Computational & Mathematical Organization Theory, 9, 109–125, 2003

The Other Side of the Network Coin: Cost Considerations of Network Structure

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Abstract

The purpose of this study is to investigate the differential impact that inter-organizational network connections have on organizational level change. Drawing from the strategic leaning perspective on adaptation, this study investigates how the nature of inter-organizational ties among top management impact the cost and the effectiveness of an organizational level change process. To build on the existing empirical work in this area, this study employs a virtual experiment to create a controlled laboratory investigation of the hypothesized relationships among the strength, formalization, and functional equivalence of network ties; and the cost and effectiveness of an organizational change process. The findings of this study provide support for the strength of weak ties argument and structural hole theory, in addition to suggesting a caveat to Galbraith's information processing model. Furthermore, the results reveal that the tradeoff between increasing effectiveness and decreasing costs is not universally applicable across all decisions regarding network structure.

Keywords: adaptation, organizational change, networks, strategic learning perspective

1. Introduction

Organizational adaptation is a popular topic in many facets of contemporary organizational research. This paper aims to contribute to the study of organizational adaptation by employing a computational approach to investigate a question residing at the conceptual intersection of the organizational adaptation and network perspectives. Findings from empirical research purport the value of network ties in facilitating organizational change (e.g. Uzzi, 1997; Kraatz, 1998) and suggest that certain types of ties offer advantages over others (Kraatz, 1998). In addition to demonstrating the link between networks and adaptation, these findings also motivate additional questions directed at achieving a deeper, more fine-grained understanding of how network connections impact organizational level change. This study addresses one of these questions by comparing the cost and effectiveness of an organizational change process given different types of network connections.

The control afforded by a computational approach makes the investigation of this question feasible by allowing the manipulation of network characteristics, as well as the observation of the impact that these manipulations have on the change process. The assumption of a meta-network perspective within this virtual experiment allows for the modeling of network ties at the inter-organizational level, and the modeling of an organizational change process at the intra-organizational level. The ability to design an interconnected, dual level model within the virtual experiment permits the investigation of the impact of inter-organizational ties on the organizational level cost and effectiveness outcomes of an organizational change process. Consequently, the findings of this virtual experiment contribute to the study of organizational adaptation by addressing a gap in our understanding of the impact of network connections on organizational change.

2. Organizational Adaptation and Networks

The organizational adaptation perspective represents one of two competing perspectives on organizational change (Aldrich, 1999). The environmental selection perspective views organizations as inert actors whose survival is at the mercy of environmental selection forces (Hannan and Freeman, 1977, 1984, 1989). On the other hand, the organizational adaptation perspective views organizations as flexible and capable of changing, and adapting to their environment (Cyert and March, 1963; Levitt and March, 1988). While acknowledging the environmental selection perspective, as well as the contemporary perspective that views adaptation and selection as complementary (Astley and Van de Ven, 1983; Scott, 1987) or interdependent (Levinthal, 1991; Aldrich, 1999) processes, this paper adopts an adaptation perspective because the central question addresses a set of factors that influence an organizations ability to change, which inherently implies that organizations can, and do, change.

Adaptation represents a multi-level phenomenon because adaptation occurs at various levels of analysis. For example, adaptation occurs at the individual level (March and Simon, 1958; Hastie, 1986; Levitt and March, 1988), the design level (Lawrence and Lorsch, 1969; Hannan and Freeman, 1977; DiMaggio and Powell, 1983; Eccles and Crane, 1988), the strategic level, and the operational level (Carley, 1998; Carley and Svoboda, 1996). This paper focuses primarily on strategic level of adaptation which incorporates both inter-organizational ties and change processes occurring within organizations.

The strategic learning perspective on organizational adaptation emphasizes the role of top management in organizational change by proposing that design level change, and the organizational learning associated with change at this level, result from a process spear-headed by the strategic planning of central management (Carley, 2000). However, we know little about how top management should approach strategic adaptation. In particular, the literature lacks suggestions about the relative advantage of different strategies, or guidance regarding what path an organization should take. (Carley, 1998). The purpose of this paper is to address this gap in the adaptation literature by investigating the role that different network connections have on organizational adaptation. Therefore, this study represents an effort to provide some guidance on structuring inter-organizational networks in a way that positively impacts strategic adaptation.

The investigation of networks is important to the study of organizational adaptation because networks have the ability to constrain or to facilitate change (Granovetter, 1985). Networks occur when individual entities interact with each other (Salancik, 1995). Consequently, the multiplicity of connections among individuals, groups, and organizations creates an ecology of networks (Carley, 1999b) in which networks occur at, and across, all levels of analysis. This paper focuses on the impact of inter-organizational networks because inter-organizational ties enable organizations to learn from each other through imitation and the transference of valuable information, or best practice (Carley, 1999b). Drawing from the social learning perspective, the ties among organizations, which are usually manifested through interactions among the managerial levels of the organization, have the potential to impact strategic adaptation within a given organization through the information made available to executive management via network connections. Consequently, the structuring of network associations among executive management represents a strategic tool in the adaptation effort.

The value and importance of networks resides in their ability to provide access to information or resources, which contributes to an organization's ability to maintain competitive advantage. For instance, the combination of the sociological view of networks, which highlights affiliation and influence, and the strategic view of networks, which highlights the quest for rents (Van Alstyne, 1997), suggests that an inter-organizational network represents a set of connections fostered to enable the members to gain or sustain competitive advantage. Specifically, networks have the potential to impact an organization's ability to maintain competitive advantage by affecting the access to information, which in turn influences the quickness, quality, and accuracy of organizational decisions (Carley, 1999a), including those related to organizational change. Furthermore, the information accessed through network connections is particularly important given that the communication and diffusion of new technology and information still centers on who knows who, and who knows what, even as technology advances and makes information more accessible (Contractor and Eisenberg, 1990; Rice and Aydin, 1991; Aydin and Rice, 1992; Wellman et al., 1996; Wellman, 1998).

Since organizational performance depends on timely access to information and the ability to use this information to make the appropriate decisions, organizations need to adopt strategies of change (Carley, 1999b) that center on information. Given the importance of network structure, who knows who and who knows what, in the propagation of information, organizations should think strategically about network interactions given the key role played by information in organizational adaptation.

The task of evaluating this aspect of network structure, who should know whom, necessitates a theoretical view of networks that suggests the possibility that network interactions are actually observations, as opposed to givens. For example, instead of analyzing existing communication networks, a network theory might ask how to structure interactions so that diffusion increases or decreases, or how do certain patterns of interaction influence coordination (Salancik, 1995). "When interactions are not taken as givens, theorists may begin to model their role in constructing coordinating structures and in carrying information or ideas from place to place." (Salancik, 1995, p. 347). This perspective opens the door for considering and investigating how to structure inter-organizational connections in a way that facilitates adaptation.

3. Hypotheses

In general, two opposing schools of thought address the most beneficial type of network tie for facilitating organizational change (Kraatz, 1998). First, the strength of weak ties argument (Burt, 1982; Granovetter, 1973) purports the importance of a large number of heterogeneous connections because these ties allow an organization better access to a wider base of information. Second, the strength of strong ties argument (Granovetter, 1982; Krackhart, 1992; Uzzi, 1996) purports the importance of a limited number of long standing, high frequency connections because these ties enable access to richer, more detailed information. Given the uncertainty associated with organizational change (Aldrich, 1999), I argue that strong ties possess greater potential to facilitate organizational change by providing access to more relevant and more detailed information. Empirical findings from two studies also provide support for this logic. An ethnographic study of the New York garment industry (Uzzi, 1997) and a longitudinal study of private colleges (Kraatz, 1998) both provide support for the value of strong ties in facilitating organizational change.

The current study provides a contribution that builds on and extends these findings in two ways. First, this study provides a direct comparison of strong versus weak ties on a given change process. Second, this study extends the set of outcomes addressed by exploring the cost considerations of strong versus weak ties, in addition to the benefits. Existing theoretical and empirical work addresses the benefits of strong versus weak ties, but this work remains silent about the cost implications of strong versus weak ties, which represents an important, yet neglected, outcome of network interactions.

Given that the exchange of rich and detailed information characterizes strong ties (Granovetter, 1982; Krackhart, 1992; Uzzi, 1996), strong ties have the potential to result in higher costs relative to weak ties. In particular, the exchange of rich information requires more interaction and coordination than the exchange of less detailed information. The increased level of interaction and the associated coordination translates into increased costs given that managers invest some organizational time and resources in these relationships. Consequently, stronger network ties possess the potential to facilitate organizational change by providing access to richer information relative to weaker ties; however, increased costs also accompany the benefits of strong ties as a result of the increased amount of interaction and coordination required to obtain richer information.

Hypothesis 1a. Increasing the strength of network ties results in higher coordination costs of the network.

Hypothesis 1b. Increasing the strength of the network ties improves the effectiveness of the network in facilitating organizational change.

In addition to comparing the relative impact of strong versus weak ties, assuming the perspective that network connections are not givens lifts a constraint that enables inquiry regarding the implications of other structural elements (Salancik, 1995). This study focuses on the structural elements related to the transfer of information because network structure impacts the ease and flexibility of information exchange (Krackhardt, 1989). Furthermore, prior research highlights the importance of networks as sources of information that impact organizational change. For example, research addressing the role of networks in organizational change reveals that networks provide valuable information about organizational practices (Gulati, 1995) and innovative practices (Kraatz, 1998), which both foster and inform organizational change. Consequently, hypothesizing about the structure of network connections addresses a key element of networks that impacts organizational change.

In particular, approaching the study of network connections from the perspective that connections are not given provides the opportunity to hypothesize about the formalization of the network. The absence of consensus regarding the compatibility of formal versus informal organizational structures (DiMaggio, 1992; Krackhardt and Kilduff, 1990; Stacey, 1996; White, 1992) implies that informal and formal structures have both divergent composition and effectiveness (Nelson, 2001). When applied to the central concern of this paper, the impact of network connections on organizational change, the issue becomes whether informal or formal network ties have a greater capacity to facilitate organizational change.

According to Bensaou and Venkatraman (1995), the formalization of a network represents a continuum related to whether the interaction is designated for control purposes (high formalization) versus coordination purposes (low formalization). Hence, the formalization of the network relates to the degree to which the determination and direction of the interactions is exogenous to the interacting parties. The predominant theme in the network literature suggests that informal organizational networks play an important role in the distribution of a wide array of resources (Brass, 1992; Krackhardt, 1990), which suggests that lower formalization may benefit organizational change. Specifically, lower formalization has the potential to facilitate the exchange of information in network interactions (Bensaou and Venkatraman, 1995), which represents an important opportunity to facilitate organizational change. Consequently, lower formalization represents a more advantageous way to structure network connections relative to higher formalization when the goal is to facilitate organizational change.

Relaxing the formalization of interactions provides flexibility and opportunity, which benefit organizational change; however, relaxing formalization also creates increased coordination costs borne by the parties to the interaction (Burt, 1997). Since the aim of a more formalized network is control as opposed to coordination (Bensaou and Venkatraman, 1995), the decrease in control creates an increase in coordination costs as individual players become responsible for managing their interactions (Burt, 1997). Coordination costs increase as coordination becomes the responsibility of many, as opposed to being concentrated in management. Consequently, increased coordination costs accompany the benefits of lower formalization.

Hypothesis 2a. Decreasing the formalization of network interactions results in higher coordination costs of the network.

Hypothesis 2b. Decreasing the formalization of network interactions improves the effectiveness of the network in facilitating organizational change.

When taken together, the structural hole theory of Burt (1992) and the strength of weak ties argument of Granovetter (1973) suggest another structural element of network connections that possesses the potential to impact organizational change, who is connected to whom. Structural hole theory focuses on position within the network and the weak ties argument centers on the nature of the connection; however, both perspectives highlight the importance of who is connected to whom. In particular, these perspectives purport the value of heterogeneity in network connections. The value of heterogeneous connections results from an increased access to new information by avoiding the redundancy of connections possessing similar information (Burt, 1997). Hence, these perspectives purport that the access to a wider, nonredundant pool of information is more advantageous.

Given that the focus of the current study addresses inter-organizational interactions and the impact of these connections on organizational level change, I am focusing on the functional parallelism of the network ties based on an interest in the instrumental impact of network connections on an organizational change process. I hypothesize that the connections between parties from dissimilar functional/departmental areas are more advantageous following the logic of Burt's structural hole theory. Specifically, nonparallel network linkages enable organizational members undergoing a change process to access new, yet relevant, information, which enhances the effectiveness of the network.

On the other hand, functionally parallel network linkages may decrease the coordination costs due to the efficiency and relevance of the interaction between individuals of the same functional background. Not only may the information exchanged between those of a similar background and training be more specified, but the interaction may be more efficient, and therefore more cost effective. In other words, those talking the same language (i.e. those from similar functional areas) have the capacity to interact in a more cost efficient manner relative to those speaking different languages (i.e. those from different functional areas). Consequently, a tradeoff exists between functionally parallel connections and functionally nonparallel connections; parallel connections are more cost efficient and nonparallel connections are more effective.

Hypothesis 3a. A network of functionally parallel linkages has lower coordination costs relative to a network of nonparallel linkages.

Hypothesis 3b. A network of functionally parallel linkages decreases the effectiveness of the network relative to a network of nonparallel linkages.

4. The Virtual Experiment

The investigation of the differential effects of various network connections on organizational change is an appropriate endeavor for computational organization science for two reasons. First, networks and their member organizations are both computational in nature since they have the ability to acquire, process, store, or provide information (Carley, 1999a). Second, the computational approach is appropriate because it complements other methodological approaches by providing a more controlled environment for the study of questions that have been explored by other methods. In particular, "The computational approach is strongest when the underlying models are empirically grounded and embed, are driven by, or are validated against, other forms of data including detailed anthropological case studies, lab experiments, survey results, and large scale data that can be automatically collected over the web." (Carley, 1999b, p. 6) Furthermore, the precision and control of computational methods fosters convergence when prior research methodology possesses the alternative strengths of generalizability or realism (McGrath, 1982). Hence, the computational approach is a sound choice for the investigation of the question at hand given the presence of the prior empirical work on the role of networks in organizational change (e.g. Uzzi, 1997; Kraatz, 1998), which forms the foundation of this virtual experiment.

The simulation platform used in this study is ViteProject, which Dr. Ray Levitt and his colleagues at Stanford University developed. ViteProject represents a modeling and simulation tool that enables managers to design and analyze complex and interdependent work processes, and the associated organizational structure using a virtual prototype (The ViteProject Handbook). Vite allows the modeling of agents, tasks, groups, and interactions, which makes it possible to build and manipulate a dual level model that incorporates the network and organizational levels. The ability to design a model in which agents interact across organizational boundaries while also being connected to intra-organizational activities gives ViteProject the advantage over other existing models of organizational change. For example, CORP, CONSTRUCT, ORGAHEAD, and simulated annealing represent previously used models of organizational change; however, ViteProject possesses a greater capacity to construct network connections at the inter-organizational level and a change process at the intra-organizational level within a single model so that the impact of network structure on organizational change can be investigated. Furthermore, this platform allows the analysis of both the cost and effectiveness of various structural arrangements, which makes this platform well suited for investigating the hypotheses proposed in this study.

The suitability of ViteProject for addressing the questions of interest indicates the validity of the simulation model since the validity of a simulation model relates to the ability of the model to answer the questions at hand (Burton and Obel, 1995). Furthermore, in an another attempt to address the validity issue, the network modeled within the simulation is only as complex as needed to address the questions at hand because, "Balance suggests that realism is important, but only within the context of the purpose" (Burton and Obel, 1995, p. 61). Given the ability to model activities, actors, and interdependencies within ViteProject, the model represents a degree of realism while maintaining simplicity by depicting organizational members with inter-organizational connections, which influence the intra-organizational processes within the responsibility of these members.

4.1. The Model

The motivation and foundation for the model used in this study was the work done by Kraatz (1998), which investigated the role of consortium membership in the adoption and implementation of professional schools in small liberal arts colleges. At the network level, I replicated consortium membership as an inter-organizational network in which the top managers of distinct organizations interact and exchange information. At the organizational level, I replicated the adoption of professional programs as a generic model of change occurring within each of the distinct organizations. The network and organizational levels of the model are connected through the members of the inter-organizational network who are also assigned to tasks within the organizational level change process.

Within this virtual experiment, members of top management represent the focal members of the inter-organizational network and key points of influence on change within the organization. The strategic learning perspective on adaptation and the network perspective place the top executives of an organization at this critical juncture between the environment and the organizational change processes. The strategic learning perspective emphasizes the role of the top management in organizational change by proposing that design level change and the accompanying organizational learning results from a process spearheaded by the strategic planning of central management (Carley, 2000). The network perspective emphasizes the role of top management in connecting the organization to the environment, which enables organizational learning through the transference of valuable information and best practice (Carley, 1999b). In sum, these two perspectives imply that the top executives of an organization play a pivotal role in organizational adaptation since top executives represent the point of entry for new information and they dictate change at the strategic level.

Consequently, within this virtual experiment, I model the inter-organizational network by connecting top managers across organizational boundaries through information exchange interactions. Necessitating information exchange among organizational members is done to simulate the existence of network ties with other organizations and their members within the model. In an effort to maintain parsimony, the network consists of two organizations and five organizational members.

At the organizational level, the generic model of change was identical for each of the organizations. Change within organizations requires that managers manipulate the four key internal features of the organization (i.e. conduct, capabilities, controls, and culture) by redefining the vision, reallocating resources, modifying systems, and creating general commitment, respectively (Fombrun, 1994). Therefore, these four activities serve as the basis for the change process modeled within this virtual experiment.

The initial step in implementing change, redefining the vision, necessitates the communication of information. Given that effective communication represents an essential component of successfully implementing organizational change (Brown and Eisenhardt, 1997; O'Connor, 1993; Clarke, 1994; Fombrun, 1994), *Inform* represents the first activity in the change process. Paralleling the second step set forth by Frombrun, *Mobilize Resources* represents the second activity in the change process because implementing change demands resources (Brege and Brandes, 1996). Following several popular models of organizational systems including Leavitt's diamond and the McKinsey 7S model, which hold people to be separate from systems or facilities/technology (Hussey, 1995; O'Connor, 1993), I separate the modification of systems into two activities: *Personnel changes* and *Infrastructure changes*. The last activity in the change process, the generation of commitment, entails carrying out the transformation while motivating participation across the organization (Frombrun, 1994). Due to the multiple tasks involved in generating commitment, I designate *Integration* as the last activity in the change process. To complete the organizational level of the model, I assigned each of the members within the organization to one of the of the change activities as demonstrated in the Table 1.

4.2. *The Experimental Design*

I used the simulated network of organizations described above to generate data as I manipulated model parameters to investigate each of the hypotheses. In essence, this study employs the simulation software as a tool to generate data in the same manner in which data is produced in a laboratory experiment. Consequently, the empirical aspect of this study parallels a controlled laboratory experiment in which all variables are held constant, or controlled, except for the independent and dependent variables of interest.

Table 1. Actors and activities.

Change activity	Responsible actor
Inform	CEO
Mobilize resources	Finance
Personnel changes	Human resources
Infrastructure changes	Capital planning
Integration	CEO/VPs

The three sets of hypotheses suggest three independent variables of interest (the strength of network ties, the formalization of the network, and the functional parallelism of the network ties), and two dependent variables of interest (the effectiveness and the cost of the network). The strength of network ties and the formalization of the network assumed values of high, medium, and low; and the functional parallelism assumed values of parallel and nonparallel, as I recorded the cost and effectiveness outcomes. Given the number of independent variables and the number of values assumed by each independent variable, this study consisted of a total of 18 separate experimental conditions.

4.3. The Independent Variables

In this study, the frequency of the information exchange represents a proxy for the strength of the network ties following the example of Granovetter (1973). I operationalized and manipulated the strength of the network ties using the *information exchange probability* parameter in ViteProject. This parameter refers to the probability that the actors connected by an information exchange requirement will send communication to each other. The information exchange probability assumed values of high (0.80), medium (0.50), and low (0.20) for simplicity, even though the information exchange probability is a continuous variable with a range from 0.0 to 1.0 within ViteProject. Hence, the strength of the network ties is a categorical variable with three levels.

I operationalize and manipulate the formalization of the network ties using the *formalization* parameter within ViteProject. This parameter refers to the likelihood that the actors will wait until a scheduled meeting to exchange information as opposed to exchanging information informally as needed. Within ViteProject, the formalization parameter can assume high, medium, and low values; therefore, formalization is a categorical variable with three levels.

I operationalize and manipulate the functional parallelism of the network ties by altering the information exchange linkages within ViteProject. I created the two conditions by building two distinct models in which the only difference is the nature of the linkages among the actors. In the functionally parallel condition, the information exchange linkages are between members of the network who occupy identical functional areas. In the nonparallel condition, the information exchange linkages are between members of the network who occupy different functional areas. Consequently, the functional parallelism is a categorical variable with two levels: parallel and nonparallel.

Table 2. Independent and dependent variables with associated model parameters.

Variables	Model parameters
Strength of network ties	Information exchange probability
Formalization of the network ties	Formalization
Functional parallelism of the ties	Information exchange linkages
Cost	Coordination cost
Effectiveness	Activity communication risk

4.4. The Dependent Variables

The cost and the effectiveness of the network are the outcome, or dependent, variables of interest in this study. Given the emphasis on the information exchange characteristic of networks, the cost variable is operationalized through the *coordination cost* outcome in ViteProject, which is a measure of the cost associated with the time that actors spend in meetings and exchanging information. The effectiveness variable is operationalized using the measure of *activity communication risk* within ViteProject, which is the ratio of missed communication relative to the total number of communications sent. Following the ViteProject handbook, increasing levels of activity communication risk suggest an increased amount of quality risk in the output of the process. Given the importance of information and the exchange of information during organizational change, these outcomes represent logical measures of the coordination cost and the effectiveness of an inter-organizational network in the presence of organizational level change.

A tabular outline of the variables and the model parameters used to operationalize these constructs is shown in Table 2.

5. Results

To evaluate the research hypotheses statistically, I generated a sample of $n = 450$ by running 450 single run trials within VitePorject. I conducted a large number of single run trials to generate a set of data points large enough to draw well founded inferences from the data (Axelrod, 1997). With $n = 450$, each cell in the $2 \times 3 \times 3$ factorial model included 25 trials.

I investigated the hypotheses by estimating two $2 \times 3 \times 3$ factorial ANOVA models given a significance level of $\alpha = 0.05$ using SPSS for Windows 9.0. I estimated one model using coordination cost as the dependent variable, and I estimated a second model using effectiveness as the dependent variable. Tables 3 and 4 depict the correlation matrix and descriptive statistics, respectively.

The null hypothesis tested was that all means across all conditions were equal. Contrary to the null hypothesis, I hypothesized a difference in the cost and effectiveness of the network based on the functional parallelism, formalization, and the strength of the network ties. The omnibus null hypothesis was rejected ($F(5{,}444) = 767.32$, $p = 0.000$) for the cost model,

Table 3. Correlation matrix.

	Parallelism	Strength	Formalization	Cost	Effectiveness
Parallelism	1.00				
Strength	0.00	1.00			
Formalization	0.00	0.00	1.00		
Cost	0.18**	0.62**	−0.67**	1.00	
Effectiveness	−0.66**	0.20**	−0.19**	0.07	1.00

**Correlation is significant at the 0.01 level.

which indicated that the not all of the group means were equal across all conditions. To investigate the three hypotheses addressing the coordination cost of the network, I examined the main effects of functional parallelism, formalization, and the strength of the ties. The main effects for functional parallelism ($F(1{,}444) = 138.09$, $p = 0.000$), strength of ties ($F(2{,}444) = 874.20$, $p = 0.000$), and formalization ($F(2{,}444) = 975.05$, $p = 0.000$) were all significant for the cost model, which suggests that the levels of these variables does significantly influence the coordination costs of the network.

The results provide support for Hypothesis 1a, which proposed a positive relationship between the strength of network ties and coordination cost. Increasing the strength of network ties resulted in a statistically significant increase in coordination cost as demonstrated by the significance of the main effect for the strength of ties and the means shown in Table 4. The results also provided support for Hypothesis 2a, which proposed a negative relationship between network formalization and coordination cost. Decreasing the formalization of the network resulted in a statistically significant increase in coordination cost as demonstrated by the significance of the main effect for formalization and the means shown in Table 4. Lastly, the results provided support for Hypothesis 3a, which proposed that functionally parallel network linkages generate lower coordination cost relative to nonparallel linkages. Parallel linkages resulted in statistically lower coordination costs relative to nonparallel linkages as demonstrated by the significance of the main effect for the functional parallelism and the means shown in Table 4.

The omnibus null hypothesis that all means are equal across all conditions was also rejected ($F(5{,}444) = 93.95$, $p = 0.000$) for the effectiveness model, which indicated that not all of the group means were equal across all conditions. Once again, I examined the main effects of functional parallelism, formalization, and the strength of the ties to investigate the three hypotheses addressing the effectiveness of the network. The main effects for functional parallelism ($F(1{,}444) = 395.33$, $p = 0.000$), strength of ties ($F(2{,}444) = 19.90$, $p = 0.000$), and formalization ($F(2{,}444) = 17.30$, $p = 0.000$) were significant for the effectiveness model, which suggests that the levels of these variables does significantly influence the effectiveness of the network.

The results did not provide support for Hypothesis 1b, which proposed a positive relationship between the strength of the network ties and the effectiveness of the network. Even though the relationship between the strength of the network ties and the effectiveness of the network was statistically significant, increasing the strength of the ties hindered the effectiveness of the network ties given that *communication risk* represents the measure of

Table 4. Descriptive statistics.

Cost						Effectiveness					
Parallel	Strength	Formal.	N	Mean	SD	Parallel	Strength	Formal.	N	Mean	SD
Yes	Low	Low	25	1.33	0.14	Yes	Low	Low	25	0.39	0.04
		Med.	25	0.70	0.13			Med	25	0.41	0.07
		High	25	0.44	0.10			High	25	0.33	0.10
			75	0.83	0.40				75	0.38	0.08
	Med	Low	25	2.87	0.16		Med	Low	25	0.47	0.03
		Med	25	1.58	0.17			Med	25	0.41	0.04
		High	25	0.91	0.12			High	25	0.38	0.06
			75	1.79	0.83				75	0.42	0.06
	High	Low	25	2.80	0.17		High	Low	25	0.48	0.03
		Med	25	2.35	0.15			Med	25	0.45	0.03
		High	25	1.27	0.14			High	25	0.42	0.05
			75	2.14	0.67				75	0.45	0.04
	Total	Low	75	2.33	0.73		Total	Low	75	0.45	0.05
		Med	75	1.55	0.69			Med	75	0.42	0.05
		High	75	0.87	0.36			High	75	0.38	0.09
			225	1.58	0.86				225	0.42	0.07
No	Low	Low	25	1.53	0.14	No	Low	Low	25	0.30	0.04
		Med	25	0.85	0.12			Med	25	0.28	0.08
		High	25	0.47	0.09			High	25	0.30	0.09
			75	0.95	0.46				75	0.29	0.07
	Med	Low	25	3.59	0.17		Med	Low	25	0.32	0.03
		Med	25	1.86	0.14			Med	25	0.32	0.05
		High	25	0.99	0.16			High	25	0.31	0.06
			75	2.15	1.10				75	0.32	0.05
	High	Low	25	3.68	0.21		High	Low	25	0.31	0.04
		Med	25	2.95	0.17			Med	25	0.30	0.03
		High	25	1.62	0.18			High	25	0.30	0.05
			75	2.75	0.88				75	0.30	0.04
	Total	Low	75	2.63	0.93		Total	Low	75	0.31	0.04
		Med	75	1.72	0.81			Med	75	0.30	0.06
		High	75	0.95	0.44			High	75	0.30	0.07
			225	1.77	1.02				225	0.30	0.06

effectiveness in Table 4. Specifically, the increasing values reported in Table 4 represent the increased chance for missed communication; therefore, higher values actually indicate lower effectiveness. Consequently, the statistical significance of the effectiveness and the means provided in Table 4 actually contradict Hypothesis 1b.

Similarly, the results do not provide support for Hypothesis 2b, which proposed a negative relationship between the formalization and the effectiveness of the network. The relationship between the formalization and the effectiveness of the network was statistically significant, but as illustrated in Table 4 increasing the formalization of the network ties appears to improve the effectiveness of the network. Consequently, the statistical significance of formalization and the means provided in Table 4 also contradict Hypothesis 2b.

Lastly, the results support Hypothesis 3b, which proposed that functionally parallel network linkages would decrease the effectiveness of the network relative to unparallel linkages. The relationship between parallelism and network effectiveness was statistically significant, and as illustrated in Table 4, the functionally parallel arrangement resulted in lower effectiveness relative to the nonparallel linkages. Hence, the statistical significance of parallelism and the means provided in Table 4 support Hypothesis 3b.

To explore the robustness of the results discussed above, I conducted limited post hoc analyses. These analyses address key variables within the adaptation and network areas of research, which are not addressed by the focal research questions of this study. These post hoc analyses addressed the impact of uncertainty, which is an important element of change (Aldrich, 1999), in addition to the impact of size and density, which are key variables in research addressing networks.

Within ViteProject, uncertainty is a task level parameter that represents the unavailability of information at the initiation of a task. Higher levels of uncertainty indicate that a high degree of information regarding the execution of a task is not available at the initiation of the task. For the main experiment, I set the level of task uncertainty at medium. Given that uncertainty is a categorical variable that assumes the values of high, medium, and low, I ran an additional 20 trials with uncertainty set at high and low, respectively, for each of the 18 experimental conditions. Changing the level of uncertainty impacted the level of coordination costs (coordination costs increased as uncertainty increased); however, effectiveness remained at similar levels across high, medium, and low uncertainty. These post hoc trials also revealed the same pattern of relationships among the independent and dependent variables as demonstrated in the main analysis. Consequently, the relationships indicated in the main analysis above appear to be robust to changes in the level of uncertainty even though increased uncertainty results in higher levels of coordination cost overall.

In network research, size reflects the number of agents within the organization, or network, and density reflects the fraction of possible connections between these agents that actually exist (Carley, 1998). For the post hoc analyses examining size, I doubled the number of agents in the model, and then ran an additional 20 trials for each of the 18 experimental conditions. Similarly, for the analyses examining density, I increased the number of connections so that the density of the network increased from 0.05 to 0.21 and also ran an additional 20 trials for each of the experimental conditions.

Increasing size and density impacted the levels of coordination cost and effectiveness. Increased size and density both resulted in overall increases in coordination costs relative to the original model. Increased size improved effectiveness in the functionally parallel condition and resulted in similar levels of effectiveness for the nonparallel condition. On the other hand, increased density resulted in an overall decrease in effectiveness. However, these post analyses did reveal the same pattern of relationships among the independent and dependent variables as demonstrated in the main analysis. Hence, the relationships indicated in the results of the main analysis appear to be robust to changes in size and density even though increased size and density have an overall impact on both coordination costs and network effectiveness.

6. Discussion and Conclusions

The purpose of this study was to investigate the differential impact that network connections have on organizational change. Using a computational approach, I examined this issue in an effort provide some guidance on how organizations might structure inter-organizational connections in a way that facilitates adaptation. The results of this virtual experiment indicate that different ways of structuring inter-organizational connections have differential impact on an organizational change process. These results contribute to our understanding of the role of network structure in organizational change, and represent a first step in providing some guidance regarding how to structure inter-organizational connections in a manner that positively impacts strategic adaptation.

Theoretically, the results of this virtual experiment support a combination of the strength of weak ties argument (Granovetter, 1973; Burt, 1982) and structural hole theory (Burt, 1992). The beneficial impact of less frequent interaction (i.e. weaker ties) and connections with those in dissimilar functional areas suggest that more heterogenous inter-organizational connections are more advantageous, which follows the arguments of both Granovetter (1973) and Burt (1982, 1992). In particular, the avoidance of redundancy as indicated by cohesive connections, which are strongly connected, and by structurally equivalent connections improves the effectiveness of the network by providing access to new, additive sources of information (Burt, 1997). The avoidance of redundancy through heterogenous connections may be especially important within top management where individuals are very knowledgeable and active within their area of expertise. With this said, additional research exploring the impact of tie heterogeneity between individuals at lower organizational levels and between individuals across different organizational levels would build on the results of this study and refine our understanding of the impact of tie strength and heterogeneity.

The results also pertain to discussions about Galbraith's information processing model (1973) as applied at the inter-organizational level of analysis (Bensaou and Venkatraman, 1995). Drawing from this model, increasing the formalization of the network lowers the effectiveness of the network by decreasing its information processing capacity. However, the results of this virtual experiment indicate that increasing formalization improves effectiveness, which highlights a caveat in Galbraith's model. This caveat relates to potential benefits of increased control (i.e. higher formalization) given the context of organizational change. In particular, the increased control of more formalized interactions may improve the attentiveness of those involved, which would decrease the ration of missed communications relative to the total communications sent. When moving from the virtual experiment into a more "real world" context, increased formalization has the potential to represent a collective endorsement or directive from the top, which may increase effectiveness by motivating the attentiveness and the efforts of those involved in the change process. Consequently, the results of this study, and the caveat to Galbraith's information processing model that the results suggest, provide support for the strategic learning perspective on adaptation, which emphasizes the importance of top management in initiating organizational change.

Lastly, the examination of outcomes related to both the costs and the effectiveness of various network connections within the context of organizational change provided a comprehensive investigation, which generated insightful results. Specifically, the results of this study indicate the presence of tradeoffs between costs and effectiveness in addition to highlighting that these tradeoffs are not universal across all structural considerations for networks. For example, the increased effectiveness of functionally dissimilar connections and increased network size is accompanied by higher coordination costs. However, decreasing the strength of ties and increasing the formalization of the network result in improved effectiveness and lower costs. The challenge resides in recognizing the decisions that involve tradeoffs, and then evaluating these decisions to maximize the net benefit. This study represents a first step in attempting to examine the presence of tradeoffs involved in various network structural arrangements; however, these issues represent a fruitful path for future research aimed at identifying and examining the structural considerations that involve tradeoffs.

In conclusion, the contributions of this study go beyond its empirical findings. Hopefully, the discussion and findings of this study will stimulate and encourage future research addressing the role of networks in organizational change in addition to stimulating and encouraging future research employing simulation designs across various domains. In particular, this study exemplifies how computational and mathematical approaches can be employed to the study of organizations and their environments in a way that compliments existing theory and empirical findings while contributing to the body of knowledge. Keeping in mind the "three-horned" dilemma outlined by McGrath (1982), there is a place for simulation studies in organizational and strategy research as researchers aim for convergence through the use of multiple methodologies.

Acknowledgments

Thanks to Dr. Rich Burton, the members of Dr. Burton's Computational Organization Theory seminar (Duke University, Fall 1999), the participants at the CASOS 2000 Conference in Pittsburgh, PA, and two anonymous reviewers for the helpful comments and feedback given on earlier versions of this paper.

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