DISCONTINUITY IN ORGANIZATIONS: IMPACTS OF KNOWLEDGE FLOWS ON ORGANIZATIONAL PERFORMANCE

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4.1 ABSTRACT

Maintaining product feasibility and managing knowledge flows are difficult if a complex process is operating under an equivocal environment and by an organization with discontinuous membership across project phases. In this paper, we built upon findings from an ethnographic study and data from a knowledge network analysis of an affordable housing development project to extend an agent-based computational organization theory (COT) modeling tool. We integrated Wegner's transactive memory theory—that a team member will turn to his knowledge network to augment his incomplete cognitive skills—with Galbraith's information-processing view of organizations to test whether or not discontinuous membership could impact an organization's performance through intellective computational experiments. We found that there was no significant difference in the total work volume of organizations with a continuous versus discontinuous team

[4] Stanford University
[5] Ibid.
[6] Ibid.

member; however, the inaccuracy about other team members' cognitive skills by the new member could cause a detrimental effect on the functional quality of the tasks for which she or he is responsible. The detriment of the functional quality supports our earlier ethnographic findings that new members are at risk of becoming sources of knowledge loss when they are not aware of prior knowledge within the organization. The study highlights the need to consider knowledge flows when designing organizations, especially if they operate in a dynamic and complex environment.

Key Words: Discontinuous membership, knowledge flows, organization design, functional information-processing, transactive memory.

4.2 INTRODUCTION

During a financing program negotiation to develop a low-income family housing project, the project developer agreed to provide a children's play structure for the housing complex. Somehow, as the project progressed, the play structure eventually became an open play area by the time the property started operating. When the program sponsor found this out a year later, it fined the property owner and requested it to return the full amount or build the play structure. The property owner paid the fine and built the play structure, but at its own cost which had to be diverted from other future housing projects. This case negates Cohen and Levinthal's (1990) *absorptive capacity* theory because the prior knowledge about agreeing to build a play structure for the housing project was missing as the housing development team continued its development.

The purpose of our study is to determine how knowledge flows can impact the organizational performance of a discontinuous organization. A discontinuous organization is a group of positions operating in an environment where one or more team positions would join or leave the group while the work process is still on-going, due to the need for different skill requirements to complete different parts of the process (Ibrahim and Paulson, 2005). It differs from *turnover*, which is an operational situation where the incumbent of a position in an organizational structure is replaced with another agent to fulfill the *same position's role* while the process is on-going (ibid.). In affordable housing development, the process is complex with multiple sequential and concurrent life cycle phases. It is unique because each has its own organization overseeing the process within one phase. The 'non-standardization' of the facility development process was also a reason for the inability of experts to design a knowledge management system for the construction industry (Corillo, et al., 2004). A study by Ibrahim, Shumate, et al. (2005) on knowledge flow behaviors suggests that the non-hierarchical (or informal) knowledge networks within the life cycle phase may influence the organizational performance of the project team.

Most theory and practice of *organization* theory are based on Galbraith's (1974) hierarchical *information-processing theory* of the firm to design an organization (Burton and Obel, 1998; Jin and Levitt, 1994). Earlier organization scholars (such as Lawrence and Lorsch (1967), and Scott (1998)) have suggested the integration of informal structure within the hierarchical decision-making structure of an organization that would enhance an organization's capability in responding to changing operating environment. Moreover, Ibrahim, Shumate, et al's (2005) study highlights the need to consider non-hierarchical information-processing process in the design of discontinuous organization in addition to considering the knowledge type (tacitness versus explicitness) dominance of the knowledge areas within a process phase.

Our long term objective is to extend the representation and reasoning of the extant VDT in integrating Wegner's (1987) *transactive memory* theory with Galbraith's (1977) hierarchical *information-processing* theory for the design of knowledge-networked organizations. This study is our first attempt to prove that discontinuity in an organization could affect its organizational performance by way of disrupting knowledge flows among the team members. We extended an agent-based computational organization tool called the *Virtual Design Team* (VDT) (Jin and Levitt, 1996; Kunz et al., 1998) to test this hypothesis. We first present the literature review on discontinuous organization, our research method, how we extend the VDT tool, and the results we obtained. Then, we conclude with discussions on the results and provide recommendations for further study.

To guide the reader, we use the term *organization* to represent an entity that comprises several team members working on a process. We use the term *enterprise* to represent an entity that comprises several *organizations* to complete a process. A process can be sequential or concurrent. A sequential process may comprise of several different organizations working on different parts of the process. In a concurrent process, a different organization could work on different parts of the process independently. We define *knowledge* as a set of commitments and beliefs of its holder that enables the holder to undertake certain action (Nonaka, 1994). The criterion for using the term 'knowledge' in this paper is its *enabling action* entity that allows the beholder of a knowledge entity to undertake certain action. *Explicit knowledge* is the selected and applicable group of facts that is transmittable in a formal systematic language that enables its beholder to take some action to complete a task; and *tacit knowledge* is the entity of "knowing how" that an individual or an enterprise possesses in selecting and applying a group of facts that enables action to complete a task (Polanyi, 1971; Nonaka, 1994). On the other hand, *information* is the selective collection of facts that an agent *can use* to perform a task, while *data* are facts that an individual or enterprise *can use* to analyze or make a decision.

4.3 LITERATURE REVIEW

4.3.1 Discontinuity in Organizations

Discontinuous membership is the operating situation where one or more team members join or leave an organization while the work process is still on-going due to the need for different skill requirements to complete successive parts of the process (Ibrahim and Paulson, 2005). A study by Ibrahim and Paulson finds several unique operating environmental characteristics in the facility development organization that explain the knowledge loss (K-loss) phenomenon inherent and on-going in complex processes despite investment in latest information technology by the project owners. The facility development process is complex in general, but the affordable housing development process is more complex due to the financial and regulatory constraints that state and federal programs impose on their developments and operations (Ibrahim, 2001; NCR, 1994). Ibrahim (2001) divides the sequential phases of the facility development life cycle process into *feasibility, entitlements, building permit, construction,* and *property management* phases. Ibrahim and Paulson (2005) found that among the unique environmental characteristics are 1) the facility development life cycle process consists of several sequential and concurrent phases; 2) each life cycle phase has different workflow process that requires different skill sets for the team to complete the tasks; 3) tasks in a workflow are interdependent with some tasks in another or several workflows of the life cycle phases; and 4) individual phase are dominated by different knowledge type (i.e. tacit versus explicit knowledge). Ibrahim and Nissen (2005) further refined the four environmental characteristics into three constructs for the development of a knowledge-based organizational performance model: *knowledge flow, work complexity,* and *team knowledge transaction.* Knowledge flow (Nissen in review) includes explicitness, reach, life cycle, and flow time of dominant knowledge in a phase. Work complexity considers the ratio of tasks and workflow concurrency in the complex process. Team knowledge transaction addresses the discontinuous nature of the team members in response to the knowledge flow within the organization, and several studies have recommended further research on the effects of knowledge flows on organizational performance due to this discontinuous attribute (Ibrahim and Paulson, 2005; Ibrahim, Shumate, et al., 2005).

4.3.2 Knowledge Flow Dynamics

Knowledge management is increasingly concerned in the design of organizations, the effects of knowledge flow on organizational performance is emerging as the measuring factor on how scholars reviewed knowledge flow in organization (Nissen and Levitt, 2002). The development of literature concerning knowledge transfer is recent (Alavi and Leidner, 2001; Carlile and Rebentisch, 2003) where scholars noted abundance of knowledge management literature in the areas of knowledge creation, knowledge storage, and knowledge retrieval. The study of knowledge flow dynamics is recent (more so since Nonaka, 1994). Central to knowledge transfer scholars' arguments (e.g., Nonaka, 1994; Kogut and Zander, 1992) is that knowledge is held by individuals, and regularities in an organization depict the success of knowledge transfer in an organization. Nonaka (1994) supports that knowledge resides within individuals and organizational membership play a critical role in articulating and amplifying that knowledge. Kogut and Zander (1992), however, pose that firms are more successful in transferring knowledge within organizations than between organizations. Nonaka (1994) proposes four modes of knowledge transfer mechanism—*socialization*, *externalization, combination, and internalization* (SECI)—for internal and external knowledge transfer of an organization. The SECI mechanism is a dynamic spiral epistemological relationship between tacit and explicit knowledge as it extends its ontological reach from individual to inter-organizational of that organization.

Nissen (2002) extends Nonaka's dynamics of knowledge flow theory by integrating the life cycle process of knowledge flow through the enterprise: 1) creation, 2) organization, 3) formalization, 4) distribution, 5) application, and 6) evolution. This six-step knowledge life cycle was an amalgamation of earlier views of knowledge life cycle, which were proposed by Davenport and Prusak (1998), and Depress and Chauvel (1999). Von Hippel (1994) coined the term 'stickiness' on how needed info can 'stick' with the problem-solving capabilities in a different location. Stickiness connotes the difficulty experienced in the process in which an organization recreates and maintain a complex, causally ambiguous set of routines in a new setting (Szulanski, 2000). In Nissen's later work (under review), he states that new organizational forms may obtain and even dominate through a focus on dynamic knowledge flows. Nissen's work provides discrete qualitative categories for potential operationalization of knowledge flow in enterprise, but yet to be measured empirically. His four knowledge flow dimensions are *type* of knowledge (tacit versus explicit), *level of socialization* associated with the knowledge (individual, group, organization, and inter-organization), activities of *knowledge work* (create, share, apply, etc.), and *flow time*.

In order to understand knowledge creation by individuals, Grant (1996) conceptualizes that the firm is an institution for integrating knowledge at the next organization level. Grant attempts to devise mechanisms for integrating individuals' specialized knowledge. He proposes four mechanisms to coordinate the integration of knowledge within an enterprise: (a) having rules and directives to enable the conversion of tacit knowledge to explicit knowledge; (b) sequencing of the workflow process that minimizes communication, but ensures the input of expert in a different time slot; (c) creating routines to support complex patterns of interactions between individuals in the absence of rules, directives, or even significant verbal communication; and (d) establishing group problem solving and decision making. The resulting knowledge-based firm theory has implications for the basis of organizational capability, the principles of organization design (in particular, the analysis of hierarchy and the distribution of decision-making authority), and the determinants of the horizontal and vertical boundaries of the firm. Grant's knowledge-based view of the firm encourages us to perceive interdependence as an element of organizational design and the subject of managerial choice rather than exogenously driven by the prevailing production technology. Grant emphasizes knowledge application and the role of the individual as the primary actor in knowledge creation and the principal repository of knowledge.

However, he points to further research need on knowledge-based theory of the firm that will embrace knowledge creation and application.

4.3.3 Organization

We also reviewed literature on organizations to see whether it would enlighten the knowledge-dominant difference within different life cycle phases. However, much literature concentrates on the organization formation and behavior (March and Simon, 1958; Cyert and March, 1963; Galbraith, 1974; Mintzberg, 1992; Scott, 1998; Burton and Obel, 2003). Most focus upon hierarchy as the basic structure for organizing complex social activity where cooperation among members is achieved through vertically imposed bureaucratic processes (Grant, 1996). March and Simon (1958) identify the use of rules or program to coordinate behavior between interdependent subtasks. Galbraith's *information-processing* model is an extension of Lawrence's and Lorsch's (1967) *contingency theory* where the efficiency of an organization depends upon it adapting to its environmental context. The *information-processing* model of organization (Galbraith, 1974) proposes that decision-makers need to process information well during exception-handling if the organization wants to perform well. Galbraith argues that the greater the task uncertainty, the greater the amount of information that participants in an organization must process.

As an organization faces greater uncertainty, its members face situations for which they have no rules. At this point, the hierarchy is employed on an exception basis (ibid., p. 86) where lower-ranked staff would seek guidance or information from their supervisors. Built upon Galbraith's *information-processing* model of organization, Burton and Obel (2003) extended the *contingency theory* and developed six *contingency factors* for *contingency fit* during the design of organizations. They are *management style*, *climate*, *size/ownership*, *environment*, *technology*, and *strategy*. Since organization theory has emphasized vertical information-processing structure in organization design, non-hierarchical information-processing structure for decision-making is of particular interest to us. Recent scholars such as Lambert and Shaw (2003) have turned to Wegner's (1987) transactive memory theory to explain the existence of this non-hierarchical information-processing structure in organizations. We would like to explore the possibility of integrating transactive memory theory with Galbraith's (1974) information-processing theory in organization design.

4.3.4 Transactive Memory

A follow up study by Ibrahim, Shumate, et al. (2005) on Ibrahim and Paulson's (2005) study also recommends the integration of non-hierarchical information-processing within the common hierarchical information-processing of an organization. An emerging theory, which is establishing itself as the prime foundation for this purpose, is Wegner's (1987) *transactive memory* theory. Transactive memory theory involves understanding the informal knowledge transfer—communication to retrieve or allocate information—between individuals in an organization. Wegner (1987; in Hollingshead, 1998), describes transactive memory as a shared system for encoding, storing, and retrieving information. The three key processes of a transactive memory system are (a) directory updating, where people learn what others are likely to know; (b) information allocation, where new information is communicated to the person whose expertise will facilitate its storage; and (c) retrieval coordination, which is a plan for retrieving needed information on any topic based on knowledge of the relative expertise of the individuals in the memory system.

Wegner (1987) and later Moreland (1999) posed that organizational teams may act like a large brain, where individuals store information to be combined with others. When individuals in that team need information they go to the "expert node" or expert member. When individuals gain new information related to a particular expert area, they allocate it to an "expert node". As individuals gain new information through experiences about the expertise of the others in their "brain", they update their individual directory of where information should be and is stored. Ibrahim, Shumate, et al. (2005) hypothesized that the behavior of members in transferring knowledge among them are similar between a discontinuous and a stable organization. Although the purpose of this project is determining the impact of knowledge flow processes in discontinuous membership teams, we too expect similar patterns posed by transactive memory theory.

> (H1) A *continuous* member in a dynamic organization, who possesses an accurate cognition of his other team members' knowledge skill, will be able to utilize his knowledge network to maintain the organization's performance when he turns to other team members to complement his incomplete cognitive skills.

A number of communications scholars, (such as Monge and Contractor (2004); Contractor, et al. (in review); and Yu Yuan, et al. (in review)) are examining the social influence on development of knowledge networks among individuals. Other contemporary scholars (such as Lambert and Shaw, 2002; Hollingshead, 1998) are studying whether or not hierarchical decision-making process is applicable in today's fast-track project delivery. Lambert and Shaw (2002) merge *transactive memory* theory

(Wegner, 1987) with the information-processing views of organizational work processes. Lambert and Shaw argue that in current high-technology environment where participants have equal access to information, organizations can minimize the need to perform hierarchical decision-making process if participants know from whom to seek information from. While Lambert and Shaw focus on "who knows what", Hollingshead's (1998) study focuses on the function of communication behaviors. Lambert and Shaw, and Hollingshead do not consider the expertise level of knowledge the enterprise possesses. In addition, Ibrahim and Nissen (2005) suggested integration of non-hierarchical information-processing for better representation of dynamic knowledge flows within an organization.

Transactive memory is more important in temporal organizations where most members have the skills and expertise to perform their tasks independently or as peers in product development project teams (Ibrahim, Shumate, et al. 2005). The system may operate more effectively in teams where individuals have higher interdependence and have developed a more convergent cognitive map of tasks-person-expertise relationships (Brandon and Hollingshead, 2005). Ibrahim, Shumate, et al. (2005) explains that the knowledge of "who knows what" enables peers to consult independent team members in order to complete their own tasks, especially when their supervisor lacks the cumulative level of expert knowledge needed of all the team members combined. In a temporal organization, in particular, the supervisor primarily acts as a bridge spanner or the chief coordinator. There is a thin line of hierarchical authority in such situation. Thus, other experts in the team may have more specialized expertise than the supervisor. A product development team, specifically the facility development organization, reflects a norm of discontinuous membership while the team works on the workflow process (Ibrahim and Paulson, 2005). In this instance, Ibrahim, Shumate, et al. suggest that the transactive memory in knowledge flows may be governed by two additional mechanisms. The first mechanism is seeking information from a mediator when one's directory of expertise is incomplete. Wegner (1995) describes this process of seeking information as taking on a higher dimension, when team members need to know "who knows who, who knows what." For example, the remaining team members would know "who knows what" and can provide the resource to newly joined team members when they seek information. The second mechanism particular to discontinuous membership teams may be to seek information from those who were in the previous phase of the project and to allocate information to those who will continue in the next phase of the project (Ibrahim, Shumate, et al., 2005). In this mechanism, it is not proper embedding of knowledge in experts, but continuing the life of the knowledge that is the key factor governing knowledge flow patterns (ibid.).

Wegner (1987) acknowledges that an effective transactive memory system has several advantages for a group process. Foremost is the expansion of an individual's expertise when the individual gains others' domains of expertise. Another is that an individual also gains access to new knowledge that is created through integrations occurring within the transactive process. Integration affirms the need to have a group in the first place, showing all members the utility of coming together to remember because the group exerts a strong directive pressure on what is to be encoded, stored, and retrieved and places a special premium on integrative transactions (ibid.). The third advantage is the possibility of others processing the knowledge and making decisions even when the individual is not available. Finally, Mooreland (1999 in Ibrahim, Shumate, et al., 2005) finds that groups that develop effective transactive memory systems can complete tasks more efficiently. In our study, we would like to determine if the effective transactive memory systems in stable membership organizations will apply equally to discontinuous membership organization.

Despite the advantage of a group having a larger pool of knowledge expertise, the transactive memory system is prone to errors made by individual members (Wegner, 1987). Several sources for errors are 1) the label that is used at the beginning of the transactive retrieval attempt can be translated into another label by another member, 2) incomplete specification of paths of knowledge responsibility within the group may leave certain individual not knowing who is expert in important domains of knowledge, 3) lack of information when other members were left out during the creative reproduction of different retrieved knowledge, and 4) low quality information could cause a group to make poor decisions. The biggest disadvantage is that when a group dissolves, formerly interdependent individuals are left with useless and potentially troublesome individual remnants of what was once a transactive system. Similarly, Ibrahim, Shumate, et al. (2005) propose that when a new member joins in, he would not know what others had done or their knowledge expertise.

> (H2) A *discontinuous* member, who does not have an accurate cognition of his other team members' knowledge skills, can put the organization at risk when he turns to other team members to complement his incomplete cognitive skills.

4.3.5 Knowledge Flow and Computational Organization Theory

To study knowledge flow in organizations, three items are important: the process under study, the organization responsible, and how they are connected. Both process and organization must be linked because the flow of knowledge is assumed occurring with the passage of time as the process progresses. We found the Virtual Design Team (VDT) tool closest in fulfilling our needs. In fact, the first attempt to simulate knowledge flow in organization design using a computational organization (COT) tool was made by Nissen and Levitt (2002) using VDT. In their study, they draw upon current research advances in COT to describe a dynamic representational environment used for formal organizational modeling, and employed this environment to describe a computational model of an enterprise's knowledge-flow process. Their reason for utilizing the Virtual Design Team (VDT) Research Program was due to its established reputation as a planned accumulation of collaborative research over two decades to develop rich theory-based models of organizational processes. VDT uses an agent-based representation (Cohen, 1992; Kunz et al., 1998) that conducted research on micro-level organizational behaviors, which were formalized to reflect well-accepted organization theory (Levitt et al., 1999). Extensive empirical validation projects (e.g., Christiansen, 1993; Thomsen, 1998) further established its reliability. Nissen and Levitt (2002) also describe the limitation of VDT. Unlike mathematical representations and analyzable micro-behaviors of physical systems, the dynamics of organizations are influenced by a variety of social, technical and cultural factors, and are difficult to verify experimentally (ibid.) they are yet amenable to numerical representation, mathematical analysis or precise measurement (ibid.). Nissen and Levitt expect ambiguity when people and social interactions—distinct from physical systems—drive the behavior of organizations.

Nissen and Levitt (2002) point the advantage of the VDT tool to its well-embedded time-tested collection of micro-theories that lend themselves to qualitative representation and analysis. Among the collection are Galbraith's (1974, 1977) information-processing abstraction, March and Simon's (1958) bounded rationality assumption, and Thompson's (1967) task interdependence contingencies. Although the representation is qualitative (e.g., lacking precision offered by numerical models), Nissen and Levitt (2002) accept that it becomes formal (e.g., people viewing the model agree on exactly 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) through computational modeling. Once a model has been validated to accurately emulate the qualitative behaviors of the field organization it represents, it can be used to examine a multitude of cases under controlled conditions, hence, offering great promise for theory development (ibid.). The approach they took to modeling knowledge flow dynamics was due to the strong integration of qualitative and quantitative models, enhanced by strong reliance upon well-established theory and commitment to empirical validation, that their study differs from extant knowledge-flow research to provide new insight into the dynamics of organizational behavior. While we support their arguments in our attempt to extend Wegner's (1987) transactive memory in Galbraith's (1974, 1977) information-processing concept, Ibrahim, Shumate, et al. (2005) provide an empirical support that affirmed the existence of such non-hierarchical process. Ibrahim, Shumate, et al. found different knowledge flow behaviors caused by the different explicitness level of the knowledge areas involved in a process where while functional expertise is reliable to facilitate knowledge flow in explicit-dominant process, tacit-dominant process relies on the presence of the organization's members during that process.

4.4 RESEARCH METHOD

Computational Organization Theory Tool (SimVision®)

We use SimVision®, educational version 3.11.1, which was developed by Vité Corporation and is licensed from ePM, LLC, Austin Texas. Refer http://www.epm.cc/ for details.

A virtual concept design project

Using SimVision®, we created an idealized work process model consisting of ten sequential and concurrent tasks conducted by seven team members to represent a hypothetical conceptual design project (see Figure 4-1). In SimVision®, a project is modeled as a set of graphical objects that represent the work process performed by members of one or more organizations to achieve a key business milestone. Each project is composed of tasks, milestones, positions, meetings, and the links among these components. We analyze this virtual conceptual design project at the *Project* level.

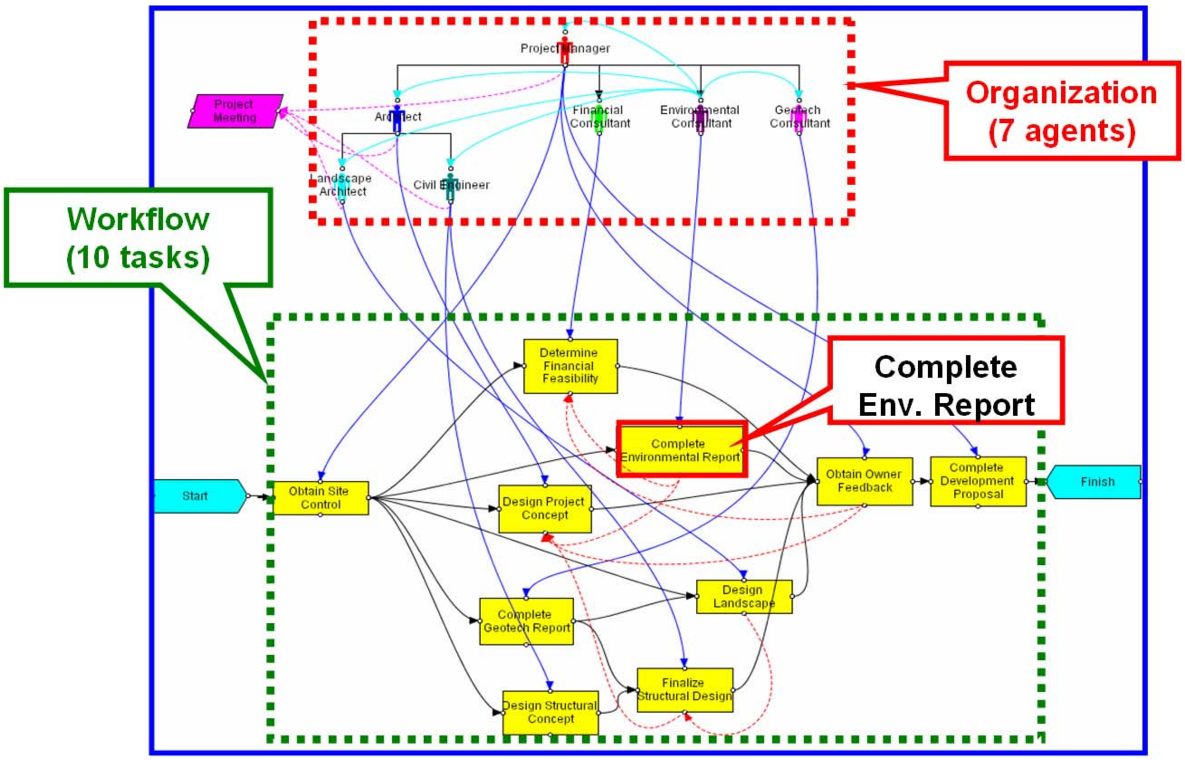

Figure 4-1. The organization and workflow for the hypothetical concept design project.

Test Case 1: Baseline

We set the project parameters to MEDIUM for *team experience,* LOW for *centralization,* MEDIUM for *formalization,* MEDIUM for *matrix-strength,* 0.70 rating for *communication-probability, 0.15* rating for *noise-problem,* and 0.15 rating for *project-exception-probability.* Due to having a small number of task volumes in the test cases, we set the behavior parameters for *noise-problem*, *functional-exception-probabilities,* and *project-exception-probabilities* somewhat higher than the normal construction industry practice in order to amplify the effects of knowledge flows on outcomes.

Team members' parameters. Table -11 lists the organization's micro-behaviors and knowledge skills (K-skills). The micro-behaviors include *fulltime-equivalent* (FTE), *role, application experience,* and *salary*; while the knowledge skills we represented are *architectural-engineering-construction* (AEC), *regulatory and authority requirement* (RAR), and *development project finance* (DPF). We selected the environmental consultant (EC) to test the accuracy of an agent's knowledge network (Knetwork) in this organization. Table 4-2 lists the accurate and inaccurate cognitive perception by the EC towards the other agents in the organization. Each cognitive perception is appointed LOW, MEDIUM, or HIGH expertise. For the Baseline case, all six knowledge links in the EC's Knetwork have similar K-skill cognitions as the members' K-skills in the *project*'s position.

Table 4-1. Baseline Parameters for Discontinuous Membership Organization

ID	POSITION	INI	MICRO-BEHAVIORS				KNOWLEDGE SKILLS		
			FTE	ROLE	APP EXP	SALARY	AEC	RAR	DPF
1	Project Manager	PM	0.3	PM	M	80	M	M	M
2	Architect	AR	1.0	SL	H	150	H	M	L
3	Civil Engineer	CE	0.5	ST	H	140	M	M	L
4	Landscape Architect	LA	0.5	ST	M	100	M	L	-
5	Financial Consultant	FC	1.0	ST	H	200	-	H	H
6	Environmental Consultant	EC	1.0	ST	L	100	L	L	-
7	Geotech Consultant	GC	1.0	ST	M	100	M	L	-

Table 4-2. Environmental Consultant's Knowledge Cognition of Other Team Members in Baseline and X-Baseline Cases

EC's Knowledge Cognition	PM	AR	CE	LA	FC	GC
Accurate (Baseline)	M	M	M	L	H	L
Inaccurate (X-Baseline)	L	L	M	M	-	M

Test Case 2: X-Baseline

X-Baseline case is the inaccurate Knetwork model. It has similar project parameters as the Baseline model. To represent the inaccurate knowledge cognition (see Table 4-2), we made several changes to the team members' parameters. Two members (e.g., PM and AR) who have HIGH K-skills to solve the exception were changed to low, so the new member will miss the opportunity to obtain correct feedback. The two LOW K-skilled members (LA and GC) were assigned higher skill levels, so that the new member will obtain incorrect feedback. Only one member out of the five in the new member's Knetwork has the accurate K-skill to solve the exception.

Analysis Method

We ran 50 trials for each simulation, and made ten simulation runs (N=500). We compared the Baseline and X-Baseline cases on selected performance variables at *project, task,* and *position* levels.

Limitation and validation

This computational simulation experiment was conducted and validated only for an idealized case—i.e., "Intellective Validation" (Thomsen, et al., 1999)—to emulate the behaviors of an idealized organization with discontinuous membership. Although idealized, the organization's staffing is relatively closely based on an earlier Knetwork study using knowledge network analysis (Ibrahim, Shumate, Levitt, Contractor, 2005). We ran the same simulations ten times to provide us a larger population, N = 500 trials, which we perform a two-tail t-test at 95% for each parameter we compare.

4.5 FUNCTIONAL EXCEPTIONS PARAMETER EXTENSION FOR KNOWLEDGE NETWORK

There are two types of exceptions generated by VDT-Knetwork (VDT-KN) model: *project exceptions* and *functional exceptions.* All project exceptions will be processed via the normal hierarchical information-processing method of VDT (Jin and Levitt, 1994). The VDT-KN extension simulates generation of functional exceptions, and how agents handle them within the agent's Knetwork. We describe below the manner how the functional exceptions will be handled via the Knetwork information-processing methodology. Based on H1—when an agent seeks other members in his Knetwork to complement his incomplete cognitive skill—the VDT code will randomly decide who to pass the exception to basing on the perceived K-skill level of the agents. The following steps explain the iteration and the affects on the project, task, and position caused by the flow of exception-handling by various agents in the organization.

Step 1: Generation of functional exceptions from task. A task is divided into twenty sub-tasks. When a subtask is completed (i.e., when one work-day is completed for tasks requiring more than 20 days to complete), a task-functional-exception-probability will generate a functional exception. The initial task-functional-exception-probability is a function of the project-functional-exception-probability, requirement complexity, and K-skill of the agent. The factor for the requirement complexity is 1.5 if HIGH, 1.0 if MEDIUM, and 0.67 if LOW. The K-skill factor of the agent corresponds to his application experience. When the assigned agent has the required skill, his skill factor corresponds to his application experience. The higher the application experience he has, the lower the number of exceptions will be generated. For example, if the assigned agent has HIGH application experience, his K-skill factor is 0.5 compared to 0.7 and 0.9 for a MEDIUM or LOW application experience. If the assigned agent's K-skill does not match the task's required K-skill, the application experience is set at default at 2.0 for HIGH, 2.5 for MEDIUM, and 3.5 for LOW. It means that there will be more exceptions being generated when the K-skill does not match the task requirement.

Step 2: Who to pass the exception to? When a functional exception is generated, the assigned agent will either resolve the exception himself, or send it to a member of his Knetwork with the same or higher perceived rating of the K-skill required by the task. If there is at least one Knetwork member with that skill, the probability that it will be passed to the network is determined by the assigned agent's K-skill rating. The passing to his Knetwork rate is 0.2 if HIGH, 0.5 if MEDIUM, and 0.8 if LOW or NONE respectively. This means that if the agent has higher K-skill, he tends to resolve the exceptions himself while a low K-skilled agent tends to pass the exception to his Knetwork for solution. When the exception is passed to the agent's Knetwork, and if there is more than one agent in his Knetwork with the highest skill, one agent is selected at random.

Step 3: Affects on coordination volume. Whenever an exception is generated, the assigned agent or the agent in his Knetwork who received the exception will increase his coordination volume due to the additional workload. The coordination volume is increased by a factor of 0.15 times the subtask's volume.

Step 4: How does the agent respond to an exception? The selected functional agent who will decide on the outcome of the exceptions will make a decision according to his rating on the K-skill required by the task that generates the exception. When the agent's K-skill level is higher, there is a greater likelihood that the agent will require reworking the subtask. This reduces the likelihood of future exceptions. For example, if the agent's K-skill is HIGH; the factors for rework, correction, and ignore are 0.65, 0.30, and 0.05 respectively. If the agent's K-skill is MEDIUM, the factors for rework, correction, and ignore are 0.40, 0.40, and 0.20 respectively. And if the agent's K-skill is LOW, the factors for rework, correction, and ignore are 0.05, 0.35, and 0.60 respectively.

The agent who is assigned to handle the exception will incur additional coordination volume due to the additional workload of processing the exception. The coordination volume increases by a factor of 0.10 times the subtask's volume. In addition, if the decision was to rework the subtask, the rework volume of the task that generates the exception increases by a factor of 1.0 times the subtask volume. If the decision was to correct the subtask, the task's rework volume is increased by 0.5 times the subtask volume.

Step 5: Affects on the functional error probability. The functional error probability of the exception task will be adjusted according to the decisions made by the agent who makes decision on the exception. It is based on the decision-maker's K-skill and the type of decision he makes. The probability adjustment is:

1.0 + (decision-weight – 1.0) * volume-weight, where

the volume-weight is a subtask's work volume of 8 hours. The decision-weight depends on the agent's K-skill. If the agent's K-skill is HIGH, the rework factor is 0.90, the corrected factor is 0.95, and ignored factor is 1.05. On the other hand, if the agent's K-skill is LOW, the rework factor is 0.95, the corrected factor is 1.10, and ignored factor is 1.20. The functional error probability reflects the need to do rework on a task when exceptions are being ignored by less K-skilled agent. The higher the functional error probability, the higher the functional risk index is.

4.6 RESULTS AND ANALYSIS

Our computational simulations illustrate that a new member in a discontinuous membership organization who uses his inaccurate cognition of his other team members to complement his incomplete cognitive skill, can expose his task to higher risk of failure, which in turn can be detrimental to his overall team's organizational performance in the long run. The results support H1 and H2, and subsequently our main research question on how knowledge flows can impact the organizational performance of a discontinuous organization. At the *project* level (see Table 4-3), there is minimal change to the overall *simulated durations* and *total work volumes* of both Baseline and X-Baseline cases. *Rework volume* is reduced (by 10%) in the X-Baseline case because less skilled team members are ignoring the exceptions that the EC had allocated to them for solutions. The *coordination volume* shows a slight increase because the positive and negative increments of multiple members roughly cancelled one another out. On the other hand, the *wait volume* has a huge increase (57%) in the X-Baseline case because more exceptions are occurring due to increasing error rate caused by inaccurate Knetwork's skill matching. The *project's FRI* increases from 0.346 to 0.535 respectively from the Baseline to X-Baseline case. *FRI* is a measure of the likelihood that components produced by a project have defects. In the X-Baseline case, the EC's task to *complete environmental report* has a higher likelihood of having errors.

Table 4-3. Comparison of Selected Organizational Performance Measures for Continuous Versus Discontinuous Membership

PERFORMANCE MEASURES	BASELINE (SD)	X-BASELINE (SD)	PERFORMANCE CHANGE
PROJECT			
Simulated Duration (days)	189.259 (7.059)*	189.048 (8.119)*	0%
Total Work Volume (days)	119.052 (3.673)*	119.709 (4.768)*	+1%
Rework Volume (days)	13.161 (2.445)*	11.828 (2.619)*	-10%
Coordination Volume (days)	11.853 (0.790)*	12.119 (1.081)*	+2%
Wait Volume (days)	3.037 (1.844)*	4.762 (1.881)*	+57%
FRI	0.346 (0.073)*	0.535 (0.067)*	+0.189
TASK			
FRI	0.315 (0.101)*	0.667 (0.076)*	+0.352
Functional Exceptions Probability	0.197	0.479	+0.282
Rework Volume (days)	7.084	5.713	-19%
Coordination Volume (days)	1.400	1.685	+20%
Wait Volume (days)	2.865	4.554	+59%

Note: * $p < 0.05$ (two-tail t-test); N=500

At the *task* level, the *FRI* in the X-Baseline case doubled from 0.315 to 0.667 from the Baseline case. The *functional exception probability* increased by 0.282 points. This is because the error rate increased when the EC allocated and retrieved inaccurate solutions for his exceptions from lesser skilled members. In VDT's organizational design recommendation, the high *FRI,* coupled with a large increase in the *functional exceptions probability* rate highlights that the *complete environmental report* task requires urgent attention and action by the *project manager* or the assigned member responsible for the task. The task also reflects the reduction in rework (-19%) due to the lesser K-skilled member's propensity to ignore exceptions. *Coordination volume* increased (20%) because more exceptions were generated that required coordination attention by the EC, while the *wait volume* reflects a big increase of 59% due to the increase of error rate made by more frequent occurrence of exceptions.

At the *position level* (see Table 4-4)*,* we highlight the effects of inaccurate Knetwork on selected members. First is the environmental consultant (EC) who passed the exception to others in his Knetwork. The other two are the landscape architect (LA) and general contractor (GC) who were perceived as having higher K-skill levels, but did not. For the EC, his *total exception volume* increased by 24% due to the increasing error rate caused by passing exceptions to lesser skilled members in his Knetwork. His *rework volume* was reduced by 19% since the lesser skilled member advised or undertook to ignore the exceptions. His *coordination volume* increased by 10% since he is required to coordinate more due to the increasing number of exceptions. The EC has the biggest *wait volume* increase (59%) because he now has to wait for decisions on an expected larger number of exceptions. For the LA, his *total exception volume* had a small increase of 4%. His *rework volume* was only 1% since he was mostly likely to 'solve' the problem although it may be incorrect. However, his *coordination volume* increased by 22% since he had higher work volume due to the increasing number of exceptions being passed to him. In addition, the LA reduced his *wait volume* by 31% because he would 'solve' the exceptions himself, albeit incorrectly. For the GC, his *total exception volume* had no change. His *rework volume* was 10% because he did handle some exceptions correctly.

Like the LA, the CG increased his *coordination volume* by 31% due to higher work volume caused by increasing passing of exceptions to him. The GC had no *wait volume.*

Table 4-4. Comparison of Organizational Performance Measures for Selected Members

PERFORMANCE MEASURES	BASELINE (SD)	X-BASELINE (SD)	PERFORMANCE CHANGE
Environmental Consultant			
Total Exceptions Volume (days)	12.328 (2.331)*	15.315 (3.591)*	24%
Maximum Backlog (days)	7.929	9.368	18%
Rework Volume (days)	7.084	5.713	-19%
Coordination Volume (days)	3.384	3.730	10%
Wait Volume (days)	2.865	4.554	59%
Landscape Architect			
Total Exceptions Volume (days)	1.480 (0.662)*	1.534 (0.677)*	4%
Maximum Backlog (days)	1.714	1.692	-1%
Rework Volume (days)	0.784	0.793	1%
Coordination Volume (days)	1.755	2.147	22%
Wait Volume (days)	0.150	0.104	-31%
Geotech Consultant			
Total Exceptions Volume (days)	2.100 (1.446)*	2.105 (1.459)*	0%
Maximum Backlog (days)	2.176	2.292	5%
Rework Volume (days)	1.24	1.36	10%
Coordination Volume (days)	1.349	1.761	31%
Wait Volume (days)	0.000	0.000	0%

Note: * $p < 0.05$ (two-tail t-test); N=500

4.7 VALIDATION

We conducted an *intellective* model comparison (Thomsen, Levitt, et al., 1999) of our simulated model with an earlier ethnographic study (Ibrahim and Paulson, 2005) to compare the outcome. A two-tail t-test at 95% significance level was applied to the sample of 50 trials from N=500 trials. We found that H1 is positive, where a *continuous* member in a dynamic organization, who possesses an accurate cognition of his other team members' K-skill, is able to utilize his knowledge network to maintain the organization's performance when he turns to other team members to complement his incomplete cognitive skills. H2 is also positive, where a *discontinuous* member, who does not have an accurate cognition of his other team members' K-skills, can put the organization at risk when he turns to other team members to complement his incomplete cognitive skills.

We used a computational simulation model to test our hypotheses. The VDT model we used has been validated by many previous researchers (e.g., Thomsen et al, 1999), and fulfills the three key criteria for being used as a "theorem prover" (Burton and Obel, 1995) - reality, content, and structure - to examine hypotheses. Further validation is provided by cross-validating Ibrahim and Paulson's (2005) ethnographic study on discontinuity in organizations. Their study found discontinuous membership contributing to knowledge-loss in the facility development projects when an enterprise works on a complex process (i.e., which has multiple concurrent phases, high task interdependencies, etc.) in a dynamic environment (i.e., high on uncertainty, complexity, and equivocality).

4.8 DISCUSSION AND RECOMMENDATIONS

Our study demonstrates that discontinuous membership negatively affects the overall performance of an organization. Several implications emerge from this study. We present these implications, and recommend future studies in this discussion section.

First, the study supports another study on how discontinuous membership is a source for the well-known knowledge loss phenomenon in the facility development life cycle (Ibrahim and Paulson, 2005). A new member could cause the task he is handling to incur higher functional risk index, and in the long run could put the whole project at risk. The incomplete knowledge of prior history of a task or project can trigger an escalation of schedule delays and cost overruns. It is unfortunate that during the pre-construction phases in the facility development, any missing knowledge may force facility owners to decide not to proceed with the construction.

Second, the discontinuous attribute undermines Cohen and Levinthal's (1990) finding about the absorptive capacity of a firm, in which an organization builds upon its prior knowledge. Instead, the progressive build-up of a discontinuous organization's knowledge is weakened because former members would bring out the organization's knowledge while the rest of the team builds up its knowledge. Hence, the process emphasis that Scott (1998) recommends in an *open system* draws our attention and support to the organization as a system persisting over time. An open system exhibits an organizational structure that stresses the complexity and variability of the individual parts—individual participants and subgroups—as well as the looseness of connections among them. Multiple parts are viewed as capable of semiautonomous action, and are loosely coupled to other parts. In the open system, individuals and subgroups form and leave the coalitions, emphasizing the earlier *contingency theory* of Lawrence and Lorsch's (1967) arguments about the fluid movement between people and process while the process is still on-going.

Third, the study saw how regularities in the organization (Grant, 1996; Kogut and Zander, 1992) do help the organization to overcome a *position's* dynamism. The *project* could still move forward despite having a new position on board or after the position is omitted. This is evidenced by the lack of significant changes to the overall total work volume and the duration of project for both test cases. However, our intellective model reflects how a subtly incomplete Knetwork can impact negatively on the performance of the overall project as a well-established organization moves forward.

Fourth, there is a need to consider the integration of non-hierarchical (Wegner, 1987) with hierarchical information-processing (Galbraith, 1974) for contingency fit in organization design (Burton and Obel, 1998). The VDT-KN extension integrated Wegner's (1987) *transactive memory theory* into the Virtual Design Team's (VDT) computational organization simulation model to handle all the functional exceptions a task generates. VDT is a well-validated computational organization theory tool (Jin and Levitt, 1996; Burton and Obel, 1995) that uses Galbraith's (1974) hierarchical information-processing process to design organization, and the intellective model proves that such non-hierarchical information-processing affects organizational performance.

Our findings recommend that future organizational design must consider knowledge flow factor as posed by Nissen (in review). This study supports his view that an enterprise could obtain or dominate a new organization through a focus on dynamic knowledge flows. Nissen's work provides discrete qualitative categories for potential operationalization of knowledge flow in enterprise. His four knowledge flow dimensions are *type* of knowledge (tacit versus explicit), *level of socialization* associated with the knowledge (individual, group, organization, and inter-organization), activities of *knowledge work* (create, share, apply, etc.), and *flow time*. Further study is recommended to establish numerical measurements for these constructs. Moreover, another study by Ibrahim, Shumate, et al. (2005) affirms that tacit-dominant knowledge area shows different knowledge flow behaviors compared to explicit-dominant knowledge area. They found that transactive memory (Wegner (1987) is not happening in tacit-dominant knowledge area, but is very much supported in explicit-dominant knowledge area. They suggest that knowledge flows in tacit-dominant environment is more via socialization and internalization (Nonaka, 1994). Ibrahim, Shumate, et al. (2005) also conclude with similar recommendation to consider knowledge flow in the design of organization.

Further literature search in the communications field in sociology reveals that organizational communication scholars (Monge and Contractor, 2003) have in recent years established a new area to study emergent communication networks in their study of information flow in organizations. The traditional interpretation of a “formal” network (Weber (1947) in Monge and Contractor (2003)) was presumed to represent the channels of communication through which orders were transmitted downward and information was transmitted upward[7] (p. 8). On the other hand, “emergent” networks represent other than the vertical hierarchical characteristics of information-processing. It includes the

[7] See Scott (1998) explanation on *rational* system, referring to the technical or functional purpose of the organization to meet the implementation goals of the work process.

development of hierarchy through socialization outside the formal structure.[8] We equate the "emergent" network as synonymous to our non-hierarchical knowledge network. The rationale for studying this emergent communication networks is due to the fact that it:

> "……has evolved out of the inconclusive findings relating formal organizational structure to organizational behavior (Johnson, 1992, 1993; also see McPhee & Pole, 2001). Jablin's (1987) review of the empirical research on formal organizational structure variables such as hierarchy, size, differentiation, and formalization. More recently, a series of meta-analytic studies have concluded that the relationships between formal structure, organizational effectiveness (Doty, Glick, & Huber, 1993; Huber, Miller, & Glick, 1990), and technology (Miller, Glick, Wang, & Huber, 1991) are largely an artifact of methodological designs. The fact that formal structural variables have failed to provide much explanatory power has led several scholars to question the utility of further research on formal structures. Rather, they have argued that it is preferable to study emergent structures because they better contribute to our understanding of organizational behavior (Bacharach & Lawler, 1980; Krackhardt & Hanson, 1993; Krikorian, Seibold, & Goode, 1997; Roberts & O'Reilly, 1978; Roethlisberger & Dickson, 1939)
>
> - Monge and Contractor (2003, p. 9)

[8] Also see Scott's (1998) explanation of *natural* system, referring to the technical or functional purpose of the organization to meet the implementation goals of the work process.

In summary, since discontinuity in organizations affects organizational performance, several implications lead us to recommend two major areas for further research. First is in organization theory, where we recommend the consideration of knowledge flows in organization design. Second is in knowledge management systems, where we recommend the consideration of different knowledge type for better knowledge transfer mechanisms.

4.9 CONCLUSIONS

We used a computational organizational theory tool to understand how the flow of knowledge among team members impacts organizational performance in organizations with discontinuous membership. The study establishes that a new member in a discontinuous membership organization who uses his inaccurate cognition of his other team members to complement his incomplete cognitive skill, can expose his task to higher risk of failure, which in turn can be detrimental to his overall team's organizational performance in the long run. It illustrates the need to consider non-hierarchical knowledge networks as part of organization design for better accuracy in predicting organizational performance. This study contributes by merging Wegner's (1987) non-hierarchical *transactive memory* with Galbraith's (1977) vertical *information-processing* approach to the design of organization. It extends the virtual design team tool by integrating exception handling through non-hierarchical knowledge networks among peers, while establishing how knowledge flows can affect organizational performance when the organization has discontinuous membership.

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