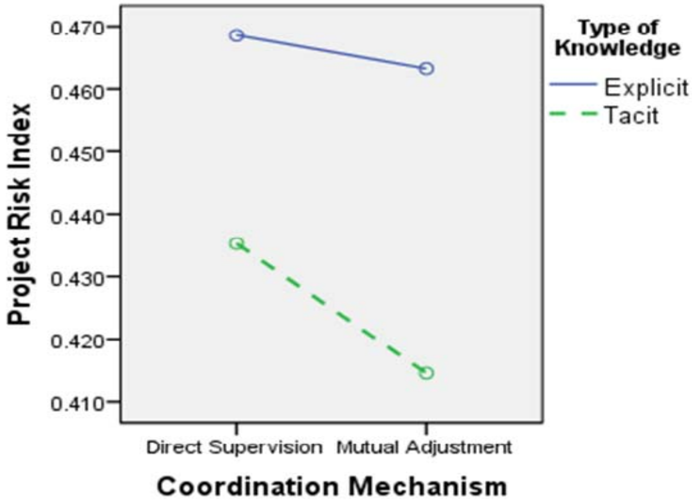

Figure 18. Plot of ANOVA Results for Project Risk

d. Communication Risk

Hypothesis 4 considers the effects on communication risk from the different coordination mechanisms and knowledge types. The results of testing the variable communication risk show interesting results. The factorial ANOVA test finds significant main effects at $p < 0.001$ for both the knowledge type ($F(1, 116) = 167.803$, $p < 0.001$, $w^2 = 0.093$ and the coordination mechanism ($F(1, 116) = 67.218$, $p < 0.001$, $w^2 = 0.071$))—see Table 17. The interaction effect between coordination mechanism and knowledge type is also significant ($F(1, 116) = 1352.039$, $p < 0.001$, $w^2 = 0.786$).

Source	Sum of Squares	df	Mean Square	F	Sig.	Effect Size ω^2
Coordination Mechanism	.007	1	.007	67.218	.000	0.071
Knowledge Type	.016	1	.016	167.803	.000	0.093
Coordination Mechanism * Knowledge Type	.131	1	.131	1352.039	.000	0.786
Error	.011	116	.0001			
Total	29.579	120				

Table 17. Tests Between-Subjects Effects on the Dependent Variable: Communication Risk

The ANOVA results show that teams made up of individuals with high tacit knowledge working under a mutual adjustment coordination mechanism have the lowest amount of communications risk ($m = 0.4430$, $s = 0.0098$). Teams made up of individuals with high tacit knowledge working under a direct supervision coordination method seem to have a significant problem regarding some aspect of communications as they perform significantly worse than individuals with high explicit knowledge operating under the direct supervision coordination mechanism ($m_{ds\text{-}tk} = 0.5239$, $s = 0.0094$, compared to $m_{ds\text{-}ek} = 0.4810$, $s = 0.0092$).

Figure 19 shows the relationship between the dependent variable of communication risk and the four conditions of the 2-factorial design. That representation points towards some fit problem between direct supervision and high tacit knowledge. The large interaction effect size ($w^2 = 0.786$), moderate effect size ($w^2 = 0.093$) for knowledge type, and small effect size ($w^2 = 0.071$) for coordination mechanism point to the importance of these relationships for consideration by managers.

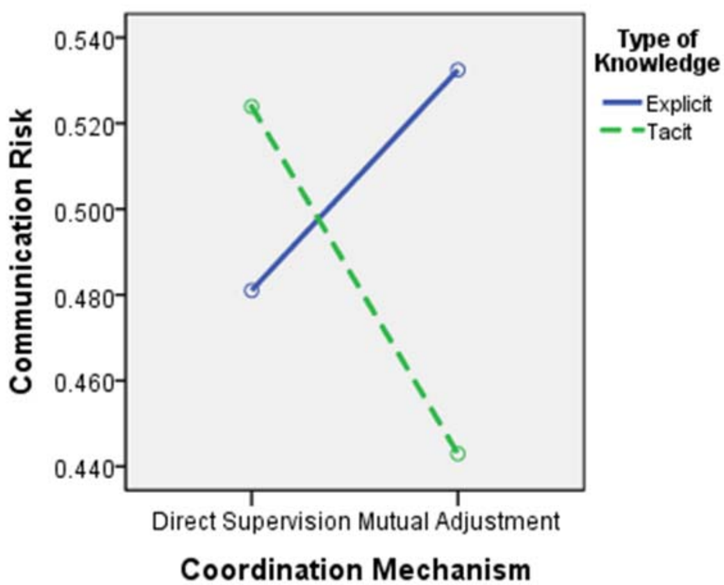

Figure 19. Plot of ANOVA Results for Communication Risk

A *t*-test is used to evaluate *hypothesis* 4a. Based on the ANOVA results, the *t*-test compares the direct supervision-explicit knowledge (DS-EK) condition to the mutual adjustment-tacit knowledge condition (MA-TK). The results show a statistically significant difference at $p < 0.05$ for communication risk between these two conditions ($t(58) = -15.528$, $p < 0.001$, effect size $r = 0.90$). This confirms the relationship stated previously that the mutual adjustment-tacit knowledge condition produces the least communication risk ($M_{ma\text{-}tk} = .4430$, $SE = .0018$ compared to $M_{ds\text{-}ek} = .4810$, $SE = .0017$). Table 18 provides details of the *t*-test results.

	N	Mean	Std. Deviation	Std. Error Mean	*t*	*df*	Sig. (2-tailed)	Effect Size *r*
DS-EK	30	.4810	.0092	.0017				
MA-TK	30	.4430	.0098	.0018				
t-test					15.528	58	< .001	.92

Table 18. Results of One-way ANOVA for the DS-EK and MA-TK Conditions for Communication Risk

D. SUMMARY

This chapter presents the empirical research used to ground a baseline computational organizational model of an interorganizational system working within the context of a developing complex international crisis event. While the organizations represented in the model are mostly non-homogeneous with respect to the larger national-level organizations within which they fit (i.e., a MOC represents a middle-line level entity of a nation's military organizational structure), they are relatively homogeneous with respect to the processes that they perform (e.g., manage the operations of the full panoply of capabilities of maritime assets). The baseline model, built using a well-validated computational organization design modeling tool, represents clear patterns of similar tasks performed by similarly organized planning teams. Simulation runs of the baseline model produce performance results (e.g., *simulation duration* output measures) that correspond well with the observed interorganizational phenomenon; hence, there is confidence in the validity of the model and its use in computational experimentation.

The baseline model represents one of the four required models necessary to conduct the experimental runs in this two factorial ANOVA hypothesis testing research design. Theory driven structural and design parameter changes were made to the baseline model which represents the direct supervision-tacit knowledge (DS-TK) condition. The three other models represent the remaining conditions in the two factorial research design (i.e., direct supervision-explicit knowledge (DS-EK), mutual adjustment-tacit knowledge (MA-TK), and mutual adjustment-explicit knowledge (MA-EK)). Table 19 presents a summary of the results of the hypotheses tested.

Dependent Variable	Low Performance	Midrange Performance	High Performance
Speed	Mutual Adjustment-Explicit Knowledge Direct Supervision-Explicit Knowledge	*** Direct Supervision-Tacit Knowledge	*** Mutual Adjustment-Tacit Knowledge
Functional Risk	Direct Supervision-Explicit Knowledge Mutual Adjustment-Explicit Knowledge		*** Direct Supervision-Tacit Knowledge *** Mutual Adjustment-Tacit Knowledge
Project Risk	Direct Supervision-Explicit Knowledge Mutual Adjustment-Explicit Knowledge		*** Mutual Adjustment-Tacit Knowledge *** Direct Supervision-Tacit Knowledge
Communication Risk	Direct Supervision-Tacit Knowledge Mutual Adjustment-Explicit Knowledge	*** Direct Supervision-Explicit Knowledge	*** Mutual Adjustment-Tacit Knowledge

The *** code represents statistical significance ($p < 0.001$) and compares the asterisked condition to the condition in the column to its left.

Table 19. Summary of Performance Results

The results point to the conclusion that where independent teams of individuals that possess a high level of tacit knowledge (e.g., a combination of in depth knowledge and experience) collaborate over virtual tools (e.g., virtual meeting applications) on a project, then a mutual adjustment coordination mechanism is a good fit for achieving high performance across the dimensions of speed, functional risk (i.e., component quality), project risk (i.e., project integration quality), and communication risk (i.e., the ratio of missed or mishandled communication among actor to number of attempted communication exchanges). Across all variables except communication risk, teams that possess a high level of tacit knowledge outperform teams comprised of individuals that only possess explicit knowledge (e.g., written procedures). For the management personnel and organization decision makers that enter into an interorganizational relationship using virtual collaborations technologies during the early stages of a crisis, assembling the most knowledgeable and experienced personnel available should be encouraged. If that can be achieved, then a mutual adjustment coordination mechanism is likely to be the best fit to achieve high performance.

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V. CONCLUSION

This chapter summarizes the research method and then presents the contributions and limitations of this research. It concludes with suggestions for further research and a summary of the findings.

A. SUMMARY OF RESEARCH METHOD

This dissertation is an example of mixed-method research, where immersive qualitative research informs computational modeling for quantitative hypothesis testing experiments. It explores organization design issues at the interorganization level of analysis using a structural contingency theory lens combined with computational organizational theory and agent-based computational modeling predicated on information processing theory. At issue are the possible contingency effects of *knowledge type* (i.e., tacit and explicit) interacting with *coordination mechanisms* (i.e., direct supervision and mutual adjustment) in the activities of boundary spanning teams from multiple interdependent but structurally independent (i.e., no shared formal lines of authority or contracts) organizations. This phenomenon sometimes occurs during the early stages of a crisis event (e.g., natural disasters) where multiple organizations respond and find that they are reciprocally interdependent. Due to the complex and turbulent situations that abound in disaster events, organizations find themselves sharing knowledge, resources and capabilities to help achieve some relatively common goals.

Structural contingency theory has much to offer managers and organization leaders regarding which coordination mechanisms are fit with environmental conditions and task interdependencies. These insights are generally applicable at the organizational level, but little is known about how they apply at the interorganizational level. This research explores this area by investigating the activities of a certain set of boundary spanners (e.g., planning teams) as they perform their typical intra-organizational work (i.e., developing plans that coordinate operations) and perform new interorganizational coordination tasks (e.g., coordinating planning activities and coordinating operations plans). In this research, the unit of analysis is the team of planners at a maritime headquarters.

Immersive qualitative field research was conducted at six maritime headquarters (i.e., four national fleet headquarters representing three different countries, and two multinational headquarters) located in four different countries. Six teams of participant observers each observed a planning team from the participating headquarters as those planners attempted to perform planning tasks while collaborating with two other planning teams, each from another headquarters. Since none of the maritime headquarters were co-located, these interorganizational collaborations represented a *virtual team* phenomenon (Clancy 1994; Lipnack & Stamps 1997; Wong & Burton 2001). In essence, each maritime headquarters was co-equal in this interorganizational system, and in general, they shared common goals regarding responding to a crisis event. All interactions took place simultaneously during a major maritime multinational field exercise where the crisis was synthetic—i.e., hypothetical events were disclosed to the participants through pre-designed scripts and dynamic scenario injects (e.g., a team of expert exercise controllers fielded information requests and orders emanating from the planning teams and provided feedback as deemed appropriate).

At each maritime headquarters, there was a team of participant observers that collected archival data, documented the planning and collaboration processes performed and conducted open-ended interviews of select participants to ensure that the process and knowledge flows were documented. This qualitative research phase led to the development of a baseline computational organizational model that represented a generalized model of the observed phenomena. Once the baseline model was validated, select design parameters of that baseline model were modified to create new models for use in hypothesis testing computational experiments. Those modifications are grounded in organization design and knowledge flow theories.

The POW-ER agent-based modeling tool is used to create all of the models and run Monte Carlo simulations to generate the data necessary to test the hypotheses articulated in Chapter II. The hypotheses are tested predominately using parametric analysis of variance (ANOVA) statistical techniques. The results of those tests are presented in Chapter IV and a summary is provided in Chapter V.B.2—see Table 20.

B. CONTRIBUTIONS

This dissertation contributes to knowledge in the field of organization research in two main ways. The first broad area of contribution regards facilitating the inquiry of fleeting interorganizational phenomena. Such phenomena often exist during the early phases of disaster response operations. The other broad area of contribution is made in the field of organization design, specifically structural contingency theory where support is found for knowledge type (i.e., *tacit* and *explicit*) being a relevant structural contingency factor. Summary details of these two contributions follow.

1. Exploring Fleeting Interorganizational Phenomena

As interorganizational systems become more prevalent in the world, and knowledge flows are recognized as highly valuable to organizations, it is natural that more research into the intersection of knowledge flows and interorganizational systems will emerge. This research demonstrates one way to explore the organizational design space for interorganizational systems, and compare important interactions of traditionally recognized coordination mechanisms and important knowledge dynamics.

Computational organization theory has set the stage for the development of powerful tools to support organization design research. This research has operationalized a mixed method research approach to explore a relevant, fleeting interorganizational phenomenon—i.e., coordination among an interorganizational system in a disaster environment. Grounded in an objective, positivistic perspective, the qualitative phase captures work processes, structural coordination mechanisms, and knowledge flows of a virtual team in order to inform the creation of a baseline agent-based computational organization model. Once this baseline model has been validated (e.g., checked for internal and face validity), computational experiments can be conducted by modifying select elements (e.g., design parameters and organization structures) of this baseline model to create distinct executable agent-based models of other observed or envisioned organizations. Using Monte Carlo simulation techniques, these agent-based organization models can produce comparable performance results. Hence, this research enables the exploration of complex and fleeting interorganization phenomena.

2. Extending Structural Contingency Theory

Structural contingency theory is generally used to explain organization performance based upon recognized structural organization design variables interacting with relevant contingency factors. This research extends the traditional focus of structural contingency theory—i.e., the exploration of organizational phenomena, to the important and relevant activity of exploring design issues that potentially affect performance of interorganizational systems.

In this research, the fit of traditional structural design coordination mechanisms (i.e., direct supervision and mutual adjustment) interacting with different knowledge types (i.e., tacit and explicit) is explored at the interorganizational level of analysis. While there are many other relevant units of analysis to use to explore this interorganizational phenomena, this research focuses on a specific boundary spanning team (Mintzberg 1979; Callahan & Salipante 1979) of multiple interacting organizations. That boundary spanning team in this research is the planning team. The statistical analysis, summarized in Table 20 clearly shows some relevant performance effects of those interactions. This new knowledge is important to managers when interorganizational systems, specifically virtual teams, are in the early stages of formation.

Coordination Mechanism / Knowledge Type	Direct Supervision	Mutual Adjustment
Tacit	*Functional Risk*[%] *Project Risk*[%]	*Speed*[*] *Functional Risk*[%] *Project Risk*[%] *Comm. Risk*[*]
Explicit	*Speed*[#]	*Comm. Risk*[#]

Based on statistical significance where $p < 0.001$, the following legend applies:
[*]Best performance. [%]Tied for best performance. [#]Worst performance.

Table 20. Performance Summary of 2-Factorial Experiment

This research looks into a relevant condition where virtual teams of military personnel from different organizations collaborate to achieve coordination without having to experience the significant organizational changes that come with detaching from their organization and physically moving to work at a newly formed multinational headquarters. In general, that multinational headquarters formation process takes travel time, time to learn new applications and procedures, and removes people from direct and familiar means to interface with their parent organization's knowledge network. Time is generally not a luxury available in crisis response operations. Networking technologies and information processing applications point to potential interorganizational system performance implications of virtual teams (Wong & Burton 2001).

This research finds that there are different effects on interorganizational performance metrics (i.e., speed of project completion, functional risk associated with process step completion, overall project risk, and communications risk) based on the interaction of different coordination mechanisms (i.e., direct supervision and mutual adjustment) and different knowledge types (i.e., tacit and explicit). Hence, managers and organization leaders faced with reciprocal interdependencies with other organizations should apprise themselves of the knowledge types available to perform interorganizational collaboration work, especially if that work may be performed in the context of *virtual teams*: knowledge type has a contingent effect on interorganizational performance based on the fit of different coordination mechanisms.

This research shows that a mutual adjustment coordination mechanism is most fit (i.e., mutual adjustment outperforms direct supervision in all cases except function risk where there is no statistically significant difference between the two) when teams are made up of people with a high level of tacit knowledge applicable to the task at hand. Hence, the efficacy of mutual adjustment coordination mechanisms in interorganizational virtual team collaborations among experts is fairly conclusive.

Of note, the result of testing communications risk shows an interesting interaction effect—see Figure 20. During a crisis or disaster response situation, managers may not have a high degree of control over the availability of expertise (e.g., generalist or specialist) and experience from within their organization. As task uncertainty increases, agility is postulated as an important organizational characteristic (Postrel 2002; Mowshowitz 2002; Alberts & Hayes 2003). Agility connotes movement: the ability to modify or change. Developing virtual teams may be a viable option for enhancing the ability to attain goals, especially in crisis or disaster response situations where organizational goals are often generally similar. This research shows that the knowledge type available has an effect on different performance measures. Hence, manager and leaders should consider not only the efficacy of virtual teams, but also which coordination mechanism is fit with the type of knowledge (e.g., tacit or explicit) prevalent in the boundary spanning teams that have an early role in interorganizational coordination.

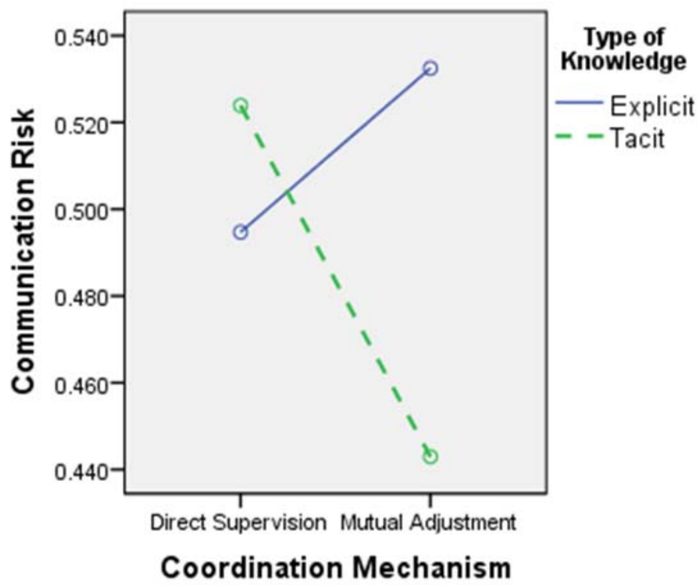

Figure 20. Plot of ANOVA Results for Communication Risk

This research provides insight into the ongoing debate regarding the three competing theoretic perspectives about effective ways to achieve coordinated actions among an interorganizational system responding to a disaster. The debate involves 1) the emergent coordinating group (e.g., see Dynes & Quarantelli 1968; Dynes 1978; Kreps 1978; Perrow 1984; Drabek 1986; Harrald et al. 1994), 2) the centralized system (e.g., see Meyer & Rowan 1977; Pfeffer & Salancik 1978; Staw et al. 1981; DiMaggio & Powell 1983), and 3) the distributed system (e.g., Dynes & Quarantelli 1968; Lawrence & Lorsch 1969; Galbraith 1973; Malone 1987; Comfort 1994; Harrald et al. 1994).

The emergent coordinating group perspective predicts that groups of organizations will "spontaneously coalesce during a crisis to help manage the interdependencies of individual responding organizations and to reduce conflict." (Topper & Carley 1999 p. 69) The participants in this coordination group may have little experience or authority to perform the required tasks. In large-scale disasters that require extensive resources, the mutual adjustment coordination mechanism appears to be only "accidentally effective." (Wright 1976 p. 82) The general trend to the development over time of the emergent coordinating group is to start with mostly disconnected organizations and a few pre-planned coordination structures operating. This is followed by a phase of self-organizing behavior where new coordination structures between pairs of organizations emerge. Furthermore, for coordination by mutual adjustment to emerge, it seems to require a lack of available coordination expertise (Wright 1976).

The centralized system looks to a single organization to assume the dominate coordination role for the rest of the organizations in its affected area. This centralized coordination method—similar to direct supervision, seeks to capitalize on perceived vertical information processing efficiencies and reduction of uncertainty within the interorganizational system. Wright (1976) drew on multiple disaster event case studies and identified an apparent contingency theoretic perspective that interorganization coordination through centralized control was more likely to be effective in smaller disasters where fewer resources were needed, and actors with appropriate coordination expertise were available. This centralized system is very similar to "military style" coordination network typically referred to as a command and control organization. This pre-planning and centralized control, however, has been maligned in other prominent disaster research studies (see Harrald et al. 1994, Dynes 1998, and Suparamaniam & Dekker 2003).

The distributed system draws on contingency and information processing theories. These theories explain that distributed team-like structures respond quickly and accurately to the turbulent environment found when responding to a disaster (Carley & Lin 1997; Topper & Carley 1999). Others have corroborated these finding, pointing to organizational agility and lateral ties between subsystems being fit with turbulent environments (see Krackhardt & Stern 1988; Carley 1992; Harrald et al. 1994; Dekker 2005). A key aspect of this interorganizational structural fit is early identification and agreement on common goals, and a reliance on coordination through feedback rather than coordination via rigid pre-planned responses (Topper & Carley 1999). By feedback mechanisms and informal communications, the structure that produces interorganizational coordination is allowed to emerge and become distributed. As the disaster response moves along in time, this interorganizational system is agile enough to allow the organizations to effectively begin cooperating with local community entities, which is a key performance enhancement finding of Harrald et al. (1994).

The preceding sections highlight the debate regarding the effectiveness of different coordination mechanisms in achieving high performance in crisis response operations where interorganizational systems frequently operate in the face of high uncertainty. It has been shown that knowledge types (e.g., trans-specialist and specialist) within an organization produce varying performance results (Nissen et al. 2008). Again, in this dissertation, types of knowledge (i.e., tactic and explicit) interacting with different coordination mechanisms (i.e., direct supervision and mutual adjustment) are explored to assess their affects on the performance of interorganizational systems that respond to disaster event.

The findings of this research support the idea that where experienced and knowledgeable teams are present, a distributed system of self-organizing (i.e., mutual adjustment coordination mechanism) boundary spanners will be highly effective. Where experience and skills are not prevalent in the boundary spanning team, the communications risk is highest in the self-organizing interorganizational system, thus its feedback mechanisms and informal communications may cause performance problems in crisis response events. The effects that different knowledge types have on communication risk for a centralized coordination system (i.e., direct supervision), shows a different relationship than for that of the distributed system (i.e., mutual adjustment): boundary spanning teams that are highly experienced and knowledgeable incur a greater communications risk than teams armed with only explicit knowledge. Those results may provide insight as to why *hypothesis 3a* (i.e., high tacit knowledge combined with direct supervision coordination mechanism will performance best with respect to minimizing project risk) was not supported. It is reasonable to conclude, that when operating in a virtual team condition, missed formal and informal communications opportunities under the direct supervision coordination mechanism adversely impact the ability to achieve integration quality among the participating organizations.

C. LIMITATIONS AND FUTURE RESEARCH

The theoretical underpinning of this research stems from structural contingency theory, knowledge flow theory, and information processing theory. None of these theories specifically address output measures to assess the level of coordination achieved in planning projects. Without an accepted scale for measuring level of coordination within and among plans, the level of internal validity of this dissertation's baseline model regarding project risk is slightly degraded. Research should be conducted to develop a reliable scale that assesses the degree of coordination achieved in plans and during planning tasks. That research should also cover the differing types of operation plans that organizations develop (e.g., plans for combat operations and disaster relief operations).

One important social science variable that is available to be directly modeled in the POW-ER computational modeling tool used in this research is *trust* between agents. This could have a profound effect on information and knowledge flows in an interorganizational system, especially one that is reliant on network communications technology. Perhaps there are organizational performance relationships between the types of media (e.g., see media richness theory—Daft & Lengel 1986) and trust. Research into these areas to update computational organization modeling tools would be most productive.

The computational modeling environment used in this research models meetings based solely on face-to-face information exchanges. With the advent of other synchronous collaborative meeting applications, future research should explore information processing and knowledge flow modeling associated with the many different ways to conduct meetings (e.g., video teleconference, online meeting applications, and telephone conference calls) and the effects of different numbers of participants (e.g., what is the difference in component quality or product quality of a physical coordination meeting of 50 people and an online meeting 50 people?). This could lead to enhanced ways to explore and make recommendations regarding the organization design space based on information technology available or proposed. Research into developing computational modeling elements to account for how knowledge flows occur would be a significant enhancement to the current POW-ER modeling capability.

This research looks at the phenomenon of interorganizational collaboration based on the unique case of relatively homogeneous processes and structures among the organizations. To be sure, there are many more complex relationships that need to be explored, such as the interorganizational collaborations between different military service headquarters (e.g., Army and Air Force). Even more complexity is involved when considering how military headquarters collaborate and coordinate with other governmental agencies (e.g., USAID) and also non-governmental organizations (e.g., International Red Cross). This research is a stepping stone: it demonstrates the beginning of a viable path for exploring more complex interorganizational relationships, especially those fleeting ones that emerge during times of crisis where no one organization has enough resources, especially knowledge, to achieve common goals.

This example of mixed method research could lead to a campaign of experimentation where laboratory experiments could be conducted to further confirm or refute the findings of this research. From that, more robust field events could be conducted to inform decision makers regarding organization design issues, especially those related to organizational agility in response to dynamic and complex environments.

D. SUMMARY

This research sheds light on a relevant and practical gap in the organization design literature, specifically at the interorganizational level of analysis. There is a related ongoing debate in the disaster research literature regarding how crisis response operations should be managed to effectively achieve coordination among multiple responding organizations. Drawing on structural contingency theory, knowledge flow theory, and computational organization design theory, this research developed and tested multiple hypotheses that are useful for managers, organization design researchers, and disaster responders. Table 21 provides a concise overview of the hypotheses tested and the results.

Hypothesis	Significance	Effect Size	Test	Assessment
In virtual teams, different knowledge types interacting with different coordination mechanisms will affect the *speed* of project completion	$p_k < .001$ $p_{cn} < .001$ $p_{cm\text{-}k} < .001$	Large Small Very Small	F-test	Supported.
Virtual teams with high TK operating under a MA coordination mechanism will complete the project fastest	$p < .001$	Large	t-test	Supported
In virtual teams, different knowledge types interacting with different coordination mechanisms will affect the *functional risk* (i.e., component quality) of the project.	$p_k < .001$ $p_{cm} > .05$ $p_{cm\text{-}k} > .05$	Large Very Small Very Small	F-test	Supported.
Virtual teams with high TK operating under a MA coordination mechanism will produce the lowest functional risk (i.e., highest component quality)	$p > .05$	-	F-test	Not supported.
In virtual teams, different knowledge types interacting with different coordination mechanisms will affect the *project risk* (i.e., project integration quality)	$p_k < .001$ $p_{cm} > .05$ $p_{cm\text{-}k} > .05$	Medium Small Very Small	F-test	Supported.
Virtual teams with high TK operating under a DS coordination mechanism will produce the lowest project risk (i.e., highest product integration quality)	$p > .05$	-	F-test	Not supported.
In virtual teams, different knowledge types interacting with different coordination mechanisms will affect the project's *communication risk*	$p_k < .001$ $p_{cn} < .001$ $p_{cm\text{-}k} < .001$	Medium Small Large	F-test	Supported.
Virtual teams with high TK operating under a MA coordination mechanism will have the least communication risk.	$p < .001$	Large	t-test	Supported

Subscripts: k = main effect for knowledge type, cm = main effect for coordination mechanism, and cm-k = interaction effect for coordination mechanism and knowledge type.

Table 21. Summary of Hypotheses Tested

As the finding show, there is evidence that performance of virtual teams is affected by different knowledge types interacting with different coordination mechanisms. While knowledge clearly has a large or medium effect size on various performance parameters, it is interesting to discover that for virtual teams, the coordination mechanism factor did not have a medium or large effect on any performance parameter. There were, however, small effects based on coordination mechanism, and one large effect based the interaction of the coordination mechanism and knowledge type factors. This adds to Wong and Burton's assertion that "...when organizations are considering the formation of virtual teams, they should...be aware of the coordination complications that typically result in virtual teams." (Wong & Burton 2000 p. 357) This research points towards the importance of investing highly skilled and experienced people in the virtual teams that initiate boundary-spanning activities. The debate regarding which interorganization coordination system to use during a crisis event did not consider the idea of virtual teams. This research points to the efficacy of virtual teams and the distributed system concept, especially where high tacit knowledge can be invested in the boundary spanning activities of the virtual teams.

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LIST OF REFERENCES

Alavi, M., & Leidner, D. E. 2001. Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues. ***MIS Quarterly***, 25(1): 107–136.

Alberts, D. S., & Hayes, R. E. 2003. ***Power to the edge: Command…control… in the information age***. Washington, DC: DOD Command and Control Research Program Publications.

Aken, M., & Hage, J. 1968. Organizational interdependence and intraorganizational structure. ***American Sociological Review***, 33(6): 912–930.

Andrews, F. E. 1952. ***Corporation giving***. New York, NY: Russell Sage Foundation.

Ashby, W. R. 1958. Requisite variety and its implications for the control of complex systems. ***Cybernetica***, 1(2): 83–99.

Auf der Heide, E. 2006. The importance of evidence-based disaster planning. ***Annals of Emergency Medicine***, 47(1): 34–49.

Axtel, R. A., Epstein, J. M., & Cohon, M. D. 1996. Aligning simulation models: A case study and results. ***Computational and Mathematical Organization Theory***, 1: 123–141.

Baker, W. E., & Faulkner, R.R. 2002. Interorganizational networks. In Baum, Joel A. C. (Ed.), ***The Blackwell companion to organizations***: 520–540. Malden, MA: Blackwell Business.

Banner, D., & Gagne, T. 1995. ***Designing effective organizations: Traditional & transformational views***. Thousand Oaks, California: SAGE Publications.

Bass, B., & Leavitt, H. 1963. Some Experiments in planning and operating. ***Management Science***, 9(4): 574–585.

Baum, J., & Rowley, T. 2002. Companion to organizations: an introduction. In Baum, J. A. C. (Ed.), ***The Blackwell companion to organizations***: 1–34. Malden, MA: Blackwell Business.

Becerra-Fernandez, I., Madey, G., Prietula, M., Rodriguez, D., Valerdi, R., & Wright, T. 2008. ***Design and development of a virtual emergency operations center for disaster management research, training, and discovery***. Proceedings of the 41st Hawaii International Conference on Systems Sciences, Waikoloa, HI.

Becerra-Fernandez, I., & Sabherwal, R. 2001. Organizational knowledge management: A contingency perspective. ***Journal of Management Information Systems***, 18(1): 23–55.

Benbasat, I., Goldstein, D. K., & Mead, M. 1987. The case study research in studies of information systems. ***MIS Quarterly***, 11(3): 369–386.

Bertalanffy, L. 1969. ***General system theory: Foundations, development, applications***. New York, NY: Braziller Publishing

Bigley, G. A., & Roberts, K. H. 2001. The incident command system: High-reliability organizing for complex and volatile task environments. ***The Academy of Management Journal***, 44: 1281–1299.

Birkinshaw, J., Nobel, R., & Ridderstrale, J. 2002. Knowledge as a contingency variable: Do the characteristics of knowledge predict organizational structure? ***Organizational Science***, 13(3): 274–289.

Blau, J., & Rabrenovic, G. 1991. Interorganizational relations of nonprofit organizations: An exploratory study. ***Sociological Forum***, 6(2): 327–347.

Blau, P. 1970. A formal theory of differentiation in organizations. ***American Sociological Review***, 35(2): 201–218.

Blau, P. 1972. Interdependence and hierarchy in organizations. ***Social Science Research***, 1(1): 1–24.

Blau, P., & Schoenherr, P. 1971. ***The structure of organizations***. New York: Basic Books.

Blau, P., & Scott, W. R. 1962. ***Formal organizations: A comparative approach.*** San Francisco, CA: Chandler Publishing.

Borchert, R. A., & Jones, C.R. 1999. ***Organizational fitness of a proposed network centric organization***. Paper presented at the 4th Command and Control Research and Technology Symposium, Newport, RI.

Boulding, K. 1956. General systems theory: The skeleton of science. ***Management Science***, 2(3): 197–208.

Brown, S. L., & Eisenhardt, K. M. 1998. ***Competing on the edge: Strategy as structured chaos***. Boston, MA: Harvard Business School Press

Burns, T., & Stalker, G.M. 1961. ***The management of innovation***, London: Havistock.

Burton, R. M. 2003. Computational laboratories for organization science: Questions, validity and docking. ***Computational and Mathematical Organization Theory***, 9(2): 91–108

Burton, R. M., Lauridsen, J., & Obel, B. 2002. Return on assets loss from situational and contingency misfits. ***Management Science***, 48(11): 1461–1485.

Burton, R. M., & Obel, B. 1995. The validity of computational models in organization science: From model realism to purpose of the model. ***Computational and Mathematical Organization Theory***, 1(1): 57–71.

Burton, R. M., & Obel, B. 2004. ***Strategic organizational diagnosis and design: The dynamics of fit*** (3d ed.). New York: Kluwer Academic Publishers.

Callahan, R., & Salipante, P. 1979. Boundary spanning units: Organizational implications for the management of innovation. ***Human Resource Management***, 18(1): 26–31.

Carley, K. M. 2002. Intraorganizational complexity and computation. In Baum, J.A.C. (Ed.), ***The Blackwell Companion to Organizations***: 208–232. Malden, MA: Blackwell Business.

Carley, K. M., & Lin, Z. 1997. A theoretical study of organizational performance under information distortion. ***Management Science***. 43(7): 976–997.

Chandler, A.D. 1962. ***Strategy and structure: Chapters in the history of the American industrial enterprise***. Cambridge, MA: MIT Press.

Child, J. 1973. Predicting and understanding organizational structure. ***Administrative Science Quarterly***, 18(2): 168–185.

Chisholm, R. F. 1998. ***Developing network organizations: Learning from practice and theory***. Reading, MA: Addison Wesley Longman, Inc.

Christiansen, T. 1993. ***Modeling efficiency and effectiveness of coordination in engineering design teams***. Doctorial dissertation, Stanford University, Palo Alto, CA.

Chua, A. Y. K. 2007. A tale of two hurricanes: Comparing Katrina and Rita through a knowledge management perspective. ***Journal of the American Society for Information Science and Technology***, 58(10): 1518–1528.

Chua, A. Y. K., Kaynak, S., & Foo, S. S. B. 2007. An analysis of the delayed response to hurricane Katrina through the lens of knowledge management. ***Journal of the American Society for Information Science and Technology***, 58(3): 391–403.

Clark, B. 1965. Interorganizational patterns in education. ***Administrative Sciences Quarterly***, 10(2): 224–237.

Cohen, A. 1962. Changing small group communications methods. ***Administrative Science Quarterly***, 6(4): 443–462.

Cohen, G. 1992. ***The virtual design team: an object oriented model of information sharing in project teams***. Doctorial Dissertation, Stanford University, Palo Alto, CA.

Cohen, W. M., & Levinthal, D.A. 1990. Absorptive capacity: A new perspective on learning and innovation. ***Administrative Sciences Quarterly***, 35: 128–152.

Comfort, L. 1985. Integrating organizational action in emergency management: Strategies for change. ***Public Administration Review***, 45, Special issue: Emergency management: A challenge for public administration, 155–164.

Conklin, J., & Weil, W. 1999. Wicked Problems: Naming the Pain in Organizations. from the lean construction web site: http://www.leanconstruction.org/pdf/wicked.pdf last accessed 15 May 2008.

Cook, J.D., Hepworth, S. J., Wall, T. D. & Warr, P. B. 1981. ***The experience of work: A compendium and review of 249 measures and their use***. New York, NY: Academic Press, Inc.

Corbin, J., & Strauss, A. 1990. Grounded theory research: Procedures, canons, and evaluative criteria. ***Qualitative Sociology***, 13(1): 3–21.

Croadsdell, D. T., Jennex, M., Yu, Z., Christianson, T., Chakradeo, M., & Makdum, W. 2003, ***A meta-analysis of methodologies for research in knowledge management, organizational learning, and organizational memory: five years at HICCS.*** Paper presented at the 40th Hawaii International Conference on Systems Sciences, Waikoloa, HI.

Cyert R., & March, J. 1992. Organizational design. In Cooper, Leavitt & Shelly (Ed.), ***New perspectives in organization research***. New York, NY: John Wiley & Sons.

Daft, R. L. 2001. ***Organization theory and design*** (6th ed.). Cincinnati, OH: South-Western College Publishing.

Daft, R., & Bradshaw, B. 1980. The process of horizontal differentiation: Two models. ***Administrative Science Quarterly***, 25(3): 441–456.

Daft, R. L., & Lengel, R. H. 1986. Organizational information requirements, media richness and structural design. ***Management Science***, 32(5): 554–571.

Davidow, W., & Malone, M. 1993. ***The virtual corporation***. New York, NY: Harper-Collins.

Day, R. E. 2005. Clearing up “implicit knowledge”: Implications for knowledge management, information science, psychology, and social epistemology. ***Journal of the American Society for Information Science and Technology***, 56(6): 630–635.

DeSanctis, G., & Monge, P. 1999. Introduction to the special issue: Communication Processes for virtual organizations. ***Organization Science***. 10(6): 693.

Dess, G. G., & Beard, D. W. 1984. Dimensions of organizational task environments. ***Administrative Sciences Quarterly***, 29(1): 52–73.

Donaldson, L. 1996. The normal science of structural contingency theory. In Clegg, S.R., Hardy, C., Lawrence, T. B., & Nord, W. R. ***The sage handbook of organization studies*** (2d ed.): 57–76. London: Sage Publications.

Donaldson, L. 2001. ***The contingency theory of organizations***. London: Sage Publications.

Dourandish, R. Zumel, N., & Manno, M. 2007. **Command and control during the first 72 hours of a joint military-civilian disaster response**. Paper presented at the 12th Command and Control Research and Technology Symposium, Newport, RI.

Drucker, P. 1995. ***Managing in a time of great change***. New York: Truman Talley.

Duncan, R. 1979. What is the right organizational structure. ***Organizational Dynamics***, Winter: 59–79.

Dynes, R.R., & Aguirre, B. E. 1976. ***Organizational adaption to crises: Mechanisms of coordination and structural change***. Preliminary paper for the University of Delaware Disaster Research Center. Newark, DE.

Dynes, R.R., & *Quarantelli*, E. L. 1976. ***Organizational communications and decision making during crises***. Miscellaneous Report,18. Disaster Research Center.

Emery, F., & Trist, E. 1965. The causal texture of organizational environments. ***Human Relations***, 18: 21–31.

Etzioni, A. 1964. ***Modern organizations***. Eaglewood Cliffs, New York: Prentice Hall.

Etzioni, A. 1964. Organizational control structure. In March, J.G. (Ed.) ***Handbook of organizations***. USA: Rand McNally & Company.

Evan, W. M. 1966. The organization-set: Toward a theory of interorganizational relations. In Thompson, J.D. (Ed.), ***Approaches to organization design.*** Pittsburg, PA: University of Pittsburg Press.

Fayol, H. 1994. From declarative and procedural knowledge to the management of declarative and procedural knowledge. ***European journal of psychology of education***. 9(3): 179–190.

Feld, M. 1959. Information and authority: The structure of military organization. ***American Sociological Review***, 24(1): 15–22.

Field, A. 2005. ***Discovering statistics using SPSS***. Thousand Oaks, CA: Sage Publishing, Inc.

Frey, B. 2006. ***Statistics hacks***. Sebastopol, CA: O'Reilly Media, Inc.

Fry, L., & Slocum, J. Jr. 1984. Technology, structure, and workgroup effectiveness: A test of a contingency model. ***Academy of Management Journal***, 27(2): 221–246.

Galbraith, J. R., 1973. ***Designing complex organizations***. Boston, MA: Addison-Wesley Longman Publishing Co., Inc.

Galbraith, J. R. 1977. ***Organization design***. Reading, PA: Addison-Wesley Publishing.

Galbraith, J. R., & Nathanson, D. A. 1978. ***Strategy implementation: The role of structure and process***. St. Paul, MN: West Publishing Co.

Galbraith, J. R., Downey, D., & Kates, A. 2002. How networks undergird the lateral capability of an organization—where the work gets done. ***Journal of Organizational Excellence***, 21(2): 67–78

Gateau, J. G., Leweling, T. A., Looney, J. P., & Nissen, M. E. 2007. ***Hypothesis testing of edge organizations: modeling the C2 organization design space.*** Paper presented at the 2007 International Command & Control Research and Technology Symposium, Newport, RI.

Glaser, B., & Strauss, A. 1967. ***The discovery of grounded theory***. Chicago, IL: Aldine.

Gonzalez, R.A. 2008. ***Coordination and its ITC support in crisis response: Confronting the information-processing view of coordination with a case study***. Paper presented at the 41st Hawaii International Conference of Systems Sciences, Waikoloa, HI.

Granovetter, M. 1973. The strength of weak ties. ***American Journal of Sociology.*** 78(6): 1360–1380.

Grant, R. 1996. Towards a knowledge-based theory of the firm. ***Organization Science***, Special Issue: 109–122.

Gulati, R., Lawrence, P. R., & Puranam, P. 2005. Adaption in vertical relationships: Beyond incentive conflict. ***Strategic Management Journal***, 26: 415–440.

Hage, J. 1965. The axiomatic theory of organizations. ***Administrative Science Quarterly***, 10(3): 289–320.

Hazlett, S., McAdam, R., & Gallagher, S. 2005. Theory building in knowledge management: in search of paradigms. ***Journal of Management Inquiry***, 14: 31–42.

Ibrahim, R., & Nissen, M.E. 2003. ***Emerging technology to model dynamic knowledge creation and flow among construction industry stakeholders during the critical feasibility-entitlements phase***. Paper presented at the Joint Symposium on Information Technology, Nashville, TN.

Ibrahim, R., & Nissen, M. E. 2005. ***Developing a dynamic knowledge-based organizational performance model for discontinuous participatory enterprises***. Paper presented at the 38th Annual Hawaii International Conference on System Sciences, Waikoloa, HI.

Inkpen, A. C., & Li, K. Q. 1999. Joint venture formation: Planning and knowledge-gathering for success**.** ***Organizational Dynamics***. 24(7): 33–47.

Ishida, K., & Ohta, T. 2001. On a mathematical comparison between hierarchy and network with a classification of coordination structures. ***Computational and Mathematical Organization Theory***, 7(4): 311–330.

Jackson, S. 1992. Team composition in organizational settings: Issues in managing an increasingly diverse workforce. In Worchel, S., Wood, W., & Simpson, J. (Eds.) ***Group Process and Productivity***. Newbury Park, CA: Sage Publications.

Janowitz, M. 1959. ***Military Conflict: Essays in the Institutional Analysis of War and Peace***. Beverly Hill, CA: Sage Publications.

Jick, T. D. 1979. Mixing qualitative and quantitative methods: Triangulation in action. ***Administrative Sciences Quarterly***, 24(4): 602–611.

Jin, Y. & Levitt, R. E. 1996. The virtual design team: A computational model of project organizations. ***Computational and Mathematical Organizational Theory***, 2(3): 171–196.

Katz, D., & Kahn, R. 1966. ***The social psychology of organizations***. New York: Wiley.

Kenis, P., & Knoke, D. 2002. How organizational field networks shape interorganizational tie-formation rates. ***Academy of Management Review***, 27(2): 275–293.

Kerlinger, F. N., & Lee, H. B. 2000. ***Foundations of behavioral research*** (4th ed). New York: Wadsworth Publishing.

Klonglan, G., Warren, R., Winkelpleck, J., & Paulson, S. Interorganizational measurement in the social services sector: Differences by hierarchical level. ***Administrative Science Quarterly***, 21(4): 675–687.

Kraus, W.A. 1984. ***Collaboration in organizations: Alternatives to hierarchy***. New York, NY: Human Sciences Press.

Kumar, K., Kuldeep, K. & van Dissel, H. G. 1996. Sustainable collaboration: managing conflict and cooperation in interorganizational systems. ***MIS Quarterly***, 20(3): 279–300.

Lawrence, P. R., & Lorsch, J. W. 1969. ***Organization and environment***. Chicago, IL: Richard D. Erwin, Inc.

Leavitt, H. 1965. Applied organizational change in industry: Structural, technological, and humanistic approaches. In ***Handbook of Organizations***. Chicago, IL: Rand McNally.

Leavitt, H., Pinfield, L., & Webb, E. 1974. ***Organizations of the future: interaction with the external environment***. New York, NY: Praeger Publishers.

Levine, S., & White, P. S. 1961. Exchange as a conceptual framework for the study of interorganizational relations. ***Administrative Science Quarterly***, 5(4): 583–601.

Levitt, R. 2004. Computational modeling of organizations comes of age. ***Journal of Computational and Mathematical Organization Theory***, 10(2): 127–145.

Levitt, R. E., Cohen, G., Kunz, J. C., Nass, C., Christiansen, T. R., & Jin, Y. 1994. The 'virtual design team': simulating how organization structure and information processing tools affect team performance. In Carley, K., & Prietula, M. (Eds.) ***Computational Organization Theory***, Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Levitt, R. E., Orr, R.J., & Nissen, M.E. 2005. Validating the virtual design team (VDT) computational modeling environment. The Collaboratory for Research on Global Projects, Working Paper #25, 1–15. Available at: http://cprg.stanford.edu/publications/working _papers/WP25.pdf last accessed 12 Oct 2006.

Levitt, R. E., Thomsen, J., Christiansen, T. R., Kunz, J.C., Jin, Y., & Nass, C. 1999. Simulating project work processes and organizations: Toward a micro-contingency theory of organizational design. ***Management Science***, 45(11): 1479–1495.

Liang, D. 1994. The effects of top management team formation on firm performance and organizational effectiveness. Unpublished Doctoral Dissertation, Carnegie Mellon University, Pittsburg, PA.

Lipnack, J., & Stamps, J. 1997. ***Virtual teams: Researching across space, time and organizations and technology***. New York, NY: John Wiley & Sons.

Litwak, E., & Hylton, L. F. 1962. Interorganizational analysis: A hypothesis on co-ordinating agencies. ***Administrative Sciences Quarterly***, 6(4): 395–420.

Looney, J. P., & Nissen, M.E. 2006. ***Computational modeling and analysis of networked organizational planning in a coalition maritime strike environment***. Paper presented at the 2006 Command & Control Research and Technology Symposium, San Diego, CA.

Malone, T., & Crowston, K. 1990. ***What is coordination theory and how can it help design cooperative work systems***. Proceedings of the Conference on Computer Supported Cooperative Work, Los Angeles, CA.

March, J. G. 1991. Exploration and exploitation in organizational learning. ***Organization Science***, 2(1, Special Issue: Organizational Learning: Papers in Honor of (and by) James G. March): 71–87.

March, J. G., & Simon, H. A. 1958. ***Organizations***. New York, NY: Wiley.

McGarth, J. 1984. ***Groups: Interaction and performance***. Englewood Cliffs, NY: Prentice-Hall.

Merei, F. 1949. Group leadership and institutionalization. ***Human Relations***, 2(1):23–39.

Miles, R. E., & Snow, C.C. 1995. The new network firm: A spherical structure built on a human investment philosophy. ***Organizational Dynamics***, 23(4): 5–18.

Minear, L., Clark, J., Cohen, R., Gallagher, D., & Weiss, T. G. 1994. Humanitarian action in the former Yugoslavia: The U.N.'s role 1991-1993. ***Occasional Papers***, 18.

Mingers, J. 2001. Combining IS research methods: Towards a pluralist methodology. ***Information Systems Research***, 12(3): 240–259.

Mintzberg, H. 1979. ***The structuring of organizations: A synthesis of the research***. Englewood Cliffs, NJ: Prentice-Hall.

Mintzberg, H. 1983. ***Power in and around organizations***. Englewood Cliffs, NJ: Prentice-Hall.

Meyer, J. W. & Scott, W. R.1992. ***Organizational environments: Ritual and rationality***, Beverly Hills, CA: Sage Publications.

Molnar, J. J., & Rogers, D. L. 1979. A comparative model of interorganizational conflict. ***Administrative Sciences Quarterly***, 24: 405–425.

Mowery, D.C., Oxley J. E., & Silverman, B.S. 1996. Strategic alliances and interfirm knowledge transfer. ***Strategic Management Journal***. 17: 77–91.

Mowshowitz, A. 2002. ***Virtual organization***. Westport, CT: Quorum Books.

Moynihan, D. P. 2006. ***What makes hierarchical networks succeed? Evidence from hurricane Katrina***. Paper presented at the annual meeting of the Association of Public Policy and Management, Madison, WI.

Moynihan, D. P. 2008. Combining structural forms in the search for policy tools: Incident command system in US crisis management. ***Governance***, 21(8): 205–229.

Mulford, C. L., & Rogers, D. L. 1982. ***Interorganizational coordination: Theory, research and practice***. Aimes, IA: Iowa State University Press.

Neal, D. M., & Phillips, B. D. 1995. Effective emergency management: Reconsidering the bureaucratic approach. ***Disasters***, 19(4): 327–337.

Nissen, M.E., 2005. ***Hypothesis testing of edge organizations: Specifying computational C2 models for experimentation***. Paper presented at the 2005 Command and Control Research Symposium, McLean, VA.

Nissen, M.E. 2006a. Dynamic knowledge patterns to inform design: A field study of knowledge stocks and flows in an extreme organization. ***Journal of Management Information Systems***, 22(3): 225–263.

Nissen, M.E. 2006b. ***Harnessing knowledge dynamics: Principled organizational knowing and learning***. Hershey, PA: Idea Group Inc.

Nissen, M.E., & Buettner, R. 2004. ***Computational experimentation with virtual design team: bridging the chasm between laboratory and field research in C2***. Paper presented at the 2004 Command & Control Research and Technology Symposium, San Diego, CA.

Nissen, M. E., Jansen, E., Jones, C. R., & Thomas, G. F. 2004. Contextual criticality of knowledge-flow dynamics: Understanding a US tragedy of friendly fire. ***Defense & Security Analysis***, 20(3): 209–228.

Nissen, M. E., & Levitt, R. E. 2004. Agent-based modeling of knowledge dynamics. ***Knowledge Management Research and Practice***. 2: 169–183.

Nissen, M. E., Orr, R.J., & Levitt, R. E. 2008. Streams of shared knowledge: Computational expansion of knowledge-flow theory. ***Knowledge Management Research & Practice***. 6: 124–140.

Nonaka, I. 1995. A Dynamic Theory of Organizational Knowledge Creation. ***Organizational Science***, 5(1): 14–37.

Nonaka, I., & Takeuchi, H. 1995. ***The knowledge-creating company***. New York, NY: Oxford University Press.

The Ohio State University Research Foundation Report number 4083, ***Organizational communications and decision making in* crisis**, by Dynes, R.R., & Quarantelli, E.L. 1976.

Ouchi, W. G. 1981. ***Theory Z: How American business can meet the Japanese challenge***. Reading, MA: Addison-Wesley.

Pennings, J. 1975. The relevance of the structural contingency model of organizational effectiveness. ***Administrative Science Quarterly***, 20(3): 393–410.

Pennings, J. 1987. Structural contingency theory: A multivariate test. ***Organizational Studies***, 8(3): 223–240.

Pennings, J. 1992. Structural contingency theory: A reappraisal. ***Research in Organizational Behavior***, 14: 267–309.

Perrow, C. 1967. A framework for comparative analysis of organizations. ***American Sociological Review***, 32(2): 194–208.

Pfeffer, J. 1972. Mergers as a response to organizational interdependence. ***Administrative Sciences Quarterly***, 17: 382–394.

Pfeffer, J., & Nowak, P. 1976. Joint ventures and interorganizational interdependence. ***Administrative Sciences Quarterly***, 21: 398–418.

Pfeffer, J., & Salancik, G. R. 2003. ***The external control of organizations: a resource dependence perspective***. Stanford, CA: Stanford University Press.

Pfeffer, J., & Sutton, R. 1999. Knowing “what” to do is not enough: Turning knowledge into action. ***California Management Review***, 42(1): 83–108.

Polanyi, M. 1966. ***The tacit dimension***, Gloucester, MA: Butterworth-Heinemann.

Postrel, S. 2002. Islands of shared knowledge: Specialization and mutual understanding in problem-solving teams. ***Organization Science***, 13(3): 303–320.

Premkumar, G., Ramamurthy, K., & Saunders, C.S. 2005. Information processing view of organizations: An exploratory examination of fit in the context of interorganizational relationships. ***Journal of Management of Information Systems***, 22(1): 257–298.

Provan, K. 1983. The federation as an interorganizational linkage network. ***Academy of Management Review***, 8(1): 79–89.

Powley, E. H., & Nissen, M. E. 2009, Trust-mistrust as a design contingency: Laboratory experimentation in a counterterrorism context. Paper presented at the 14th Annual International Command & Control Research and Technology Symposium, San Diego, CA.

Quarantelli, E. L. 1998. ***Disaster planning, emergency management, and civil protection: the historical development and current characteristics of organized efforts to prevent and to respond to disasters***. Preliminary Papers; 227. Disaster Research Center.

Ren, Y., Carley, K., & Argote, L. 2006. The contingent effects of transactive memory: When is it more beneficial to kow what others know? ***Management Science***, 52(5): 671–682.

Roberts, K. H. 1990. Some characteristics of one type of high reliability organization. ***Organization Science***, 1(2): 160–176.

Rogers, D. L., & Whetten, D.A. 1982. ***Interorganizational coordination: Theory, research, and implementation***. Des Moines, IA: Iowa State University Press.

Rulke, D., & Galaskiewicz, J. 2000. Distribution of knowledge, group network structure, and group performance. ***Management Science***, 46(5): 612–625.

Saabeel, W., Verduijin, T., Hagdorn, L., & Kumar, K. 2002. A model of virtual organization: A structure and process perspective. ***Virtual Organization Net***, 4(1): 1–16.

Schermerhorn, J. R. 1979. Determinants of interorganizational cooperation. ***The Academy of Management Journal***, 18(4): 846–856.

Schermerhorn, J. R. 1979. Interorganizational development. ***Journal of Management***, 5(1): 21–38.

Schoonhoven, C. 1981, Problems with contingency theory: Testing assumptions hidden within the language of contingency "theory". ***Administrative Science Quarterly***, 26(3): 349–377.

Scott, W. R. 2003. ***Organizations: Rational, natural, and open*** **systems**. Upper Saddle River, NJ: Prentice-Hall.

Shadish, W. R., Cook, T. D., & Campbell, D. T. 2002. ***Experimental and quasi-experimental designs for generalized causal inference***. Boston, MA: Houghton Mifflin Company.

Shafritz, J. 1978. In J. Shafritz & P. Whitbeck (Ed.), ***Classics of organization theory***. Oak Park, IL: Moore Publishing.

Shaw, M. 1981. ***Group dynamics: The psychology of small group behavior***. New York, NY: McGraw-Hill.

Simon, H. A. 1993. Strategy and Organizational Evolution. ***Strategic Management Journal***, 14 (Special issue: Organizations, decision making and strategy): 131–142.

Simon, H. A. 1997. ***Models of bounded rationality***. Cambridge, MA: MIT Press.

Smith, K. G., Carroll, S. J., & Ashford, S. J., 1995. Intra- and interorganizational cooperation: Toward a research agenda. ***The Academy of Management Journal***, 38(1): 7–23.

Smith, W., & Dowell, J. 2000. A case study of co-ordinative decision-making in disaster management. ***Ergonomics***, 43(8): 1153–1166.

Snow, C. C., & Miles, R. E. ***Fit, failure & the hall of fame***. Free Press, NY: Simon & Schuster.

Spradley, J. 1980. ***Participant observation***. London, UK: Thomson Learning.

Spender, J.C. 1996. Making knowledge the basis of a dynamic theory of the firm. ***Strategic Management Journal***. 17(Winter Special Issue): 45–62.

Stasser, G., & Stewart, D. 1992. Discover of hidden profiles in decision-making groups: Solving a problem versus making a judgment. ***Journal of Personality Social Psychology***, 63(3): 426–434.

Staw, B., Sandelands, L., & Dutton, J. 1981. Threat rigidity effects in organizational behavior: A multilevel analysis. ***Administrative Science Quarterly***. 26: 501–524.

Steiner, I. 1972. ***Group process and productivity***. New York, NY: Academic Press.

Stiles, J. 1995. Collaboration for competitive advantage: The changing world of alliances and partnerships. ***Long Range Planning***, 28(5): 109–112.

Suparamaniam, N., & Dekker, S. 2003. Paradoxes of power: The separation of knowledge and authority in international disaster relief work. ***Disaster Prevention and Management***, 12(4): 312–318.

Tashakkori, A., & Teddlie, C. 1998. ***Mixed methodology: combining qualitative and quantitative approaches***. Thousand Oaks, CA: Sage Publications.

Taylor, J. R., & Van Every, E. J. 2000. ***The emergent organization: Communications as its site and surface***. Mahwah, NJ: Lawrence Erlbaum Associates.

Terreberry, S. 1968. The evolution of organizational environments. ***Administrative Science Quarterly***, 12(4): 590–613.

Thompson, J. D. 1967. ***Organizations in action***, NY: McGraw-Hill.
Thomsen, J. 1998. ***The virtual design team alliance (VTA): Modeling the effects of goal incongruency in semi-routine, fast-paced project organizations***. Doctorial dissertation, Stanford University, Palo Alto, CA.

Tierney, K. J. 1985. Emergency medical preparedness and response in disasters: The need for interorganizational coordination. ***Public Administration Review***, Special issue: Emergency Management Strategies for Communicating Hazard Information: 77–84.

Topper, C. M., & Carley, K. M. 1999. A structural perspective on the emergence of network organizations. ***Journal of Mathematical Sociology***, 24(1): 67–96.

Trim, P. R. F. 2004. An integrative approach to disaster management and planning. ***Disaster Prevention and Management***, 13(3): 218–225.

Tuckman, B. 1965. Developmental sequence in small groups. ***Psychological Bulletin***, 63(6): 384–399.

Tushman, M.L., & Nadler, D.A. 1978. Information processing as an integrating concept in organizational design. ***Academy of Management Review***. 3(3): 613–624.
U.S. Navy. 2007. ***Maritime headquarters with maritime operations center concept of operations***. Government Printing Office, Washington, DC.

Van de Ven, A., Delbecq, A., & Koenig, R. 1976. Determinants of coordination modes within organizations. ***American Sociological Review***, 41(April): 322–338.

Van de Ven, A.H., & Walker, G. 1984. The dynamics of interorganizational coordination. ***Administrative Sciences Quarterly***, 29: 598–621.

VDT. 2005. The Virtual Design Team Research Group Web site http://www.stanford.edu/group/CIFE/VDT/ last accessed: 4 April 2009.

Venkantraman, N., & Camillus, J. 1984. Exploring the concept of “fit” in strategic management. ***The Academy of Management Review***, 9(3): 513–525.

von Hippel, E. 1994. “Sticky Information” and the locus of problem solving: Implications for innovation. ***Management Science***, 40(4): 429–439.

von Krogh, G. 1998. Care in knowledge creation. ***California Management Review***, 40: 133–153.

Warren, R. 1967. The interorganizational field as a focus of investigation. ***Administrative Science Quarterly***, 12: 396–419.

Weber, M. 1947 translation. ***The theory of social and economic organization***. Glencoe, IL: Free Press.

Weerawat, W. 2007. ***Efficacy of international standards on logistics in disaster management, case study: National crisis management center, Thailand***. Paper presented at the 2007 Production and Operations Management Society conference, Dallas, TX.

Weick, R. L. ***The social psychology of organizations*** (2nd ed.) Reading, MA: Addison-Wesley.
Weiss, T.G., & Campbell, K.M. 1991. Military humanitarianism. ***Survival***, 33(5): 451–465.

Wenger, D. M. 1986. Transactive memory: A contemporary analysis of the group mind. In Mullen, B., & Goethals, G.R. (Eds.). ***Theories of group behavior***. New York, NY: Springer-Verlag.

Westphal, J., Gulati, R., & Shortell, S. 1997. Customization or conformity? An institutional and network perspective on the content and consequence of TQM adoption. ***Administrative Science Quarterly***, 42: 366–394.

Whetten, D. A., & Aldrich, H.1979. Organization Setsize and Diversity. ***Administration & Society***. 11(3): 251–281.

Whetten, D. A., & Leung, T. K. 1979. The instrumental value of interorganizational relations: Antecedents and consequences of linkage formation. ***Academy of Management Journal***, 22: 325–344.

Wildeman, L. 1998. Alliances and networks: The next generation. ***International Journal of Technology Management***. 15(1): 96–108.

Williamson, O. E. 1975. ***Markets and hierarchies, analysis and antitrust implications***. New York, NY: Macmillan Publishing.

Wong, S. S., & Burton, R. M. 2001. Virtual teams: What are their characteristics, and impact on team performance? ***Computational and Mathematical Organization Theory***, 6: 339–360.

Woodward, J. 1965. ***Industrial organization: Theory and practice***, London: Oxford University Press.

Wright, J. 1976. ***Interorganizational systems and networks in mass casualty situations***. Dissertation. Columbus, OH: The Ohio State University Press.

Wyner, G., & Malone, T. 1996. Cowboys or commanders: Does information technology lead to decentralization? In DeGross, J., Jarvenpaa, S., & Srinivasan, A. (Eds.). ***International Conference on Information Systems***. Cleveland, OH.

Yamamoto, Y. 1981. **An inductive theory of interorganization coordination in crises**. A paper presented at the 76th annual meeting of the American Sociological Association, Toronto, Canada.

Yin, R. 2003. ***Case study research: Design and methods*** (3rd ed.). Thousand Oaks, CA: Sage Publications.

Young, G. 2003. Contextualizing cooperation. In West, M.A., Tjosvold, D., & Smith, K. G. (Eds.) ***International handbook of organizational teamwork and cooperative working***. West Sussex, UK: John Whiley & Sons Ltd.

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