Enhancing Cognition by Understanding Knowledge Flow Characteristics during Design Collaboration

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Abstract

Organization researchers cannot fit the complex property development workflow processes with Galbraith's information processing design theory, hence undermining attempts to ensure knowledge flow in complex multi-disciplinary design collaborations. This survey paper summarizes recently completed studies at Stanford University on knowledge flows that affect organizational performance. The studies found that knowledge flows in functional knowledge areas differ from those in tacit knowledge areas. Future research will lead to the development of a knowledge management system for sustainable property development that considers the different dominant knowledge types during different design phases.

Keywords*:* Collaborative Design, Organization Design, Computational Theories, Design Cognition, Knowledge Flows.

1. Introduction

Design collaboration assists knowledge movement among multi-discipline professionals involved in property development projects. However, synchronous collaborations are not always possible in global projects. Therefore, global projects require a highly effective asynchronous knowledge management system to support the complex process. Despite emerging processes and high performance team skills that develop as a result of the efficient and effective use of advanced IT solutions (Fruchter, 1999), knowledge still gets missing (Ibrahim and Paulson, 2005; Carillo, et al., 2004). Coupled with the fact that organization researchers (for example, Burton and Obel, 2003) cannot provide solutions to fit the complex property development workflow process with Galbraith's (1974) established *information processing* organizational design theory, we are motivated to develop a framework for effective knowledge movement during design collaboration. Galbraith (1974) states that organizations are designed to facilitate decision-making through their hierarchical structures. Galbraith assumes that supervisors who are on the higher level in the hierarchy, would know more than their subordinates. This is because they could be expected to have a broader view of a complex series of processes. Scholars have observed that the possession of knowledge within the property developments' project team (that includes designers, builders, and property managers) cannot guarantee its movement among the team members (Ibrahim, et al., 2005a; Ibrahim and Nissen, 2005).

We define *knowledge* as a set of commitments and beliefs of its holder that enables the holder to undertake certain action (Nonaka (1994) in Ibrahim, 2005). The criterion for using the term 'knowledge' is its *enabling action* property that allows the holder of a knowledge entity to undertake certain actions. *Explicit knowledge* is the selected and applicable group of facts that is transmittable in a formal systematic language that enables its holder to take some action to complete a task (Ibrahim, 2005), while *tacit knowledge* is the embedded belief that an individual or an enterprise possesses in selecting and applying a group of facts that enables action to complete a task (Polanyi (1967) and Nonaka (1994) in Ibrahim, 2005). Further, we define *organization* as a team of professionals responsible for a workflow, and *enterprise* as consisting of several organizations responsible for a workflow (Ibrahim, 2005).

The knowledge loss phenomenon (K-loss) becomes critical when a multi-disciplinary team is responsible for the design and construction of a global project. Knowledge loss occurs when existing selected information has been documented, but due to the ignorance of newcomers in a project's organization, that information is not utilized later during the process. Recent findings from a group of interstitial studies at Stanford University on the impacts of knowledge flows to organizational performance in complex processes (for example, Ibrahim and Paulson, 2005; Ibrahim, et al., 2005a; Ibrahim, et al., 2005b; Ibrahim and Nissen, 2005) shed some light on this K-loss phenomenon. They link construction errors to the discontinuity characteristic of a project development team, and highlight the influence of different knowledge types to the overall organizational performance. The term discontinuity was used by Anderson and Tushman (1990) to describe the 'break' that happened when technology advancement would force previous technology to discontinue hence forcing organizational change. In this context, the term explains the discontinuity of an organizational structure caused by the change in the workflow characteristics due to environmental influences.

These findings are pertinent since design research has long encouraged advanced collaborative design methodologies towards sustainable project developments (Reed and Gordon, 2000). Equally important is the understanding that the knowledge type dominance during different design stages influences the design methodologies and tools required during each particular stage. The Stanford University studies also found that knowledge flows in functional knowledge areas, such as architecture-engineering-construction where explicit knowledge movement dominates, supports transactive memory theory (Wegner, 1987), but not in tacit knowledge areas, such as regulatory and authority requirements, where socialization and internalization dominate (Ibrahim, et al., 2005b).

Wegner (1987) describes transactive memory as a shared cognitive 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.

This paper discusses the impacts on collaborative design when team members want to sustain and ensure efficient knowledge movement from conceptual phase to property management. It is preceded by a background literature summary from selected results of the Stanford University's studies. Additionally, it recommends future research areas that are of interest to collaborative design organizations.

2. Background Literature

This section provides the background literature based on several recently completed studies at Stanford University. They represent unique environmental characteristics obtained by an ethnographic study (Ibrahim and Paulson, 2005), computational organizational simulation studies (Ibrahim, et al., 2005a; Ibrahim, et al., 2005b), and knowledge flows theory development (Ibrahim and Nissen, 2005). These studies examined the property development process and its project team from a meta-level, i.e., in an attempt to bridge theories from several domains to understand the K-loss phenomenon. These studies were motivated by the fact that knowledge loss (K-loss) continues to occur despite the advancement of technologies. The ethnographic study (Ibrahim and Paulson, 2005) provides rich insights into the cultural and operating environment of property development teams from a project manager's perspective. It highlights the property development environment as (a) being in constant discontinuous memberships; (b) having multiple sequential and concurrent phases with different organizations responsible for each phase; (c) having multiple interdependent tasks, and (d) having different knowledge types dominating in different phases. These ethnographic findings are cross-validated by several succeeding studies (i.e., Ibrahim, et al., 2005a; Ibrahim, et al., 2005b; Ibrahim and Nissen, 2005), which seek to improve knowledge flows for better organizational performance in development project teams.

2.1 Discontinuous Memberships

The property development ethnographic study (Ibrahim and Paulson, 2005) reveals a dynamic organizational structure that varies across different property development life cycle phases. The evolving organization is caused by the need for different skill sets among its team members in order to complete the tasks in a single phase's workflow process. It was found that some team members remain in several life-cycle phases of a property development, but the frequency of their participations varies. Some team members served only in one phase, such as the environmental engineer who only served in the feasibility-entitlements phase. On the other hand, the architect was involved in three phases, involving design and construction tasks. Table 1 and 2 illustrate the involvement distribution by team members of a sample affordable housing development project.

Ibrahim and Paulson (2005) claimed that discontinuous membership is a source for knowledge losses in the property development projects. Discontinuity in an organization occurs when a position in an organizational structure is added or deleted while the process is on going. It differs from turnover, which occurs when the incumbent of a position in an organizational structure is replaced with another incumbent to fulfill the same position's role during the on-going process. Ibrahim, et al. (2005a) supported these earlier results. They found that a new member could cause the task he or she is handling to incur higher functional risk, 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 property development any missing knowledge may force development project sponsors to decide not to proceed with the project. A project development's cancellation means the lost of future income to designers and builders alike.

Table 1. Position and Contributing Fulltime Equivalent (FTE) Allocations from Owner for Different Property Development Life-cycle Phases (Adapted from Ibrahim 2005)

Agent's Position Phase	FE	BP	CO	PM	DPF	AM
OWNER						
Executive Director	0.40	0.20	0.20	0.20	0.20	0.20
Project Manager	0.50	0.20	0.20	0.20	0.25	0.15
Services Director				0.10	0.10	
Accounting Department					0.50	
Chief Operating Officer				0.30		
Public Relations Exec.				1.00		
Regional Manager				0.30		
Compliance Specialist				1.00		
Property Manager				0.30		
Site Manager				1.00		

Table 2. Position and Contributing Fulltime Equivalent (FTE) Allocations from the Architectural-Engineering Consultants and Builder Staff for Property Development Life-cycle Phases (Adapted from Ibrahim, 2005)

Agent's Position Phase	FE	BP	CO	PM	DPF	AM
A-E CONSULTANTS & BUILDER						
Title Company	1.00					
Environmental Engineer	1.00					
Surveyor	1.00		1.00			
Architect	1.00	4.00	0.50			
Civil Engineer	0.50	1.00	0.10			
Landscape Architect	0.50	1.00	0.10			
Geotech Engineer	1.00					
Financial Consultant	1.00				1.00	1.00
General Contractor	0.10	1.00	2.00			
Value Engineer	1.00	1.00				
Wood Structural Engineer		0.25	0.10			
Concrete Structural Engineer		0.25	0.10			
MEP Engineer		0.50	0.10			
3rd Party Inspector			0.10			
Geotech Inspector			0.10			
Legal Advisor					0.50	0.15
Auditor					1.00	

Note: FE = Feasibility-Entitlements; BP = Building Permit; CO = Construction; PM = Property Management; DPF = Development Project Finance; AM = Asset Management; 1FTE = 8-hour per day in a 5-day week.

Discontinuity in organizations happens because different skill sets are required to perform different tasks in different workflow processes. Despite this logical project management planning, the discontinuous attribute actually undermines Cohen and Levinthal's (1990) findings about the absorptive capacity of a firm, where knowledge of an organization is built 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 with them, while the remaining team members plus new members continue building its knowledge. The open system (Scott, 2003) explains the property development organization as a system persisting over time. It exhibits an organizational structure that stresses the complexity and variability of the individual parts—individual professional members and different working teams—as well as the looseness of connections among them. The multiple phases plus different working teams being responsible for each phase are viewed as capable of semiautonomous action, and they are only loosely coupled to other parts. In an open system, individuals and working teams can form and leave the coalitions. This behavior is explained by an earlier contingency theory of Lawrence and Lorsch's (1967) who posited that environmental conditions are the reasons why there exists fluid movement between people and process, and they noted that the movements occur while the process is on-going.

Despite the discontinuity character in property development organizations, the Ibrahim, et al. (2005a) study observes that regularities in the organization—also highlighted by Grant (1996) and Kogut and Zander (1992)—do help an organization to overcome this organizational dynamism. A property project could still move forward despite having engaged a new civil engineer, or omitted the landscape architect's position. This is evidenced by the lack of significant changes to the overall total work volume and the duration of project for two test cases in Ibrahim, et al.'s (2005a) study. More importantly, their intellective computational model reflects how a subtly incomplete task could cause a major failure in the total process if it was not addressed diligently. As in many cases, the project managers are too overloaded to catch an apparently minor error. Unfortunately, the minor error tends to be discovered after a major breakdown in the total process, which is usually in the form of financial or schedule losses.

2.2 Multiple Sequential and Concurrent Workflows

The property development life cycle process consists of several sequential and concurrent phases. These phases are unique because each life-cycle phase has a different workflow process that requires different skill sets for the team to complete the tasks (Ibrahim and Paulson, 2005). Ibrahim (2001) earlier had divided the sequential phases of the property development life cycle process into feasibility, entitlements, building permit, construction, and property management phases. The most critical is during the integrated feasibility and entitlements phases, which Ibrahim and Paulson (2005) later combined into the feasibility-entitlements phase. This early phase starts when a parcel of land becomes available for consideration, and continues until the development proposal receives its entitlements. The finance phase runs concurrently throughout the property life cycle process, and is handled mainly by non design- and construction-related team members. A distinct asset management phase tends to exist in larger organizations with large property portfolios.

2.3. Interdependent Tasks

Another finding from Ibrahim and Paulson (2005) is that the workflow in each phase can have interdependent tasks with tasks in different workflows belonging to other concurrent phases. For example, property developers require building permits before starting construction, but they need to close the construction loan before issuing the site hand-over for the general contractor to start construction. Obtaining the building permit to start construction is in a sequential workflow, but obtaining a building permit to close the construction loan to start construction is in two concurrent workflows. Despite the risky outcome that a property project may not eventually see its implementation, Ibrahim and Paulson (2005) were surprised to find the project managers were not concerned with the uncertainties and complexity of the property development life cycle process. In fact, these experienced project managers exhibited substantial tacit knowledge of their operating environment that enable them to comfortably maneuver socially, politically, and financially throughout the complex process.

2.4 Different Knowledge Types

With the above-mentioned observations, Ibrahim and Paulson (2005) concluded that different characteristics of knowledge movements occur during different property development's life-cycle phases. During the feasibility-entitlements phase, tacit knowledge dominates. Project managers articulate and share knowledge through their actions, commitments, and involvement in a specific context (Polanyi, 1967). They obtain tacit knowledge by socializing and internalizing the actions and comments of the local elected officials and the public that supports them. Unlike tacit knowledge, explicit knowledge is transmittable in formal, systematic language. It can be articulated and shared via plans, drawings, documents and databases, which are the dominant form of communication among the architectural-engineering-construction team members. Subsequent studies by Ibrahim, et al. (2005a), and Ibrahim, et al. (2005b) cross-validated Ibrahim and Paulson's (2005) assumption.

Knowledge flows in the Ibrahim, et al.'s (2005b) study illustrate that discontinuous membership organizations are not only impacted by the distribution of expertise but also by continuous vs. discontinuous participation of members. Firstly, individuals would retrieve information from more expert members of the group. However, the knowledge retrieval results illustrate that in a discontinuous organization, while expert members would tend to wait for lesser expert members to retrieve knowledge from them, they would also tend to seek information from other members. Secondly, individuals would allocate information to more expert members of the group. However, again their study found an interesting additional knowledge allocation pattern. Experts in this discontinuous organization also tended to allocate information to a greater number of others than their less expert counterparts. Thirdly, in a discontinuous membership organization, members will turn to continuous members to augment their knowledge by referring to "who knows what." Individuals who were continuous members also have higher tendency for both knowledge retrievals and knowledge allocations. Both the knowledge retrieval and allocation behaviors show that both continuous and expert members do turn to other members in their network to augment their knowledge by referring to "who knows what" when their cognitive knowledge networks are incomplete.

3. Discussions and Recommendations

In this section, we discuss some critical impacts on collaborative design arising from the above findings. They target design computing and cognition research at the K-loss point of conception, understanding the organizational behavior of the design team, extending transactive memory theory for collaborative design teams, and developing a knowledge management system that support the complex environmental characteristics in property development.

3.1 Targeting the K-Loss Point of Conception

A comparison was made by Ibrahim (2005) between the three viewpoints—namely those of the city authorities, the property developer, and the architect—to see whether these three parties agree on their definitions of a property development process. In general, the city authority is not concerned with whether the project sponsors benefit from their development projects. On the other hand, project sponsors are concerned about the financial sustainability of their facilities, while the architect provides technical support to the project sponsors. From the project sponsor's point of view, how the design proposals advance from schematic drawings to construction documents is not its concern as long as it is aware that the architect is coordinating the design and construction documents. This is because, during the planning approval to construction periods, property developers are busy lining up their permanent financing in order to close their construction loans. This scenario hints at a dual side of the development process prior to the construction phase: the well-known architectural-engineering-construction (AEC) design-construction process versus the property developer's [project sponsor's] public and financing processes. The only period when both processes require one another's continuous interaction is during the entitlements (planning approval) process (Ibrahim and Paulson, 2005). During the planning approval process, architects are the ones preparing or coordinating the bulk of planning and architectural documents for the planning approval. The documents provide the means for project sponsors to cost and plan their development schedule. Additionally, they use these documents to obtain construction and permanent financing. Ibrahim and Paulson (2005) identified that this is the period during which most of the K-loss occurrences start manifesting themselves in the property development process. Discontinuity in the property development enterprise starts becoming prominent during the entitlements phase. Therefore, we are recommending the need to develop continuous integration tools and methodologies to mitigate against the segregation of professional inputs between the project sponsors and its design team.

3.2 Understanding Design Team's Organizational Behavior

The Stanford University studies illustrate that the design team, consisting mainly of architects and engineers, is part of a bigger property development organization that includes the project sponsor's management and finance teams. Design researchers will need to work with organization researchers on extending Galbraith's (1974) information processing theory for the design of dynamic organizations. The information processing theory states that an organization is designed for enabling decision-making through information analysis and synthesis by the supervisor (i.e., information processing activity) because the supervisor is more knowledgeable about the tasks in a workflow process than the subordinates. The information processing theory, however, limits the exception handling in an organizational structure vertically. It cannot perform satisfactorily in non-hierarchical peer-to-peer situations—such as in design collaboration teams—and in discontinuous enterprise—such as the property development organization (Ibrahim, et al., 2005a; Ibrahim, et al., 2005b; Ibrahim and Nissen, 2005). We believe that the design field can benefit from further studies on how design organizations can continue learning in such a complex environment, especially when the team members can freely join and leave the team, as and when they are required. Furthermore, it is recommended that design researchers should work with knowledge management researchers to develop measurements for knowledge flows and organizational learning and thereby improve the current knowledge management system that supports sustainable global property projects efficiently.

3.3 Extending Transactive Memory for Design Teams

An effective transactive memory system (Wegner, 1987) has several advantages for a group process. Among them is the expansion of an individual's expertise when the individual gains access to knowledge of other experts. Another is that an individual also gains access to new knowledge that is created through integrations occurring within the transactive process (Wegner, 1987). This is due to the fact that integration affirms the need to have a group in the first place, and reminds all members of the benefits of coming together. Moreover, Mooreland (1999) found that groups with effective transactive memory systems could complete tasks more efficiently. Until the study by Ibrahim, et al. (2005b), it was not known if the advantages of effective transactive memory systems in continuous membership organizations will apply equally to discontinuous membership organizations. Foremost, it is integral for design researchers to continue documenting tacit knowledge and communication transfer for effective design collaborations using IT. The ethnographic research methodology is useful in such field conditions. These studies will lead to research and the development of new constructs that merge transactive memory and contingency theory supporting the design of discontinuous property development teams. We also recommend researchers to study emerging theories at the meta-level in order to bridge the multi-disciplinary nature of this complex property development life cycle that exhibits multiple sequential and concurrent workflows. They can no longer study a design team per se, but the design team within a property development enterprise.

3.4 Developing a Dynamic Knowledge Management System

Another implication concerns the practical aspects of knowledge transfer among temporal members and organizations. The Ibrahim, et al. (2005a) study provides 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. Ibrahim and Nissen (2005) later grounded Nissen's (2002) knowledge-flow trajectory model and Nonaka's (1994) dynamics of knowledge creation and flow theories when they developed the knowledge-based organizational performance model. Ibrahim and Nissen (2005) propose to add knowledge as the seventh contingency factor (i.e., as articulated by Burton and Obel 2003) for the design of organizational structure, where its measures are tacit and explicit. They also propose discontinuous as another structural configuration measure, and reach as another design parameter property measure. Their proposal supports Nissen's (2005b) claim that future organization design can be based on knowledge flows. In view of this, we are recommending future research to develop propositions for knowledge contingency fit for inclusion in the well-established diagnosis and design (Burton and Obel, 2003) for design collaboration teams. More research will be required to develop descriptive and measurable knowledge-flow constructs. Further extension of transactive memory theory (Wegner, 1987) must include knowledge access to another member who is not present in the current team. More research is recommended to review how design organizations create, store, retrieve, and transfer knowledge, especially tacit knowledge that belongs mainly to individuals.

4. Conclusions

This paper highlighted recent findings on the environmental characteristics of property development that affect design organizations. These organizations have discontinuous memberships, having multiple sequential and concurrent phases with different team responsible for each phase, having interdependent tasks, and having different knowledge type dominance in each phase. It also signifies that design organizations are working in dominantly tacit knowledge areas during planning and conceptual design phase, which increasingly progress towards explicit-dominant knowledge areas culminating in the property management phase. We recommend further research in the design field that would support the discontinuous characteristic of property development teams. Among them are targeting design integration research at the K-loss point of conception; work with organizational and knowledge management researchers to develop measurements for knowledge flows and organizational learning; extending transactive memory theory with contingency theory to understand and support the discontinuous property development teams; and developing constructs and measures for knowledge contingency fit that supports design collaboration teams. In conclusion, it is recommended that design researchers extend their research at the meta-level as the nature of design collaboration requires understanding of various disciplinary inputs to improve their research syntheses. It is expected that such studies will lead to the development of a sustainable knowledge management system that supports dynamic design teams as the development project progresses.

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