DISCONTINUITY IN ORGANIZATIONS: DEVELOPING A KNOWLEDGE-BASED ORGANIZATIONAL PERFORMANCE MODEL FOR DISCONTINUOUS MEMBERSHIP

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ABSTRACT

Knowledge management research needs consistent and empirically supported theory for sound foundations. Our research seeks to understand how to extend established organization theory and emerging knowledge-flow theory to inform the design of organizations through development of empirical theory. Because knowledge flows enable workflows, and workflows drive performance, theory suggests the organization of knowledge—particularly tacit knowledge—is critical for competitive advantage. However, tacit knowledge does not flow well through the enterprise. It attenuates particularly quickly in organizations that experience discontinuous membership. The research described in this article builds upon an ethnographic study of facility development to understand the knowledge-flow patterns and pathologies in an organization that experiences severe discontinuous membership. Informed by ethnography, we employ methods and tools of computational organization theory to assess alternate organizational designs and knowledge-flow patterns. This work extends organization theory to address the dynamics of knowledge flows. And it informs practice through new theory on designing organizations with discontinuous membership.

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1. INTRODUCTION

Knowledge management research needs a consistent and cohesive theory supported by empirical evidence to provide sound and stable foundations for the field (Edwards et al. 2003). Our research seeks to understand how to extend established organization theory and emerging knowledge-flow theory to inform the design of organizations through development of empirical theory. Because knowledge flows enable workflows, *and workflows drive performance,* they are essential to organizational performance wherever knowledge and information work are involved. Moreover, theory suggests the organization of knowledge—particularly tacit knowledge—is critical for competitive advantage (Nonaka 1994; Carlile and Rebentisch 2003). This is the case in particular where different types of knowledge (e.g., *tacit, explicit*) exhibit different knowledge-flow behaviors (Ibrahim et al. 2005a).

The problem is, tacit knowledge does not flow well through the enterprise (Nissen 2002). Rather, it "sticks" (von Hippel 1994) predictably in specific people, organizations, places and times (Nissen 2005b). Moreover, tacit knowledge flows attenuate particularly quickly in organizations that experience discontinuous membership. More debilitating than personnel turnover—which has its own impact on impeding knowledge flows—discontinuous membership involves the coming and going of *organizational roles* (i.e., in addition to the people who play them) or *positions* during work performance (Ibrahim and Paulson 2005). Both tacit and explicit knowledge are lost routinely in such environments. And organizations that experience discontinuous membership find it difficult to learn over time and across projects. Even more insidious, however, such organizations find it difficult to remember even what they have learned before or what they know already. Plus, far from a rare occurrence or freak phenomenon, discontinuous membership affects a broad cross section of organizations, particularly those engaged in project work (e.g., automotive design, building construction, military operations). Unfortunately, little is known today about how to design organizations in a manner that mitigates or obviates the impact of discontinuous membership and that amplifies knowledge flows despite a dynamic mix of participating organizational roles.

The research described in this article builds upon an ethnographic study of facility development to understand the knowledge-flow patterns and pathologies in an organization that experiences severe discontinuous membership. Previous research has shown facility development to be a rich domain for the study of knowledge-flow patterns (Ibrahim and Nissen 2003). In particular, the creation, sharing and use of tacit knowledge are critical during the early phases (e.g., feasibility and entitlements) of the facility development life cycle process (Ibrahim et al. 2005a). Ibrahim (2001) describes this life cycle as the sequence of process activities associated with developing a new facility, and is comprised of five sequential phases: *feasibility, entitlements, building permit, construction, and property management*. The feasibility phase starts as soon as a landowner reviews a parcel with the idea of building. This first life-cycle phase ends when the landowner formally applies for a development permit. The succeeding entitlements phase begins with the formal application for development permit and ends when construction commences at the site. Knowledge flows are particularly important during these two early phases, when the majority of influential decisions are made (Paulson 1976). Poor knowledge flows can cause severe project setbacks in terms of rework and delays (Jin and Levitt 1996). Such severe impacts are common in the construction industry among others.

For instance, Ibrahim and Paulson (2005) describe how a facility developer, using his accumulated tacit knowledge and experience, agreed with a city's authority to maintain an oak grove at one corner of a property site planned for new development. A few months into the facility development process, his building permit was rejected, because the mechanical engineer had submitted a building plan that routed the water piping system through this oak grove. From the perspective of the mechanical engineer (ME), using his accumulated tacit knowledge and experience, this pipe-routing plan was logical and reflected high professional competence. That corner was the location for all major water in-take points to the site, and that route would be the cheapest since it was the shortest.

In terms of knowledge flows, the organization had no process through which discontinuous members such as the ME—that started participating later in the facility development life cycle—could learn easily about commitments made by the developer—who was both knowledgeable and experienced—in an earlier phase of the project. Notice this knowledge-flow error involves more than a simple mistake of missed communication. The developer, relying upon the architect as the main architectural-engineering design coordinator and the ME's professional competence and experience, assumed that the oak grove preservation would be integrated automatically. The architect, who provided the architectural documents to the ME, was present during the city council's meeting. Neither did the ME think to inquire about or read through a file of development commitments. The architect's document is usually taken as 'the basis' for his professional services. Here, knowledge in one part of the life-cycle process (i.e., known by the developer) failed to flow to another (i.e., to the ME).

Even more disturbing than this costly mistake is the fact that similar knowledge-flow problems are pervasive, even when a facility development organization has explicit information or maintains one development project manager throughout the facility development life cycle process (Ibrahim and Nissen 2005). Given the knowledge possessed in different parts of the organization, at different times, by discontinuous members, the developer could have known about the pipe-routing problem, and the ME could have known about the oak grove commitment. But the ME did not. The organizational design and knowledge-flow patterns precluded him from knowing. This phenomenon causes us to question some tenets of absorptive capacity theory (Cohen and Levinthal 1990; e.g., that an organization's current knowledge builds upon its prior knowledge). In our facility development example, the prior knowledge was possessed and known in the organization (e.g., separately by the developer and the ME), and explicit knowledge of both the oak grove commitment and main water connection point existed (Ibrahim and Paulson 2005). But knowledge possession is insufficient apparently to guarantee knowledge flows and appropriate action. And the existence of explicit knowledge is insufficient apparently to guarantee that it will be used.

Through the balance of this article, we describe theoretical foundations for a model of knowledge-based organizational performance where discontinuous membership affects the organization. The following Section 2 reviews a focused segment of the literature and presents how this study departs from present organization and knowledge-flow theories. Section 3 explains how we can extend a computational organization modeling tool to emulate the dynamic behaviors of knowledge flows discovered through investigation of the facility development life cycle process. We develop a computational organization theory (COT) case study model in Section 4; and present the results, analysis, and validation methodology in Section 5. Then, we discuss how we can further develop additional contingency parameters for the design of organizational fit. We conclude with key insights from the study, practical implications for the manager, and recommendations for future research along the lines of this investigation.

2. Literature Review

Two areas of the literature are particularly important in this study of organizational design with discontinuous membership: 1) information processing in organizations, and 2) knowledge-flow dynamics. We summarize each in turn.

2.1 Information Processing in Organizations

From the organization literature, we find much concentration on organization formation and behavior (March and Simon 1958; Cyert and March 1963; Galbraith 1974 and 1977; Mintzberg and Westley 1992; Scott 2003; Burton and Obel 2003). Most researchers focus upon hierarchy as the basic structure for organizing complex social activity. Cooperation among members is achieved through vertically imposed bureaucratic processes (Grant 1996; Weber 1947). Rules and programs to coordinate behavior between interdependent subtasks are used (March and Simon 1958).

Galbraith's (1974 and 1977) *information-processing* model is an extension of *contingency theory (*Lawrence and Lorsch 1967). The efficacy of an organization depends upon its *fit* with the environment and other contextual factors. Scott (2003) explains that people and tasks are organized to attain specific goals reflecting a *rational* view. The *natural* view perceives organizations first and foremost as "collectivities" with many seemingly irrational aspects.

In this study, we focus in particular on the rational *information-processing* model of organization (Galbraith 1974 and 1977). But we incorporate some irrational inputs of natural systems. Ibrahim and Paulson's (2005) ethnographic study demonstrates that the complex facility development life cycle (assumed as impossible to standardize in Carillo et al. 2004) can be rationalized with the understanding of several sequential or concurrent workflows combined with the identification of critical convergent points. The key to integrating the *natural* irrational environmental factors is by ensuring the linkages of interdependent tasks among the multiple workflows (Grant 1996).

Galbraith (1974 and 1977) proposes that decision-makers need to process information well during exception-handling for the organization to perform well. Galbraith argues that the greater the task uncertainty, the greater the amount of information that participants in an organization must process. Similarly, when an organization faces greater uncertainty—such as in the facility development's operating environment—its members face increasingly frequent situations for which they have no sufficient organizational routines (Nelson and Winter 1982 in Scott 2003) or rules to guide their decision-making or to inform their work performance. In such an environment, and when the structural hierarchical information-processing is in place, the norm is for lower-ranked staff to seek guidance or information from their supervisors to handle these exceptions. The ME in the oak grove case, for example, had to refer to the architect who was the design leader to inform him of the building approval's rejection.

Burton and Obel (2003) extend this contingency perspective through development and articulation of six contingency factors to guide organizational design: *management style*, *climate*, *size/ownership*, *environment*, *technology*, and *strategy*. This extension of contingency theory has been formalized via a scholarship-based expert system (Nissen 2005c) called Organization Consultant (Burton and Obel 2003) that employs automated inference to support theory-based design of organizations. Despite years of successful description and explanation, however, the structural emphasis during information-processing is becoming inadequate to explain the emerging knowledge network workforce (Monge and Contractor 2003; Ibrahim et al. 2005a; Ibrahim et al. 2005b). Monge and Contractor (2003) rationalize studying *emergent communication networks* when findings are inconclusive in relating formal organizational structure to organizational behavior. In addition, Ibrahim et al. (2005a) find different knowledge types affecting knowledge-flow behaviors differently. Ibrahim et al. (2005b) provide early empirical evidence that informal knowledge networks do affect the organizational performance of an enterprise. Hence, integrating horizontal (or non-hierarchical) information-processing structure for decision-making is of particular interest to us.

Recent scholars such as Lambert and Shaw (2002) have turned to Wegner's (1987) transactive memory theory to explain the existence of this non-hierarchical information-processing structure. Using methods and tools of computational organization theory (COT), the Ibrahim et al. (2005b) study shows how such non-hierarchical information processing affects organizational performance. Their 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 the organization design for better organizational performance.

Wegner (1987) also 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) pose that organizational teams may act like large brains, where individuals store information to be combined with others' information. When individuals in that team need information, they go to the "expert node" or expert member. In other words, exceptions are referred to the perceived "expert" in the organization, regardless of such member's hierarchical position in the organization.

In summary, there is an apparent lack of consideration for non-hierarchical information-processing during organization design. Moreover, scholars have yet to consider the discontinuous membership characteristic of an organization.

2.2 Knowledge-flow Dynamics

Knowledge management is an increasing concern in the design of organizations. Alavi and Leidner (2001) note an abundance of literature on knowledge creation, storage and retrieval. Other scholars (e.g., Carlile and Rebentisch 2003) similarly note the emphasis on knowledge storage and retrieval in the literature. Additionally, knowledge transfer and sharing are becoming increasingly important for scholars attempting to explain dynamic flows of knowledge that enable workflow processes (and hence organizational performance; e.g., see Carlile and Rebentisch 2003, Nonaka and Takeuchi 1995, Nissen 2002). Some scholars also look at knowledge transfer in organization learning (such as Nadler, Thompson, and van Boven 2003), and how knowledge exchange affects the social and expert status of individuals (Thomas-Hunt, Ogden, and Neale 2003).

Kogut and Zander (1992) pose that firms are more successful in transferring knowledge within organizations than between organizations. Although individuals hold knowledge, it is also expressed in regularities by which members cooperate in a social community. Building upon this concept, Nonaka (1994) argues that organizational membership plays a critical role in articulating and amplifying knowledge. He proposes four modes of knowledge transfer—*socialization*, *externalization, combination,* and *internalization* (SECI)—in a dynamic spiral of interactions between knowledge type (termed *epistemological; e.g.,* tacit, explicit) and organizational reach (termed *ontological*; e.g., individual, inter-organizational).

Nissen (2002) extends Nonaka's work by integrating six stages of a knowledge-flow life cycle process: 1) creation or acquisition, 2) organization, 3) formalization, 4) distribution or sharing, 5) application, and 6) evolution or refinement. This six-step knowledge life cycle is an amalgamation of earlier views of knowledge life cycle (e.g., as proposed by Davenport and Prusak 1998, Depress and Chauvel 1999).

Von Hippel (1994) uses the term ‘stickiness’ to describe how enabling tacit knowledge can ‘stick’ with problem-solving capabilities in different locations. Stickiness connotes the difficulty experienced in transferring tacit knowledge (Szulanski 2000). For example, when an organization recreates knowledge while having to maintain a complex, causally ambiguous set of routines in a new setting.

In Nissen’s later work (i.e., Nissen 2005a), he states that new organizational forms may obtain and even dominate through a focus on dynamic knowledge flows. Nissen provides discrete qualitative categories for potential operationalization of knowledge flows in the enterprise. Building further upon Nonaka (1994), Nissen’s four knowledge flow dimensions are *type* of knowledge (e.g., tacit, explicit), *level of socialization* associated with the knowledge (e.g., individual, group, organization, inter-organization), life cycle activities of *knowledge work* (e.g., create, share, apply), and *flow time* (e.g., lengthy, brief).

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 workflow processes that minimize communication but ensure the input of expertise at different times; (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 routines.

Grant's resulting knowledge-based theory of the firm 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 horizontal and vertical boundaries of the firm. His knowledge-based view perceives 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 also calls for further research needed on the knowledge-based theory of the firm that can embrace knowledge creation and application.

Cohen and Levinthal (1990) argue that the ability of a firm to recognize the value of new, external information, to assimilate it, and to apply it is critical to its innovative capabilities. They term this capability as a firm's *absorptive capacity* and suggest that it is largely a function of a firm's level of prior related knowledge. Cohen and Levinthal describe the basis for an individual's absorptive capacity to include: 1) development of specific knowledge cognition, 2) development of experience and skills, and 3) development of problem-solving skills. They refer to the prior possession of knowledge before any type of individual development. However, there is a distinction between an individual's absorptive capacity with that of an organization. The absorptive capacity of an organization is not simply the sum of every employee's knowledge. Rather, it includes the organization's ability to exploit such knowledge. Absorptive capacity at the organizational level depends on the organization's direct interface with the external environment. It depends also on transfers of knowledge across and within subunits that may be quite removed from the original point of knowledge entry or creation. This aspect refers to how the organization—a group of individuals—perceives the inherent tacit knowledge from its environment and gains from that experience.

To study a firm's absorptive capacity, Cohen and Levinthal focus on the structure of communication between the external environment and the organization, as well as among the subunits of the organization. They focus also on the character and distribution of expertise within the organization. Both scholars argue that the development of absorptive capacity, and in turn innovative performance, are history- or path-dependent. They argue how lack of investment in an area of expertise early on may foreclose the future development of a technical capability in that area. Such is the case with our oak grove preservation example cited above. The facility development life cycle process faltered in part because the facility owner did not invest in a mechanical engineer during the feasibility-entitlements phase.

In summary, we note an interest in the role of knowledge transfer in organizational learning, an increasing need for literature in the area of tacit knowledge transfer, and a call for empirical, theoretical development in the study of knowledge management. This study contributes towards the development of theory in knowledge transfer within the tacit realm involving discontinuous organization.

3. Modeling Knowledge Flows Computationally

The utilization of computational models to represent and simulate dynamic knowledge flows through and between organizations is an emerging trend in knowledge management research. For instances, Nissen and Levitt (2004) and Ibrahim and Nissen (2004) conduct such studies linking an organization with its processes to investigate the dynamics of knowledge flow. Prior computational organizational theory (COT) research has examined the dynamic work processes and information flows associated with project- or task-based organizations only (such as Carley and Prietula 1994, Levitt et al. 1994). Utilizing such dynamic computational models can provide insight into unique operating environments that are difficult (or even impossible) to test in real life. In addition, computational techniques can be used early in the facility development life cycle, to examine and compare alternate workflow approaches and organizational designs *before* committing time and money to any specific option. This can serve to reduce a project's risk while increasing its knowledge. In this section, we describe the complex facility development process we are studying, explain how we theoretically integrate knowledge-flow theory in a COT model, and explain the choice of COT tool for our study.

3.1 Facility Development Characteristics

The facility development process is characterized as 1) having multiple concurrent and sequential workflows, 2) having discontinuous membership, 3) having multiple task interdependencies, and 4) displaying different knowledge forms (i.e., tacit- or explicit-dominant knowledge areas). Recall from above how Ibrahim (2001) illustrates the division of the facility development process into five sequential phases: 1) *feasibility*, 2) *entitlements*, 3) *building permit*, 4) *constructio*n, and 5) *property management phases.*

Ibrahim and Paulson (2005) later combine the two early phases into a single *feasibility-entitlements* phase for better clarity. Our study focuses on this combined feasibility-entitlements phase and includes the activities associated with obtaining a building permit. Together these three, early stage life cycle phases comprise the *pre-construction workflow*.

Our computational modeling effort is guided by both empirical and theoretical research. Specifically, we compare the ethnographic results from Ibrahim and Paulson's (2005) study with Burton and Obel's (2003) contingency theory factors. The former ethnographic results provide a current, empirical case for application of the latter, theoretical prescriptions about organizational design. For instance, drawing from theory, our facility development workflow and organizational characteristics are prescribed to be set up in conformance with a set of organizational design propositions: if the organizational environment has high *complexity*, high *uncertainty*, and high *equivocality,* then the organizational design should reflect low *formalization* (e.g., few rules for coordination and control), low *organizational complexity* (e.g., low horizontal and vertical differentiation), and low *centralization* (e.g., infrequent direct involvement by top management in decision making).

Several aspects of the facility development process are consistent with such theory. Because the facility development environment demands multiple, concurrent and sequential workflows—i.e., five sequential processes plus two concurrent processes—it illustrates a high complexity environment with multiple interdependency links. Examination of this process in the field reveals many uncertainties, stemming principally from non-controlling, decision-making processes that involve extra-organizational, public and governing authorities (such as, whether or not the development project will obtain a funding program or obtain a permit approval). Decision processes such as these can postpone progress through the facility development life cycle or render it infeasible to continue a particular project. Equivocality is evident too, often caused by ad-hoc, external, random and unpredictable requests to accommodate certain public and authority conditions that influence the design and its process.

For instance, consider a funding program that requires a play structure but was not called out in the original project-planning brief. If no space for such structure is allocated in the design, then the design team will be required to revise the site plan to include this new element. Environmental characteristics such as these make facility development a high-risk endeavor. The non-profit developer in our case project successfully developed and completed only fourteen percent of its projects annually.

In terms of the theoretical prescription above (i.e., for low formalization, organizational complexity and centralization), our fieldwork suggests a mix of consistent and inconsistent aspects of the organizational design propositions. *Due diligence,* an analytical process, provides a good example, because project managers attempt to formalize this process but have yet to come up with a successful model of formalization. Project managers studied by Ibrahim (2001) would go through a long checklist to come up with the best development option for a property with a view of purchasing it for development. Major items on the due-diligence checklist include specific legal entities of the property, all governmental requirements, details of development schedule involving all major tasks duration and procedures, determination of the target market, program brief for design, required governmental fees, and review of available documents.

Theory predicts also that the facility development enterprises will be better off with low vertical differentiation and centralization. With top management's accumulated tacit knowledge, the due-diligence items would eventually influence the design, finance, and target market decisions for the development project. The process can take as little as two weeks to as much as three months to complete. Experience suggests it is effective to allow the project managers unlimited authority to 'create' the best development approach for the developer. In such a case, the development proposal gives good financial return, is realistically feasible to construct, and has community acceptance. Low vertical differentiation and centralization contribute to this effectiveness. The project manager orchestrates all consultants under him, while he only reports to one executive manager.

Theory predicts further a tendency by managers to get overloaded in such organizations. However, Ibrahim and Paulson (2005) note that the more experience project managers have, the more efficient and creative they become. To mitigate the effects of management overloading as suggested by theory, a team of managers and others—from multiple, matrix organizations—tend to work together on several work processes concurrently (e.g., design, financing, and asset management). Some members of one functional team may serve on another functional team, such as the project managers or the architects. But they have to divide their allocated time commitments between several functional teams to achieve different functional goals.

In this field study, we find discontinuous membership through various positions and organizational roles that come and go at different phases of the facility development life cycle. Certain organizational roles participate—for some periods of time—in some matrix organizations and workflows processes but do not participate—or participate at other times—in other organizations and processes. Current theory has little to say about organizing for discontinuous membership as such. Instead, our current understanding of discontinuous membership derives principally from empirical work.

For instance, Ibrahim and Paulson (2005) discuss how discontinuous membership occurs when a particular workflow process requires a specific mix of skills for task performance. In a matrix organization with discontinuous membership, the same person (or role) may contribute different skills when joining different organizational matrices. The effect of joining several matrices within a larger workflow process forces members to divide their total time commitments across the various, different matrices in which they participate—either concurrently or often at different times. Hence from the perspective of any individual matrix organization, such person (or role) participates intermittently (i.e., membership is discontinuous).

Additionally, theory suggests use of rich media. The study finds a mixture of both rich and poor media utilization. Media richness indicates the form, amount, and kind of information. Information richness is defined by Daft (1992, p. 286 in Burton and Obel 2003) as the *information-carrying* capacity of data in the following order (from richest to poorest): 1) face-to-face, 2) telephone and other personal electronic media, 3) letters, notes, and memos, and 4) bulletins, computer reports, and data reports.

Through the fieldwork referenced above, we find abundant media-rich sources during the feasibility and entitlements phases. For instance, project managers have numerous, repeated meetings to gauge and obtain accurate understanding of certain public or authority requirements. The goal is obtaining informal consent prior to investing further into the project. For instance, through fieldwork we identify several occasions when a facility developer would abandon the project after failing to obtain the majority of a city council's vote prior to submitting his proposal.

However, as the project progresses, the study finds less and less media richness, even as more experts participate—via discontinuous membership—on the design team. For instance, a mechanical engineer will provide heating, ventilation, and air-conditioning data, while an electrical engineer will provide lighting and energy data to the design workflow. Indeed, more and more low-richness media are used as the facility development life cycle progresses. By the final, property management phase, facility developers tend to use only computational databases for report making. This kind of longitudinal regression of media richness through the course of a facility development process provides novel insight into how choices of communication media impact knowledge flows.

Moreover, theory suggests providing result-based incentives. However, Ibrahim and Paulson (2005) find differing incentive schemes (and hence different goals) among the design team versus the finance team, for example. On the one hand, the design team aims for completion of the design documentation for their professional fees. Once the documents are complete and their fees have been collected, design team members have little incentive to be concerned about seemingly unrelated goals such as project funding; they get paid for professional services whether the project is funded or not. On the other hand, the finance team aims at obtaining project funding for the sake of the facility project's survival. Finance is crucial because, without funding, the project will be abandoned. It is willing to comply with—at times very costly—additional conditions that will increase the overall project's cost by complicating the design and requiring rework by the design team.

Overall, we find mixed empirical support for the theoretical prescriptions noted above. Although the facility development process takes place within an environment of high complexity, uncertainty and equivocality—and reflects the kinds of low vertical differentiation and centralization prescribed theoretically also—we find in contrast: an attempt at relatively high formalization; project management experience ameliorating overload; multiple, concurrent matrix organizations; a longitudinal regression of media richness; and a mixture of incentive schemes (and hence goals) across various participants. Such latter empirical findings run counter to the theoretical prescriptions summarized above. Further, we find an empirical case of discontinuous membership, about which extant theory has little to say at present.

3.2 Integrating Knowledge-Flow Theory in COT

Extant COT tools do not model the behaviors of knowledge flows well. To study dynamic knowledge flows in the facility development process, we need to identify and select a COT tool that can accommodate adaptation to represent dynamic knowledge in an organizational context. To accomplish this, we draw from and build upon Nissen's (2002) *Vertical and Horizontal Processes Model* to provide a foundation for such adaptation. This model characterizes the powerful interaction between flows of work and the enabling flows of knowledge in an enterprise. But this model is focused internally and does not examine explicitly the environment within which an organization operates. In particular, it lacks the concepts necessary to characterize an organization that experiences discontinuous membership (details to follow below).

Ibrahim and Nissen (2005) extend Nissen's model to conceptualize a new analytical unit: *Knowledge Group Set* (KGS). A KGS unit is a group of interrelated, concurrent, horizontal processes that are required to accomplish common goals along vertical processes. Here, *horizontal processes* refer to workflows, whereas *vertical processes* refer to knowledge flows. See Figure 1 for illustration. From an internal perspective, each horizontal workflow process may appear to be independent. But when viewed as a group, the *set of workflows* contains one or more, interdependent tasks that link and interrelate concurrent processes within a common timeframe. Hence an organization manager—or set of managers—must be responsible for the performance of multiple, interrelated processes, which are all linked directly to accomplishment of common goals. This represents a complex case for organizational design. With multiple, interrelated processes and managers, one may find multiple, *unrelated* organizational structures that require integration.

For example (refer to Figure 1), consider a workflow for pre-construction (labeled "Workflow Process 1"), the goal of which (labeled "G1") is obtaining a building permit to commence construction on a property. Another, concurrent workflow for finance (labeled "Workflow Process 2") has a different but related goal (labeled "G2") of obtaining the necessary construction loan to finance the building construction. Notice how some tasks in each workflow require input from one another.

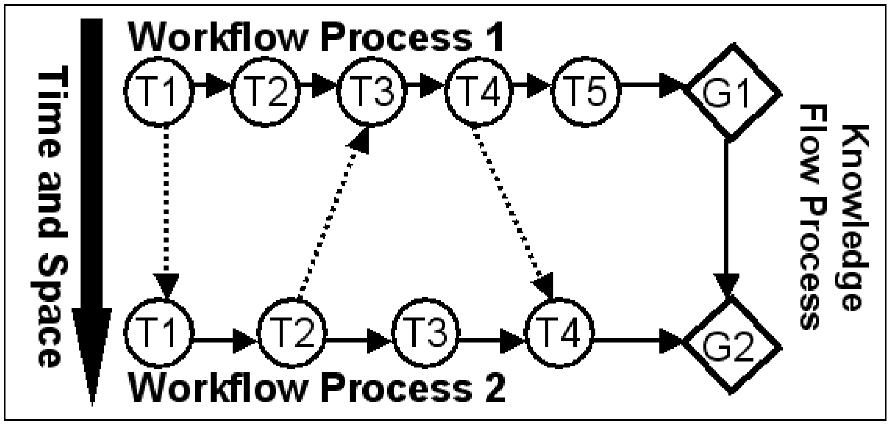

Figure 1: A Knowledge Group Set (KGS) unit consisting of two or more horizontal workflow processes with task interdependency links during knowledge life cycle period (Adapted and revised from Nissen's Horizontal and Vertical Processes Model (Nissen 2002, Fig. 3)).

For instance, knowledge obtained through performance of Task 1 (labeled T1) at the top workflow process provides a critical input to performance of the first task of the bottom workflow; knowledge from Task 2 of the second workflow is required for performance of Task 3 in the first workflow; Task 4 knowledge from the top feeds Task 4 work on the bottom; and so forth. Notice also, the goals associated with each workflow are linked in the figure. For instance, Goal 1 (labeled G1) is required to achieve Goal 2. The KGS concept captures the kinds of interdependent and concurrent knowledge flows and workflows depicted in Figure 1 and identified in the facility development process.

More specifically in the facility development process, upon obtaining *site control* from a property owner, the finance team sets out to seek potential investors in the project. Meanwhile, the concurrent design team proceeds with its design work that is based on the initial project brief provided by the facility developer. In negotiating the financing support, for instance, an educational funding program may require a computer cluster within a family housing project to qualify. Hence, the facility developer would instruct the design team to integrate a computer cluster in the community center. In Workflow Process 1, the design team succeeds in obtaining the building permit (i.e., accomplishing G1), after integrating the additional computer cluster. In Workflow Process 2, the finance team succeeds in obtaining the construction loan (i.e., accomplishing G2) after the design team includes a computer cluster in the design proposal. G1 has to be completed first before G2.

Notice that there are different skill sets requirements for the different teams. In the design team, there is a strong component of building-related professionals such as architects, engineers, and builders, whereas the finance team requires complementary knowledge such as accounting, finance and law, along with familiarity with the building process.

Further, Ibrahim and Paulson's (2005) study highlights that some members of one team may be concurrent members of one or more, other team too. Such members, who participate concurrently in multiple matrix organizations, have to divide and allocate their time across the various matrix organizations in which they participate. This division and allocation of members' time across different matrix organizations illustrates clearly an effect of discontinuous membership. And by capturing the relative percentages of time that various members spend participating in the different organizations, we discover an approach to representing discontinuous membership—along with its knowledge effects—via computational models.

We can further combine several KGS units to form a larger knowledge flow framework as depicted in Figure 2. Here we illustrate six, concurrent, interdependent workflows (i.e., horizontal processes) that feed into three, sequential KGS units (i.e., vertical arrows labeled “KGS 1,” 2, & 3). Each KGS corresponds to one phase of the facility development life cycle. The diamond shapes in the figure represent (possibly) *different* matrix teams; that is, the membership (i.e., organizational positions or roles) of the various matrix teams changes—both along the flows of work (i.e., horizontally) and across the life cycle phases (i.e., vertically)—through both space and time (e.g., they may be geographically distributed and temporally distinct). We refer to such compositions of interrelated KGS units as *Knowledge Group Set (KGS) Flow Models*.

More specifically in the facility development process, we further break the facility development life cycle process into smaller phases. One KGS unit represents a phase in the facility development process. Based on Ibrahim’s (2001) facility development life cycle, *KGS1* in the figure represents the feasibility phase, *KGS2* represents the entitlements phase, and *KGS3* represents the building permit phase. Knowledge from the feasibility phase (i.e., KGS1) flows into the succeeding entitlements phase (i.e., KGS2). The goal for KGS1 is submitting the application for the development permit, while the goal for KGS2 is obtaining the development permit. When it transits into the next phase, the matrix team combination may change because of different skill sets required in the different workflows.

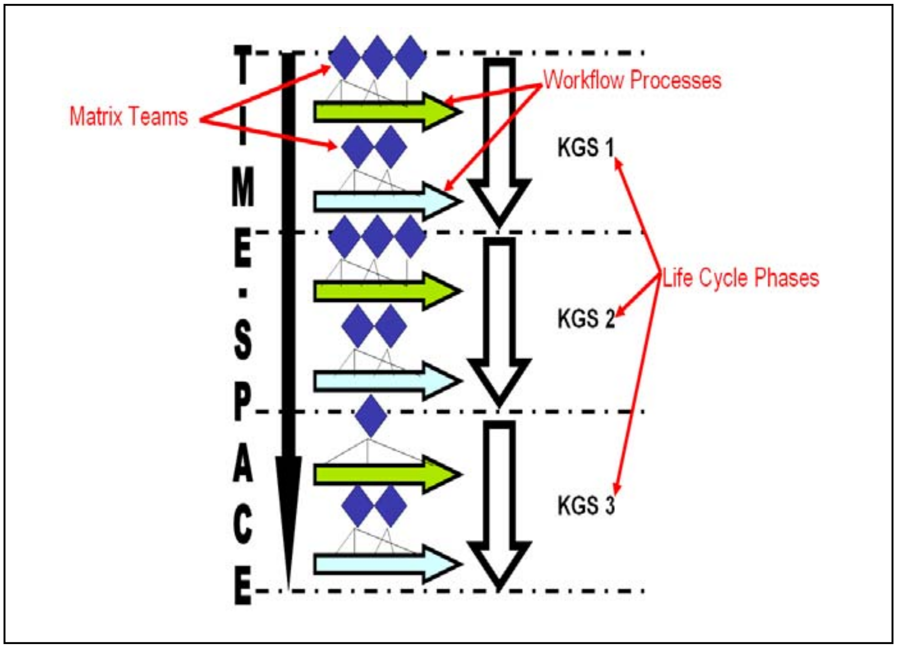

Figure 2. Knowledge Group Set (KGS) Flow Model during

a facility development process.

The mechanical engineer and the electrical engineer, for instance, usually join during the building permit phase (i.e., KGS3) because the building permit submission requires a document that illustrates compliance of providing a healthy and safe facility project. Such new, engineering experts provide inputs on heating, ventilation, air-conditioning, electrical needs, and like knowledge-based tasks. The goal at the end of this KGS3 unit is *start of construction*. Similarly, the flow of knowledge from one phase to the next is represented by the downward arrow. Such knowledge flows require considerable time—normally several years—to complete the transit across all life cycle phases. Knowledge flows also cross considerable geographical space, as multiple matrix team members participate, often from many different firms. The KGS enables us to model such phenomena identified through fieldwork.

3.3 A COT Tool

We utilize the Virtual Design Team (VDT) computational tool to model and emulate knowledge flows. The VDT Research Program is well established as a planned accumulation of collaborative research over two decades to develop rich, theory-based models of organizational processes (Nissen and Levitt 2004). VDT uses an agent-based representation (Cohen 1992; Jin and Levitt 1996; Kunz et al. 1998) that incorporates into the computational tool research on micro-level organizational behaviors, which were formalized to reflect well-accepted organization theory (Levitt et al. 1999). This contributes toward VDT external validity and generalizability. Extensive empirical validation projects (e.g., Christiansen 1993) contribute further toward such validity and generalizability.

However, no extant computational tool is perfect for our task. And Nissen and Levitt's (2004) study highlights some limitations of VDT. Unlike mathematically representable and analyzable micro-behaviors of physical systems, the dynamics of organizations are influenced by a variety of social, technical and cultural factors. They are difficult to verify experimentally, and are not amenable to numerical representation, mathematical analysis or precise measurement. Nissen and Levitt expect ambiguity when people and social interactions—distinct from physical systems—drive the behavior of organizations. Nonetheless, VDT provides a capability to represent—statically and dynamically—the key structures and behaviors of a knowledge group set flow model. We use SimVision®—the commercial version of VDT—to model, at a relatively high level, the complex facility development process described above.

4. A COT Case Study Model

This section explains the representation of the feasibility, entitlements, and building permit phases in a KGS Flow Model in SimVision®. This KGS Flow Model represents high-level activities in two concurrent workflow processes: the three sequential phases—feasibility, entitlements, and building permit—that comprise the pre-construction workflow, and the finance workflow that is accomplished concurrently. Our COT case study is a 43-unit affordable family housing development for farm workers located in the San Francisco Bay Area. This facility development has been in operation since June 2001, but has been plagued with civil and wastewater problems since construction began.

This discussion begins with specification of a baseline model, which depicts the organization and process under conditions of *continuous* membership. Recall from above, such conditions are consistent with theory but inconsistent with our empirical observations. We then specify an Alternate model, which depicts the organization and process under conditions of *discontinuous* membership. Comparing the relative behavior and performance of these alternate, computational models enable us to isolate the effects of discontinuous membership and to examine how it impacts the performance of a complex process. A brief description of the simulation approach follows and completes a transition to results and analysis in Section 5.

Baseline Model. Our baseline model represents high-level activities of the COT case during pre-construction. As described above, there are two process workflows running concurrently: the three sequential phases of the pre-construction workflow, and the concurrent finance workflow. Together these two workflow processes consist of 39 tasks with twelve milestones. The pre-construction workflow has three company staff members and six external consultants. The finance workflow has four company staff members and two external consultants. The start date for both workflow processes is June 2, 1997, when the developer first obtained control of the property.

Figure 3 presents a screenshot from the SimVision® modeling tool showing the finance organization and workflow as represented in terms of the KGS unit discussed above. The finance matrix team consists of four owner's representatives and two external consultants. Tasks are represented by the rectangular boxes, which are linked sequentially to other tasks or milestones (symbolized by the diamond boxes) by precedence links (solid lines in the figure). Figure 4 shows similarly the pre-construction organization and workflow in KGS terms.

To represent knowledge flows, we establish task interdependencies between the pre-construction and finance workflows by having four *ghost connectors* between them. This applies to both the Baseline and Alternate Model. Ghost connectors provide modeling connections or constraints between the workflows by mimicking tasks and milestones from one workflow to another. They allow linkages to multiple, other milestones and tasks. The *ghost connectors* are used to represent flows of explicit knowledge from one concurrent workflow to another. There is also a *ghost communication* link that reflects communication between the pre-construction stage and the finance teams. It is used to represent tacit knowledge flows.

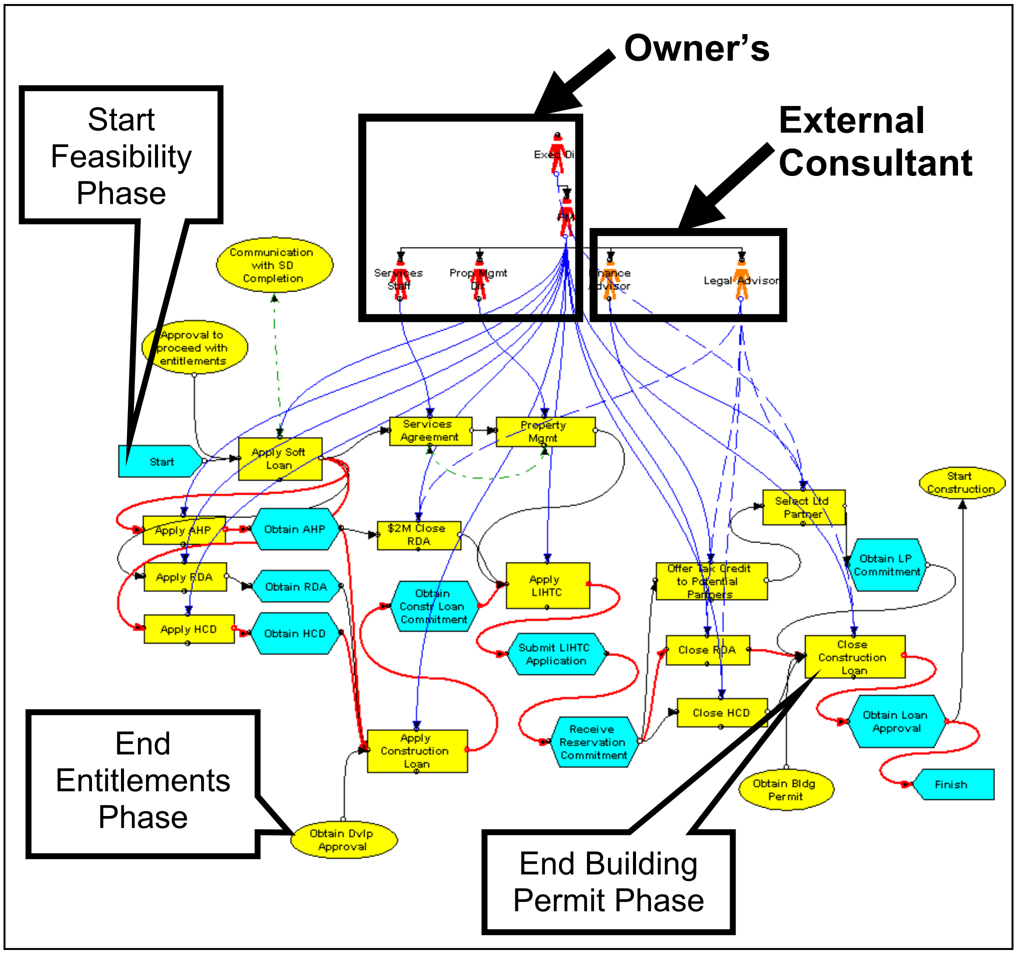

Figure 3. Network diagram of the concurrent finance phase in Baseline Model.

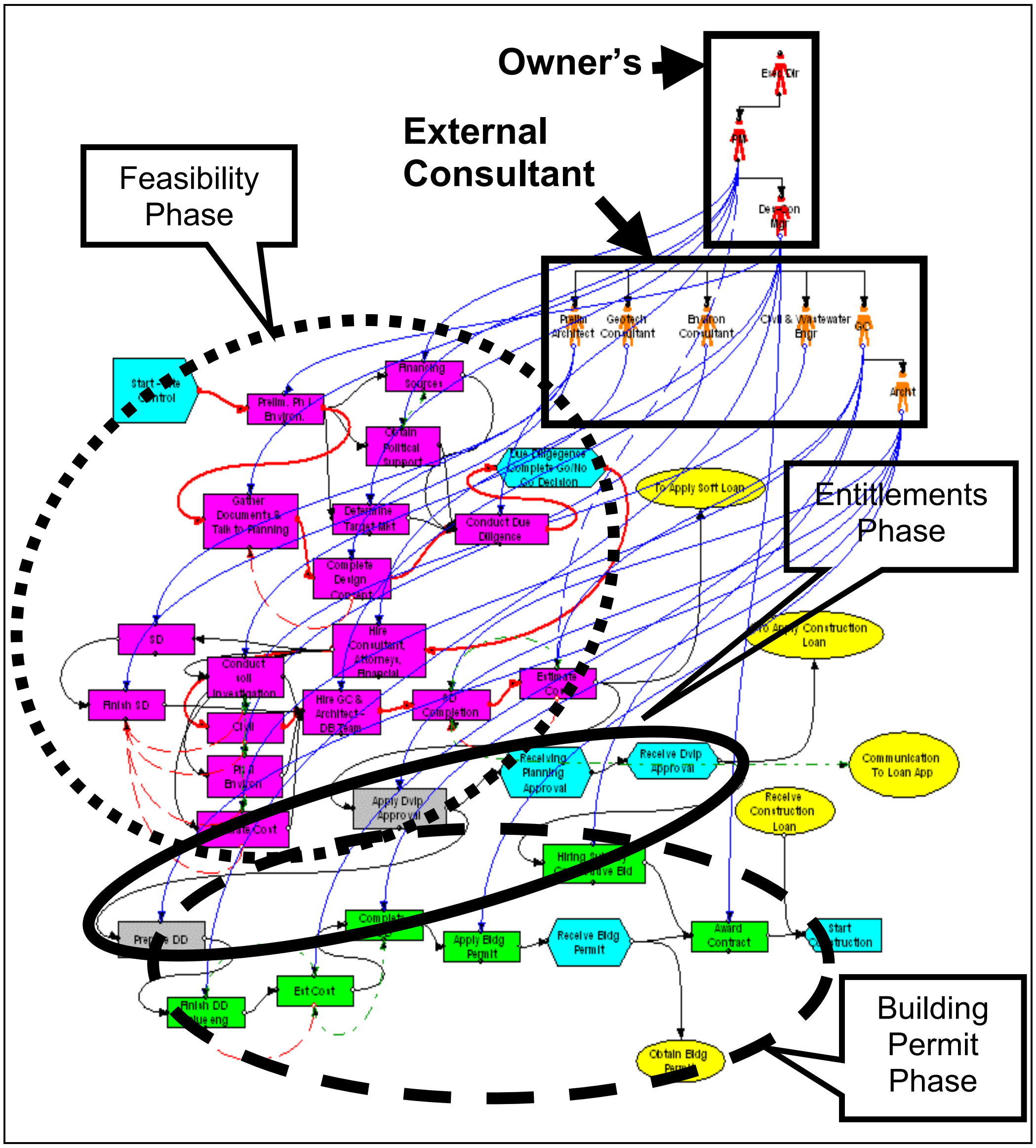

Figure 5-4. Network diagram of the sequential feasibility, entitlements, and building permit phases representing the pre-construction stage in Baseline Model.

We draw from our fieldwork to parameterize the SimVision® model. Model variables and parameter settings are summarized in Table 1. These parameter settings reflect well-established norms for specifying SimVision® models for construction projects (see Jin and Levitt 1996). We describe the variables and parameters based on

SimVision®'s definitions here. *Centralization* reflects whether decisions are made by senior project positions or decentralized to individual responsible positions. With low centralization, responsible positions tend to make their own decisions and there is thus less communication required. *Team experience* is a measure of how successfully the team has performed related projects. The team experience value contributes to the way a position's information processing speed is calculated. Other factors are the position's own application experience, skill set, skill levels, and the task's requirement complexity. *Formalization* is a measure of how formal the communication is in an organization. High formalization means communication tends to occur in formal meetings. With low formalization, it's more common for communication to occur informally between positions. *Matrix strength* is the extent to which positions are located in skill-based functional departments and supervised directly by functional managers (Low) or co-located with other skill specialists in dedicated project teams and have project supervision from a project manager (High). Medium *matrix strength* means that workers make approximately equal amounts of formal and informal communications.

Table 1: Variables and Parameter Settings for Baseline Model

VARIABLES	PARAMETER
Centralization	LOW
Team Experience	MEDIUM
Formalization	MEDIUM
Matrix Strength	MEDIUM
Information Exchange Probability	0.7
Noise Probability	0.2
Functional Error Probability	0.05
Project Error Probability	0.05
Work Volume per Full Time Equivalent	8 hours/ FTE
Work Days per Week	5 days/ week

Information exchange probability measures the level of communication in the project between positions that are responsible for interdependent tasks with communications links. *Noise probability* is a way to measure the effect of interruptions in the ordinary working day that take time away from doing the project tasks. *Functional error probability* is the probability that a task will fail and require rework. Functional errors are errors that are localized to a task and cause rework only in that task by the responsible position. *Project error probability* is the probability that a task will fail and generate rework for all dependent tasks connected to it by rework links. *Work volume* is the predicted time that all positions on a project spend doing direct work. We set the FTE to an 8-hour per day of direct work duration.

Table 2 summarizes the staffing positions we build into the Baseline Model based on our fieldwork. In Column 1, the stakeholders are divided into two categories: owner and consultants-builder. The position title is listed for each stakeholder in Column 2. Each position listed in Column 3 is assigned a full-time equivalent (FTE) value in Column 4. All of these positions and FTE values reflect empirical data collected through fieldwork. Hence the COT model matches the field organization exactly in this regard. For example, the Executive Director devotes 0.30 FTE to the project workflow. This is the FTE level reported by the Executive Director in the field.

Table 2: Total Staffing and Position FTE's for Baseline Model

STAKE-HOLDER	TYPE OF STAKEHOLDER	POSITION TITLE IN SIMVISION®	TOTAL POSITION FTE's
OWNER	DEVELOPER OWNER	EXEC DIRECTOR	0.30
		PROJECT MANAGER	0.40
		DESIGN-CONSTRUCTION MANAGER	0.50
		PROPERTY DIRECTOR	0.10
		SERVICE DIRECTOR	0.10
CONSULTANTS-BUILDER	FINANCE CONSULTANT	FINANCE ADVISOR	1.00
	LEGAL CONSULTANT	LEGAL ADVISOR	1.00
	ENVIRON MENTAL CONSULTANT	ENV STAFF	1.00
	GEOTECH CONSULTANT	GEOTECH STAFF	1.00
	CIVIL ENGINEER	CIVIL ENGINEER	1.00
	ARCHITECT	PROJECT ARCHITECT 1	1.00
		PROJECT ARCHITECT 2	
		CONCEPT ARCHITECT	
	GENERAL CONTRACTOR	GEN CONTRACTOR 1	0.15
		GEN CONTRACTOR 2	1.00

Alternate Model. Our Alternate model represents a discontinuous organization. It is derived directly from the baseline above. Indeed, we duplicate the SimVision® variables and parameter settings from the Baseline Model. The key differences are in the distribution of FTEs for staffing each position across different organizational matrices in the Alternate Model. The matrix combination reflects the different skill sets each workflow requires to perform its tasks. This is how we represent discontinuous membership. The three matrices based on our field observation are *City*, *Building*, and

Owner. The skill set of the City Matrix is expertise to consolidate public and financing support from the local jurisdictions. The skill set of the Building Matrix is the expertise to consolidate the planning, design, and technical aspects regarding the facility proposal in order to ensure compliance to build. The skill set of the Owner Matrix is the expertise to coordinate the developer's activities pertaining to the development proposal.

The FTE's distribution is summarized in Table 3. The positions, roles and total FTE levels are identical to those reported above in Table 2 for the Baseline Model. But note the middle columns in Table 3 that summarize the *distribution* of FTEs across the three, different matrices. This is how we allocate staffing to the respective positions according to involvement in the different organizations. For instance, the Executive Director staff role is listed in Table 3 with a total FTE of 0.30. This is the same FTE level listed for this role in Table 2 above. However, notice the distribution of the Executive Director's time (in FTEs) across two, different organizations: 0.20 in the City Matrix, and 0.10 in the Owner Matrix. While the Executive Director is participating in the City Matrix, such an organization receives the benefits of his or her knowledge as well as the work it enables. But such knowledge and work are not available continuously. The same applies to the other positions and staff roles.

Table 3: Distribution of FTE's for Team Members in City, Building, and Owner Matrices

STAKE-HOLDER	TYPE OF STAKEHOLDER	POSITION TITLE IN SIMVISION®	MATRIX FTE's			TOTAL STAFFING FTE's	TOTAL POSITION FTE's
			CITY	BUILDING	OWNER		
OWNER	DEVELOPER OWNER	EXEC DIRECTOR	0.20		0.10	0.30	0.30
		PROJECT MANAGER	0.20	0.10	0.10	0.40	0.40
		PRE-CONSTRUCTION PHASES MANAGER		0.10	0.40	0.50	0.50
		PROPERTY DIRECTOR			0.10	0.10	0.10
		SERVICE DIRECTOR			0.10	0.10	0.10
CONSULTANTS-BUILDER	FINANCE CONSULTANT	FINANCE ADVISOR			1.00	1.00	1.00
	LEGAL CONSULTANT	LEGAL ADVISOR			1.00	1.00	1.00
	ENVIRON MENTAL CONSULTANT	ENV STAFF			1.00	1.00	1.00
	GEOTECH CONSULTANT	GEOTECH STAFF			1.00	1.00	1.00
	CIVIL ENGINEER	CIVIL ENGINEER		0.20	0.80	1.00	1.00
	ARCHITECT	PROJECT ARCHITECT 1		0.20		0.20	1.00
		PROJECT ARCHITECT 2		0.20		0.20	
		CONCEPT ARCHITECT			0.80	0.80	
	GENERAL CONTRACTOR	GEN CONTRACTOR 1		0.05	0.10	0.15	0.15
		GEN CONTRACTOR 2		0.10	0.90	1.00	1.00

Simulation. We run a Monte Carlo simulation of 100 cases for both the Baseline and Alternate Models in SimVision® and compare their organizational performance results. Performance measures include *simulated duration*, *critical path method (CPM) duration, total work volume, cost, functional risk index, project risk index,* and *communication risk*. The steps in building the COT model provide considerable accuracy in terms of emulating the facility development organization and process behaviors. It can provide us retrospective validation, which Thomsen et al. (1999) recommend for validating computational emulation models for organizations. To obtain a retrospective validation for both models, we require the two models to maintain the construct characteristics from the ethnographic study, i.e., having multiple concurrent or sequential phases, having task interdependencies, having discontinuous memberships, and displaying different knowledge forms during the process.

5. Results, Analysis, and COT Validation

This section presents key simulation results for both Baseline and Alternate Models. We summarize the results of the Baseline and Alternate Models in Table 4. The first column includes the seven performance measures used to summarize and report the results. The second column includes values for the Baseline Model that represents an organization with continuous membership. The last column includes values for the Alternate Model that represents an organization with discontinuous membership. The first three measures depict *simulated* and *CPM durations*, and *total work volume* in days. The latter three measures depict different dimensions of risk (and hence process quality). A cost measure is included.

The *simulated duration* of the Baseline Model is shorter than that of the Alternate Model (i.e., 695 vs. 760 days). This measures a schedule penalty associated with discontinuous membership in the Alternate Model. When specific knowledge and skills are needed but unavailable in a particular organizational matrix, progress on the facility development project as a whole can lag behind. But the Baseline Model has greater *total work volume* than the Alternate Model does, (i.e., 735 vs. 715 days). This measures an economic benefit associated with discontinuous membership in the Alternate Model.

With several people (or roles) participating discontinuously in one or more organizational matrices, it reflects leaner staffing overall for the project. We note that both Baseline and Alternate Models have almost identical *CPM duration* values (i.e., 669 vs. 674 days). This measures negligible effect by discontinuous membership on the overall schedule.

Table 4: Statistics of Selected Simulated Values for Baseline and Alternate Models

VALUE NAMES	BASELINE	ALTERNATE
Simulated Duration (days)	**695**	760
Total Work Volume (days)	735	**715**
CPM Duration (days)	669	674
Cost	**$418K**	$442K
Functional Risk Index (FRI)	**0.54**	0.75
Project Risk Index (PRI)	0.59	**0.48**
Communications Risk	0.38	0.38

Note: Bold values represent comparatively better outcomes in SimVision®.

In terms of cost, the Baseline Model incurs lesser cost than that of the Alternate Model (i.e., $418K vs. $442K). This measures an economic penalty associated with discontinuous membership in the Alternate Model. The costs involved are those pertaining to the professional fees, and the salaries of the developer's employees during the pre-construction stage.

In terms of risk measures, the Baseline Model has a lower *Functional Risk Index* (FRI) than the Alternate Model does (i.e., 0.54 vs. 0.75). This measures a functional quality penalty associated with discontinuous membership in the Alternate Model. Nearly half again as many functional exceptions are left ignored or addressed incompletely in the Alternate Model than in the Baseline. Indeed, SimVision® states that a FRI or PRI value above 0.7 reflects an unacceptable level of risk for any organization. Alternatively, the

Alternate Model has a lower *Project Risk Index* (PRI) than the Baseline Model does (i.e., 0.48 vs. 0.59). This measures a project-quality benefit associated with discontinuous membership in the Alternate Model. Even with discontinuous membership, the Alternate Matrix organization leaves relatively fewer project-level tasks incomplete at the end of its workflows than the Baseline does. Finally, both Baseline and Alternate Models have identical *communication risk* values of 0.38. Apparently, discontinuous membership has negligible overall effects on communication quality. Nonetheless, this value is higher than 0.2, which SimVision® suggests is worrisome in terms of missed communications.

From the above COT simulation results, the continuous membership organization has more advantages than the discontinuous membership organization. It is superior in terms of offering a lower cost and a faster delivery schedule—two performance measures that facility developers prioritize. Hence, discontinuous membership would make the Alternate Model a less desirable organization design for facility developers. As a contribution to organization design, we compare the COT results with extant theories and seek insights to develop empirical prescriptions for designing an organization with discontinuous membership.

First, we would like to ascertain if there are any benefits when operating a discontinuous organization. As noted above, a discontinuous organization is an organization that has discontinuous membership due to the different skill set requirements to complete tasks in certain workflows (Ibrahim and Paulson 2005). The COT results show that when discontinuous membership operates during a complex process, such as facility development, there are some relative advantages, as well as some disadvantages. Among its benefits is that it reduces the total work volume required to perform the tasks in a workflow process. This gives cost savings to the facility developer (in terms of paying lower compensation because it has lower total work volume) without incurring additional delivery schedule (in terms of having almost identical CPM duration values). It is a common practice by facility developers to negotiate for better professional contracts individually while imposing an independent window of time to deliver the task. This is because the professional service provider is expert enough to perform his work independent of others. This assumption is supported by a separate study by Ibrahim et al. (2005a), which states that experts are capable of working independently and are comfortable operating in a discontinuous membership organization.

Another benefit is that discontinuous membership encourages greater project integration (e.g., fewer incomplete reworked tasks, fewer tasks that do not meet adequate quality) when compared to a continuous organization. One reason for this is that facility developers hire experts to provide their services only as and when they are needed. Therefore, fewer project-level mistakes occur, lowering the PRI value comparatively. As mentioned before, expert members have the ability to deliver their tasks independently, hence providing better PRI in a discontinuous organization. However, even the PRI value of 0.48 is relatively high (e.g., according to SimVision user guidelines), and should be worrisome to the management of either continuous or discontinuous organizations. This will require extraordinary coordination to ensure efficient knowledge flows between different workflows and different team members.

On the other hand, discontinuous membership incurs more disadvantages in terms of having greater schedule delay due to the additional coordination and wait volumes—imposed indirectly on the supervisor. The low centralization forces the supervisor to wait longer for feedback from his functional team leaders. As the supervisor, the project manager has to coordinate the functional team leaders (i.e., the hired experts) who have no direct contacts with other functional team leaders except for those being called upon by the project manager. And as noted above, an organization with discontinuous membership incurs an economic penalty in terms of higher project cost. Hence the discontinuous organization does offer some relative advantages over its continuous counterpart, but it is disadvantaged in terms of cost and schedule—arguably the most important measures of project performance.

Second, we review our techniques for representing knowledge flows via COT models. Drawing from emerging knowledge-flow theory, we would like our model to represent both explicit and tacit knowledge flows. Using ghost connectors, we model explicit links between one workflow (i.e., KGS) to the next, which enable accumulated knowledge to flow to the succeeding workflow (and indirectly to its responsible organization). In addition, we model tacit knowledge flows between different workflows by adding ghost communication links between identified interdependent tasks.

Further, our KGS Flow Model—grounded upon dynamic knowledge-flow theories—enables us to represent the essential elements of an organization reflecting discontinuous membership. This provides an advance in terms of computational modeling. Moreover, through this advance, our computational models of both continuous and discontinuous membership point to similar problems (i.e., the civil survey task failure and an overloaded project manager) that were observed in corresponding *real organizations in practice*. This provides a convincing element of intellective validation

(Thomsen et al. 1999) and promotes our claims regarding external validity of the KGS Flow Model.

Using a computational model provides some noteworthy learning in terms of organization studies. Having a semi-formal representation of two, alternate organizations (e.g., continuous and discontinuous) enables us to examine their similarities and differences closely, to start and stop the action at critical times, and to repeat the simulation many times under controlled conditions. This leads to insights that would be very difficult to capture through fieldwork alone.

For instance, a serendipitous insight occurred when we observed critical path changes across model runs. Once a set of workflows have been established for a project organization, the critical path is assumed broadly to be quite stable over time. But in our models, multiple interdependency links cause the critical path to deviate drastically and to affect multiple workflows. Since we made no changes to the modeled workflow processes, such critical path changes reveal how the shift of priorities in handling emerging issues is responsible. In one instance, the failure to obtain funding from a program caused the critical path to shift from pre-construction to the finance workflow. This insight may give scholars hope that they may, after all, formalize facility development process, and develop the much needed knowledge management system that caters to such dynamic operating environment.

Finally, the analysis of the COT results shows that our knowledge-based model is reliable in explaining how discontinuous membership affects organizational performance. As noted above, our model "predicted" project problems (e.g., functional failure of the civil survey work due to the overloaded project manager) that occurred in practice. It seems increasingly clear that organization theory is enriched through our examination of discontinuous membership. Discontinuous membership affects the structural information processing in an organization. But current theory lacks adequate prescriptions to handle discontinuous membership in organizational design. The inconsistencies of the contingency fit's prescriptions to the ethnographic study findings, and the support by evidence from our knowledge-based COT models, suggest a need to revisit contingency theory in terms of looking at designing an organization based on its knowledge flow attributes. We are guided by Nissen (in review) who posits that scholars may eventually design organizations based on its knowledge flow properties. We discuss in detail in the following section how we can further support this position.

6. Discussion

Our knowledge-based COT models provide evidence that discontinuous membership does affect the current structural information processing of an organization. Hence, organization theory needs to consider discontinuous membership attribute during the design of organization. Our focused literature review shows current theory also lacks relevant prescriptions to handle discontinuous membership in an organization. We refer to recent studies that link knowledge attributes to organizational performance. Results from the VDT-KN extension (Ibrahim et al. 2005b) provides cross-validation for an earlier ethnographic study by Ibrahim and Paulson (2005), which states that discontinuity in organizations is a factor in the knowledge loss phenomenon occurring in facility development. Ibrahim et al. (2005a) also find that knowledge flow behaviors in a discontinuous organization are qualitatively different from those of a stable organization depending on the "expertise" and "continuous" nature of the members. Moreover, their study finds that knowledge flow behaviors depend on the knowledge type—tacit- or explicit-dominant—of the knowledge areas in a workflow process.

Burton and Obel (2003) had developed six contingency factors corresponding to the situational fit for the design of organizational structure for an information-processing organization. They are *management style, climate, size/ownership, environment, technology,* and *strategy*. The situation fit requires that the design situation is internally consistent. An instance is that an equivocal environment and a routine technology do not fit, but they exist for some organizations. Facility development organizations are among this group. There is no recommended design, in fact, for this situation.

On the contrary, a discontinuous organization changes throughout the process, as and when different skill sets are required in order for the team to respond to the changing requirements of the life cycle process (Ibrahim and Paulson 2005). The organization may change for a particular phase as it progresses to the next sequential phase. Based on Ibrahim and Paulson's (2005) study, the facility development life cycle operates on a combined complex, uncertain, and equivocal environment. On the other hand, the organization structure for the concurrent phases remains constant and parallel to multiple, sequential phases. This observation relates very well to Scott's (2003) *open system perspective*. In an open system, the organizational structure 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 being capable of semiautonomous action, which are loosely coupled to other parts. In the open system, individuals and subgroups form and leave the coalition, emphasizing the earlier *contingency theory* of Lawrence and Lorsch's (1967 in Scott (2003)) on the fluid movement between people and process while the process is still on-going.

Lawrence and Lorsch (1967 in Scott (2003)) were the first to coin the *contingency* term when they argue that different environments place differing requirements on organizations: specifically, environments characterized by uncertainty and rapid rates of change in market conditions or technologies. These changes present different demands—both constraints and opportunities—on organizations than do placid and stable environments. In order for the organizations to cope with these various environments, they create specialized subunits with differing structural features. Both researchers found that the more differentiated the organizational structure, the more difficult it will be to coordinate the activities of the various subunits and the more bases for conflict will exist among participants. Hence, more resources and effort must be devoted to coordinating the various activities and to resolving conflicts among members if the organization is to perform effectively. This concept would later influence Galbraith (1974 and 1977 in Scott (2003)) for his famed *information-processing theory* of the organization.

Maintaining the production flows and feedback loops of input, throughput, and output production flows in such an organization is problematic. In fact, Burton and Obel's (2003) closest category for such dynamic organization configuration is *ad hoc.* Ad hoc configuration has no hierarchy at all (p. 64), but Ibrahim and Paulson's (2005) ethnographic study indicates that the project manager is very much in 'control' although he may be overwhelmed by an overload of information processing tasks. Their study observed an organization that is consistently evolving between the major milestone events they identified.

The dilemma in managing knowledge flows in a discontinuous organization is that the organization continues to evolve during the sequential process while another is maintained in another concurrent process. The interdependent, but loose, connection is the only link for knowledge flows to happen between the different organizations. It is easy for knowledge loss to occur when the connectivity between the organizations is loose, and made worse with discontinuous membership as evidenced by this study. By having discontinuous membership throughout various phases of the process, the enterprise is at risk of not being efficient and effective as demonstrated by the test cases in the VDT-KN simulation (Ibrahim et al. 2005b). New team members contribute new knowledge, and members who leave bring out some knowledge with them. Therefore, we are proposing the emergence of a new structural configuration of an organization called *discontinuous*.

In lieu of this unique discontinuous structural configuration, this study finds that low centralization and formalization requirements are also instigating the knowledge loss phenomenon in the facility development enterprise. According to Proposition 6.6 (Burton and Obel 2003) whereby an organization whose environment is high on equivocality, high on complexity, and high on uncertainty, then its formalization should be low, organizational complexity should be low, and centralization should be low. An organization may be able to provide routine technology to coordinate and monitor a complex environment so long as it integrates all the task interdependencies between critical tasks in its workflow processes (ibid.). The contingency fit in Burton and Obel's *contingency theory* requires that the organizational design situation is internally consistent (ibid., p. 17), which, in the facility developer's case, is not a good fit. In fact, Burton and Obel's *contingency theory* points out that it would be most difficult to have a routine technology for uncertain and equivocal environments—the dilemma facing the design and development of a much needed, yet suitable, knowledge management system for facility development.

The *contingency fit* is also unable to recommend any means for formal integration, but instead recommends an appropriate incentive system to coordinate the various activities. In this regard, Ibrahim and Paulson (2005) find evidence of conflicting incentives to various organizations within the facility development enterprise. For instance, the need for some kind of formalization (having standard operating rules) is required by the facility developer because of the need to integrate the financing requirements with the project's design. It promotes good credibility standing for for-profit facility developers' investors while ensuring the success of obtaining competitive funds for the non-profit facility developers. Prudent knowledge flow management is good practice for long-term property management. On the other hand, members of the design team are working towards financial rewards as agreed in their professional contracts. The mechanical engineer in the oak grove preservation example was working towards completing his task for which he relied on the architect's early documents while the facility developer was still negotiating with the local authority. The incentive systems for such an enterprise may as well be based on the level of its *reach* (i.e., individual, group, organization, and inter-organization) as an additional design parameter property of the organization. We foresee that in a tacit-dominant knowledge area, the higher the continuous attribute and the higher presence within one life-cycle phase, the organization could be more effective and efficient (Ibrahim et al. 2005a).

At the present status quo, we claim that the ethnographic study findings and the contingency misfits are suggesting that knowledge loss will be a never-ending problem to facility developers unless researchers and practitioners acknowledge the discontinuous attribute in the facility development's operating environment. This claim is substantiated by Ibrahim et al.'s (2005b) study, which affirms that a new member in a discontinuous organization who uses his inaccurate cognition of his other team members to complement his incomplete cognitive skill, can expose his task to a higher risk of failure that, in turn, is detrimental to his overall team's organizational performance in the long run. Knowledge flows in different phases—sequential or concurrent—depend on the dominant knowledge type most likely to transpire within the phases. Ibrahim et al. (2005a) find that experts who are continuous members of a discontinuous organization facilitate the flow of knowledge in that organization. They also find that the functional experts are self-sufficient in explicit-dominant knowledge areas, but, in tacit-dominant knowledge areas, the continuous presence of the experts is critical for knowledge flow. With support from Ibrahim et al. (2005b) that discontinuous membership could be detrimental to an organization, we pose that the explicitness level of knowledge is key to determine how effective and efficient an organization would be in various properties and structural configuration fit.

Furthermore, the knowledge network analysis by Ibrahim et al. (2005a) illustrates that within a single life-cycle phase, there could be a combination of different knowledge types—i.e., tacit and explicit—depending on which knowledge area is required to perform the task. Their study illustrates that different dominant knowledge types have different knowledge flow characteristics. Being continuous encourages expert members to contribute generously to other members of the organization during the highest risk period of the facility development life cycle, i.e., the *feasibility* and *entitlements phases*. Although Galbraith (1974 and 1977) views the organization as an information-processing entity, and that exception-handling is the responsibility of the supervisor in the organization structure, the study found a non-hierarchical communication patterns in all the knowledge areas it identified for the Knowledge Areas Mapping Exercise (KAME). Monge and Contractor (2003) called this informal network an "emergent" network, which represents other than the vertical hierarchical characteristics of information-processing. It includes the development of hierarchy through socialization outside the formal structure. The VDT-KN extension study (Ibrahim et al. 2005b) also demonstrates that non-hierarchical information-processing can affect organizational performance. The regressing media richness that occurs as a facility development process progresses provides additional support to this end. We claim that tacit knowledge within the organization flows principally through socialization and internalization (Nonaka 1994) especially during the high media rich period—i.e., during the feasibility and entitlements phases. However, instead of moving up and down the organizational hierarchy, knowledge flows through the social hierarchy where perceived expertise by individual members is the determinant (Ibrahim et al. 2005a).

Based on these earlier studies conveying the impacts of knowledge flows on organizational performance (Ibrahim and Paulson 2005; Ibrahim et al. 2005a; Ibrahim et al. 2005b), we posit that knowledge flow behaviors affect organizational performance in a substantial way. Moreover, this study illustrates that discontinuous membership affects organizational performance substantially as well. In summarizing our discussion, our arguments would support a proposal to add *knowledge* as the seventh contingency factor (i.e., as articulated by Burton and Obel 2003) for the design of organizational structure, where *tacit* and *explicit* are its measures. We also propose *discontinuous* as another structural configuration measure, and *reach* as another design parameter property measure. Our proposal supports Nissen's (2005b) claim that future organization design can be based on knowledge flows.

7. CONCLUSION

There are several noteworthy contributions and implications from this research. A major contribution of this work is that the knowledge-based organizational performance model can justify and support the addition of *knowledge* as the seventh contingency factor in Burton and Obel's (2003) contingency theory for organization design. Our claim is supported by a separate study by Ibrahim et al. (2005b) illustrating a proof-of-concept that inaccurate expertise cognition by a new member in a discontinuous organization can negatively affect the overall organizational performance of an enterprise. Future research is in line to develop *knowledge* contingency fit propositions for inclusion in the well-established diagnosis and design of organizations.

The utilization of knowledge flows in organization design provides a second contribution. Through this research, we have grounded Nissen's (2004) knowledge-flow trajectory model and Nonaka's (1994) dynamics of knowledge creation and flow theories as important factors for consideration in contingency theory. More research in developing descriptive and measurable knowledge-flow constructs is also in line for the future.

Another contribution and implication in a product development process stems from our new understanding of how discontinuous membership affects knowledge flows in an enterprise. The knowledge-based organizational performance model takes into consideration the practical aspects of knowledge transfer among temporal members. It has implications on future methods of transferring knowledge in temporal organizations. The extension of transactive memory theory to include knowledge access to another member who is not present in the current team can help improve how organizations manage and train their knowledge resources. Future research is in line to review how organizations create, store, retrieve, and transfer knowledge, especially tacit knowledge that mainly belongs to individuals of the enterprise.

In conclusion, the knowledge-based organizational performance model extends organization theory to address the dynamics of knowledge flows. It is grounded in established organization theories—by virtue of a multi-disciplinary case study research methodology—such as Galbraith's (1974 and 1977) information-processing theory, Grant's (1996) knowledge of the firm theory, Cohen and Levinthal's (1990) absorptive capacity theory, Burton and Obel's (2003) contingency theory, and Wegner's transactive memory theory (1987; in Hollingshead 1998a and 1998b). The model is further grounded in Nonaka's (1994) dynamics of knowledge creation and flows theory, and Nissen's (2002) knowledge flow trajectory of knowledge flow dynamics theory. The knowledge-based organizational performance model will inform practice through new theory on designing organizations with discontinuous membership.

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