Developing a Knowledge-based Organizational Performance Model for Discontinuous Participatory Enterprises

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Abstract

Our research seeks to understand how to extend established organization theory and emerging knowledge-flow theory to inform the design of organizations with discontinuous participation. Because knowledge flows enable workflows, and work determines 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, and it attenuates particularly quickly in organizations that experience discontinuous participation. In this paper we build upon an ethnographic study and computational organization theory (COT) to model and analyze discontinuous participation in the domain of facility development. We find organizational design characteristics such as task interdependency affect flows of tacit knowledge and hence work performance in the enterprise. Computational and analytical results suggest how we can extend organization theory to address the dynamics of knowledge flows when designing organizations with discontinuous participation.

1. Introduction

Knowledge management research needs a consistent and cohesive theory supported by empirical evidence to provide sound and stable foundations for the field [12]. Our research seeks to understand how to extend established organization theory and emerging knowledge-flows theory to inform the design of organizations and to examine empirically the relative performance of alternate designs. Since knowledge flows enable workflows, they are essential to organizational performance wherever knowledge and information work are involved. Theory suggests the organization of knowledge—particularly tacit knowledge—is critical for competitive advantage ([10]; [26]). Tacit knowledge is the 'know how' that is not explicitly available to an enterprise [10].

Tacit knowledge does not flow well through the enterprise, and such flows attenuate particularly quickly in organizations that experience discontinuous participation. In the domain of facility development, for example, utilization of tacit knowledge is observed to be critical during the earlier *Feasibility* and *Entitlements* phases [28]. We explore this example in greater detail below but introduce briefly these two phases here. Feasibility phase starts when the owner reviews a parcel of land, and it continues until he or she applies for a permit to develop the land. The Entitlements phase follows immediately after feasibility and continues until the approval application has been received. Facility development provides a rich environment for our study of knowledge flows.

In this paper we build upon an ethnographic study and computational organization theory (COT) to model and analyze discontinuous participation in the domain of facility development. We first present our motivating background problem followed by our literature and ethnography points of departure. Then we describe the research method, results and validation. The paper closes with a discussion on how we can develop a knowledge-based organizational performance model.

2. Motivating background problem

The construction industry understands very well that incomplete knowledge transfer can cause unnecessary rework and delay [34]. For instance, a facility developer agreed to maintain an oak grove at one corner of a property as one of the development approval terms with a city council. Several months down the facility development process, his building permit was rejected (costing several months delay) because his mechanical engineer submitted a building plan that routed the water piping system through this oak grove. The mechanical engineer located the piping route in that corner because it was the location for all major water in-take points to the site.

The example illustrates an honest but costly mistake to the facility developer. The latter team member had no way to *know* what the earlier members had committed to the regulatory parties. Hence this represents a problem with knowledge flows in the facility development organization. Most disturbing is the fact that similar knowledge-flow problems continue to occur, even when the facility development organization has explicit documentation and maintains one development project manager throughout the facility development life cycle process. This illustration also calls us to question Cohen's and Levinthal's [32] absorptive capacity theory (i.e., that an organization's knowledge is built upon its prior knowledge). Even though explicit knowledge is documented, such knowledge does not flow through the organization.

Burton's and Obel's [5] Contingency Theory describes the facility development life cycle's operating environment as high in *uncertainty*, high in *complexity*, and high in *equivocality*. It has high complexity because, despite having a functional organizational configuration, the facility development organization also reflects a strong matrix configuration. For example, it is common for a single project manager to handle several development projects concurrently. There are also many interdependencies between workflow processes in a development project. For instance, the facility development team needs to work with its finance and property management teams internally, while working with external design consultants and regulatory agencies to complete the development project. A facility development project has high uncertainty because, despite having a general sequential development activity schedule, each one is unique. Project managers cannot predetermine accurately which workflow path they need to concentrate on at any given time. In an example, facility developers cannot be sure which program will fund a particular facility development project, and each funding program can have different requirements and application procedures. The operating environment has high equivocality, because the many diverse stakeholders exhibit multiple and conflicting interpretations, confusion, and lack of shared understanding. These are apparent especially when dealing with regulatory agencies, city officials, and the public.

Burton and Obel also posit that there is a tendency by the managers to get overloaded in such dynamic operating environment and organization, whereby *Ad Hoc* or *Matrix* configurations are the best organizational structures to manage the workflow processes. An ad hoc configuration is characterized by high horizontal differentiation, low vertical differentiation, low formalization, decentralization, and great flexibility and responsiveness. A matrix configuration is a structure that assigns specialists from functional departments to work on one or more interdisciplinary teams that are led by project leaders. Their Contingency Theory states that a *developmental* climate organization, such as the facility development enterprise, should be medium in complexity, low in vertical differentiation and formalization, and low/medium in centralization. Burton and Obel describe the climate as a dynamic, entrepreneurial and creative place to work. Its best coordination methods are via planning, integrators, meetings, use of rich media, while its best motivation is to provide result-based incentives.

Motivated by the problems with tacit knowledge flows, we undertake an ethnographic study to understand the reason why this phenomenon is frequent in facility development projects. We seek to learn how we can mitigate this costly knowledge-flow problem and how we can assist owners to coordinate better their product life cycle process.

3. Points of departure

In this section we outline the points of departure for the research described in this article. We begin with an abbreviated literature review and then summarize preliminary ethnographic research upon which this present work builds.

3.1. Literature Review

Much of the organizational literature concentrates on organization formation and behavior ([7]; [15]; [9]; [30]; [5]). This literature extends to include the study of how organizations learn [4] and adapt to their environment ([8]; [2]). In the knowledge management literature, Alavi and Leidner [19] note an abundance of research on knowledge creation, knowledge storage, and knowledge retrieval. However, they note also the lack of research on knowledge transfer. In fact, the study of knowledge flows (e.g., including sharing and transfer) is comparatively recent (e.g., mid 1990's). Based on Kogut and Zander's [3] work on a knowledge-based theory of the firm, Grant [29] and Nonaka [10] support that knowledge is held by individuals. They support also that the organization plays a critical role in articulating and amplifying individual knowledge.

Nonaka further proposes four modes of knowledge transfer mechanism—socialization, externalization, combination, and internalization (SECI)—in a dynamic spiral relationship between tacit and explicit knowledge as it extends its reach. Nissen [20] extends Nonaka's dynamics of knowledge flow theory by studying patterns of knowledge flows within an organization. In his later work [22] Nissen posits that new organizational forms may obtain and even dominate through a focus on dynamic knowledge flows.

Even though research on the phenomenon of knowledge flows remains at a relatively early stage and does not appear ready for numerical measurement of variables, Nissen provides discrete qualitative categories for potential operationalization of knowledge flows in the enterprise. His four knowledge flow dimensions are *explicitness* (i.e., type of knowledge; e.g., tacit versus explicit), *reach* (i.e., level of socialization associated with the knowledge; e.g., individual, group, organization), *life* *cycle* (i.e., activities of knowledge work; e.g., create, share, apply), and *flow time* (e.g., hours, weeks, years).

Here we concentrate on amplifying tacit knowledge flows within an organization, and we extend Nissen's work in developing new theories on knowledge-flow dynamics. By the term *amplify*, we embrace Nonaka's [10] tacit knowledge definition—i.e. the 'know how' that is not available explicitly to an enterprise—and look to extending the reach of tacit knowledge from individuals and dyads to large groups and organizations.

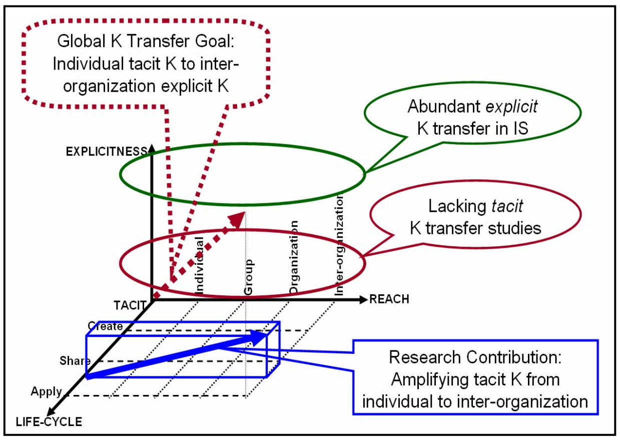

Figure 1. Research contribution to dynamics of knowledge flow theories by amplifying tacit knowledge from individual to inter-organization (adapted from Nissen [20])

Here we also summarize the literature gap and identify how this study contributes towards reducing such gap in Figure 1. We adapt Nissen's [20] three-dimensional vector representation that enables researchers to visualize enterprise knowledge flows. The global goal of knowledge transfer is expediting individual tacit knowledge to the enterprise's explicit knowledge. Referring to Figure 1, the first dimension is *explicitness* ([27]; [10]). The second dimension is *reach*. The third dimension is *life cycle*.

In terms of the gap, Alavi and Leidner [19] highlight abundant explicit knowledge transfer in the information system literature. Many researchers define knowledge as an explicit item that can be stored, retrieved, and used. On the other hand, they point also to the dearth of literature on transferring tacit knowledge. It is in this lower area of the explicitness dimension on which our study focuses and hence addresses a knowledge gap in terms of knowledge flows.

3.2. Preliminary Ethnographic Research

The first author conducted an ethnography study to examine knowledge flows in the facility development domain. Details of the ethnography study will be published separately. She wanted to understand why knowledge-flow problems occur despite the developers having invested in information technology tools for knowledge management. The ethnography results provided rich research insights into the culture and operating environment of such enterprise from the facility developer's perspective. These insights serve to inform the present study

A major affordable housing developer in the San Francisco Bay Area became the unit of analysis. At the time of the study, the affordable housing developer had completed 73 projects located in the Bay Area, and it was managing about 5,000 units of affordable housing. During the first author's summer internship at its central office in 2002, there were seven project managers handling fourteen projects at various stages of the facility development life cycle. She was a participant-observer during the initial three-month data collection period and had continued access to the organization for the next two years as an observer. She reported to the chief operating officer, the gatekeeper, who gave her access to documents and human resources in the office. The major sources of data were archival documents of 73 projects and interviews with selected executives and staff at the central office. The following describes the four major operating environment constructs she documented.

Multiple concurrent and sequential workflows: The facility development process is complex in general, but the affordable housing development process is more complex due to the financial and regulatory constraints that state and federal programs impose on their developments and operations [11]. The ethnographic observations support Ibrahim's earlier work, which divides the sequential phases of the facility development process into five phases: 1) *Feasibility*, 2) *Entitlements*, 3) *Building Permit*, 4) *Constructio*n, and 5) *Property Management Phases*. In terms of knowledge flows, the most critical appear to be the Feasibility and Entitlements Phases. For clarity, we group these two early phases together (i.e. Feasibility-Entitlements Phase).

Discontinuous participation: The second major construct represents a unique organizational character—a dynamic organizational structure that varies across different facility development life cycle phases. The dynamics of the evolving organization are caused by different skill sets that are needed by team members in order to complete the tasks in a single workflow process. We found that some team members contributed to multiple facility development life cycle phases, but the frequency and intensity of their participation varies across such phases (e.g., the architect is involved in three phases which require design and construction tasks). Other team members served in only a single phase (e.g., the environmental engineer in the Feasibility-Entitlements Phase).

Task interdependencies: The third major construct acknowledges that each phase has tasks that are interdependent with those in concurrent phases. For instance, facility developers require building permits before starting construction, but they need to finalize the construction loan before handing the site to the general contractor to start construction. The tasks to obtain a building permit and handing over the site are sequential in one phase. However, the task to finalize the construction loan is in another concurrent phase.

Knowledge form: Different forms of knowledge dominate during different facility development life cycle phases. Specifically, tacit knowledge dominates during the early Feasibility and Entitlements phase, while explicit knowledge is dominant during the later Building Permit, Construction, and Property Management phases. Tacit knowledge [27] is rooted deeply in action, commitment, and involvement in a specific context. As such it can be very difficult to articulate and share. Explicit knowledge is transmittable in formal, systematic language. As such it can be articulated and shared via plans, drawings, documents and databases. Facility developers obtain tacit knowledge by socializing and internalizing the actions and sayings of the local elected officials and the public that supports them.

4. Research method

We use the case study method [35] as our main research approach. The five components in a case study research design are: 1) research questions, 2) research propositions, 3) units of analysis, 4) the logic linking the data to the propositions, and 5) the criteria for interpreting the findings. Our main case study research question is, how do knowledge flows in an organization with discontinuous participation impact organizational performance? It is not feasible to test the discontinuous participatory phenomenon in an actual long-term facility project. The pre-construction phase usually ranges from two to three years, while the construction phase averages fifteen months. Hence we turn to computational organization theory to tests our propositions. This requires us to ensure that our COT model can represent with good fidelity the facility development operating environment. This requirement is critical for reliability and validity. In this research method section, we concentrate on how we build and validate the COT models and discuss later how we use the results to adjust the constructs to study knowledge flows in discontinuous participatory enterprise.

Based on our literature review and ethnographic findings, we are proposing that in a facility development project, discontinuous participation lowers organizational performance when tacit knowledge fails to flow well (e.g., rapidly and reliably). In most complex processes, project managers are so busy attending to (multiple) workflows that they become ineffective at sharing tacit knowledge with other team members. To test this proposition, we employ an agent-based tool that allows evaluation of multiple workflows in a single process. It also has the flexibility to represent the discontinuous nature of the participants in the organization during the process. Although SimVision® meets most our requirements for linking organization with process, we are wary of several limitations concerning knowledge flows. For instance, it does not represent or simulate knowledge flows directly. Nonetheless, we need to represent organizational performance in facility development using the dependent variable *simulated duration*.

This paper assumes some reader familiarity with agent-based modeling in general and SimVision® in particular. SimVision® is an agent-based representation ([6]; [14]) that reflects well-accepted theory of micro-level organizational behaviors [23]. Detailed background information can be obtained from Jin and Levitt [34]. Our COT case is a 43-unit affordable family housing development for farm workers located in the Bay Area. The family housing facility has been in operation since June 2001, but has been plagued with civil- and wastewater-related problems since construction. The *Baseline Model* represents high-level pre-construction activities of the COT case. At the *program* level, there are two *projects* running concurrently: the Design-Construction (Des-Cons) and the Finance-Asset Management (Fin-Assm) projects. In SimVision®, a program is a set of related projects that share dependencies and together achieve the client's business objectives. A project represents work an organization must perform to achieve a major business milestone. The Des-Cons and Fin-Assm projects consist of 39 tasks with twelve milestones. The Des-Cons project has three company staff and six external consultants, while the Fin-Assm project has four company staff and two external consultants. The start date is June 2, 1997, when the developer obtains site control.

In parameterizing the SimVision® model, we set the variable *centralization* to low; the variables *team experience, formalization,* and *matrix strength* are all set to medium based on the case study. *Information exchange probability* is set to 0.7, *noise probability* to 0.2, and both

Table 1: Distribution of FTE's for team members in City, Building, and Owner matrices compared to total staffing and position FTE's in SimVision®

DEPT	POSITIONS	STAFF	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
		DESIGN-CONSTRUCTION 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

functional and *project error probabilities* to 0.05. These parameter settings reflect well-established norms for specifying SimVision® models (see [34]). We parameterized the work volume to 8 hours per full-time equivalent (FTE) in a 5-day week. The work volume includes direct and indirect work (i.e., coordination, rework, and waiting period) based on the actual schedule and related documents the project manager provides. In the Baseline Model, we represent the organizational actors through attributes and parameters reflecting characteristics of the people actually involved in the development project. We do not model specific individuals in the projects' *position*, however, because the roles they play do not change (although specific individuals may change; see Table 1). SimVision® defines position as an abstract group representing one or more FTEs (full-time equivalents) that performs work and processes information. In a staffed project, positions represent a person or a group of persons.

Matrix Model: We allocate staffing to the positions in the Baseline model according to the involvement of different matrices in the two projects. We divide the staff according to their participation in performing the goals of three matrices we observed during the pre-construction process, i.e. *City*, *Building*, and *Owner*. The objective of the City Matrix is to consolidate public and financing support from the local jurisdictions. The objective of the Building Matrix is to consolidate the planning, design, and technical aspects regarding the facility development's proposal in order to ensure compliance to build. The objective of the Owner Matrix is to coordinate the developer's activities pertaining to the development proposal. The amount of a staff's position FTE depends on how many matrices a project requires. For instance, the project manager's position is staffed with a total of 0.4 FTE in the Des-Cons project compared to 0.3 FTE in the Fin-Assm project. This is because the Des-Cons project has all three matrix teams working on it compared to two matrix teams in the latter.

The Baseline and Matrix Models illustrate the close task interdependencies between the Des-Cons and Fin-Assm projects by having four *ghost connectors* between different projects. The ghost connectors provide modeling connections or constraints between projects by mimicking tasks and milestones from one project in another. They allow links to multiple other milestones and tasks. The *ghost connectors* reflect the flow of explicit knowledge from a preceding task in one workflow to a succeeding task in another concurrent workflow. We use these ghost connectors to represent explicit knowledge exchange. There is a *ghost communication* link that reflects communication between Des-Cons and Fin-Assm teams. It represents a formal tacit knowledge exchange.

We run a Monte Carlo simulation of 100 cases for both the Baseline and Matrix Models in SimVision® and compare their programs' organizational performance results. They are comprised of values for *simulated duration*, *critical path method (CPM) duration, total work volume,* the *functional risk index,* the *project risk index,* the *process quality risk*, and *communication risk*. In SimVision®, the principal difference between simulated and CPM durations is that the simulated results take into account all the real-world factors we modeled, whereas CPM results reflect an optimistic scenario where all positions are fully available to work all the time on all their tasks unless the tasks overlap. Functional Risk Index (FRI) represents the likelihood that components produced by this facility development have defects based on rework and exception handling. It is the fraction of effort it would take to process ignored *functional* failures normalized by the total effort to rework all predicted functional failures. Project Risk Index (PRI) represents the likelihood that the components produced by this project will not be integrated at the end of the project, or that the integration will have defects based on rework and exception handling. PRI is thus a measurement of the success of system integration. It is a fraction of effort it would take to process ignored *project* failures normalized by the total effort to rework all predicted project failures. The Project Communications Risk measures the risk that positions will handle communications about their tasks improperly.

In analyzing the results, we first compare the simulated duration periods of both models and find the causes for the difference. Then, we explain how the causes impact the organizational performance. We compare the simulation reasons with known facts we obtained through the ethnographic study. Later, we compare the results with existing theories on knowledge flows and organization, and we determine how well the theories support the knowledge-flow constructs we started with. We propose amendments to the constructs where necessary.

The steps in building the COT model provide considerable accuracy in terms of replicating the organization and process of the COT case. It can provide us retrospective validation, which Thomsen, et al. [13] suggested 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 form during the process. When the Baseline Model is successful in identifying the causes for the process breakdown, the COT model is retrospectively validated. On the other hand, the Matrix Model must also maintain similar retrospective results as per the Baseline Model, but we should expect a lower organizational performance despite negating the matrix staffing allocation effect.

5. Results, analysis, and validation

We table the results of the Baseline and Matrix Models in Table 2. The Matrix Model illustrates lower organizational performance, because its simulated duration (24.9 months/760 days) increases compared to the Baseline Model (22.8 months/695 days). The results contrast with the CPM durations, where the Matrix Model has a lower CPM duration (674 days) than the Baseline Model (695 days). The simulated durations also contrast with the total work volume, where the Matrix Model has a lower total work volume (715 days) than the Baseline Model (735 days). The total work volume reduction is due to the reduction of rework, coordination, and decision wait volumes.

Table 2: Statistics of selected simulated values for Baseline and Matrix models

Value Names	Baseline (SD.)	Matrix (SD.)
Simulated Duration (months)	22.8 (0.20)	24.9 (0.10)
CPM Duration (days)	695.1	673.8
Simulated Start Date	June 2 1997	June 2 1997
Simulated Finish Date	Jan. 31 2000	Apr. 28 2000
Total Volume (days)	735.3	714.5
Work Volume (days)	659.0	659.0
Rework Volume (days)	28.8	17.0
Coordination Volume (days)	44.3	36.5
Decision Wait Volume (days)	3.3	2.0
Functional Risk Index (FRI)	0.54 (0.05)	0.75 (0.04)
Project Risk Index (PRI)	0.58 (0.11)	0.48 (0.09)
Process Quality Risk	0.45 (0.04)	0.67 (0.033)
Communications Risk	0.38 (0.02)	0.38 (0.02)

The Baseline Model has FRI and a PRI values of 0.54 and 0.58 respectively. These values are above 0.5, which indicate a very high likelihood of project component or task quality failures if the facility developer does not take any action to lower the risks. FRI and PRI values of above 0.4 mean that many failures are not going to be reworked, and values that are above 0.7 are unacceptable level of risk for any organization. In this regard, we find the Matrix Model of interest because it has an FRI of 0.75. It means the facility development will fail indefinitely if the facility developer does not take any mitigation actions. One component which fails in our COT case is the septic tank system. It started to emerge during construction and eventually fail upon the start of the housing operation. Matrix staffing helps to improve the project risk slightly (i.e. PRI is 0.48) even though in our COT case, it is not significantly helpful. One way to lower the FRI and PRI values is increasing the supervisory responsibility of the positions whose tasks have high functional or project risk. Unfortunately, the project manager is at the highest supervisory level. Therefore, the COT case fails.

Both the Baseline and Matrix Models show a high communication risk value at 0.38. It is higher than 0.2, indicating a high process risk and subsequent high product quality risk. This value suggests possible product quality risk when the responsible positions improperly handle their communications. The communications refers to request for information, explanation, decisions, etc. and the positions ignore the communications when they are overwhelmed by other work backlogs. The *position backlog* represents the number of days of work in a position's in-tray. The optimal backlog is one day, which means the position is fully busy but is not behind in its work. Usually, positions have several days of work accumulated. Sometimes, a position has so much work accumulated that it poses a risk to the schedule and project quality. In general, a backlog of 2 to 4 days for a position will not pose any threat to the project. In order to reduce communication risks, the organization must reduce the high number of backlogs among the critical positions.

Table 3: Project manager's position backlog

Phase	Base-line	Matrix
Design-Construction (days)	29	26
Finance-Asset Management (days)	43	59

In the COT case, the critical position is the project manager's. The project manager's backlog ranges from 29 to 59 days (refer Table 3). These values are critically high and require urgent counteraction before the housing project deteriorates beyond salvage. High backlogs indicate a risk of schedule delay and the possibility that the position will take shortcuts and compromise product quality. One way of reducing the backlog is adding extra resources to the civil survey tasks or allocating work to less backlogged positions with the same skills. The project manager relied on the design-construction manager for follow-ups on the civil and structural tasks since the project manager did not have the relevant construction background. The project manager also had difficulties understanding the civil engineer, and unfortunately, had to make a number of less-informed decisions when the design-construction manager responded too late.

The project manager eventually failed to keep up with the overwhelming exception handling and coordination because the project manager in the Matrix Model has lesser FTE in the Fin-Assm project compared to the Baseline Model's, i.e. 0.3FTE instead of 0.4FTE. The project manager participates in all three matrices—City, Building, and Owner—in the Des-Cons project compared to two matrices—City and Owner—for the Fin-Assm project. The reduced FTEs force the project manager to accumulate more exception backlogs. Eventually, the project manager's position backlog reduces the quality of the whole housing development process in general.

The high communication risks affect the process quality risk values. The Baseline and Matrix Models show high process quality risk values at 0.45 and 0.67 respectively. Two common causes of high quality risk are positions ignore or partially complete rework exceptions, and the organization has low centralization. Low centralization means decision-making process are decentralized to the sub-team members, hence decision turnaround is low. In the COT case, almost all the team members do report directly to the project manager. However, due the backlogs the project manager has, the position cannot handle more exceptions than there are.

In reviewing the top ten most critical tasks in the Des-Cons and Fin-Assm projects for both models, the 'Civil Survey' is the most risky task in the Des-Cons workflow having a schedule growth. The task involves conducting topographical and geotechnical surveys of the property. The civil survey reports will help the civil engineer design optimal structural and infrastructure components, including the septic tank system, which are best-suited for the property's soil condition. The civil engineer is responsible for it. In both the Baseline and Matrix Models, the failure of communications between the project manager and the civil engineer during the 'Civil Survey' task eventually led to the failure of the septic tank design for the housing project. Moreover, the Gantt chart shows many of the project manager's tasks in both the Des-Cons and Fin-Assm projects becoming critical even though the matrix allocation does help the civil engineer and architect reduce their backlogs. Among the emerging critical tasks are 'Conduct Due-Diligence,' 'Gather Documents and Talk to Planning,' and 'Obtain Political Support.'

We also visually observe supportive characteristics of the facility development operating environment when we built the models. The most significant is the critical path changes on the workflows due to addition/reduction of task duration, addition/reduction of lag time, and change in team members staffing when the level of risks increase. We find the task and lag durations are sensitive to the position's risk exposures lading us to individual impacts on organizational performance as aforesaid. We also found task interdependencies between different workflows can cause team members working in one workflow unaware of the criticality of the other workflow processes which they are not involved. On the other hand, the task interdependencies link up individual tasks and turn them critical when risks are present. Unless someone who participates in both workflows inform other team members of the critical situation that will impact the workflows they belong, there is a high likelihood that other team members will simply proceed as per originally planned. Since the project manager is too busy with backlogs, there is lesser possibility of the project manager to ensure knowledge flows occur. In such situation, we cannot expect smooth tacit knowledge flows whereas explicit knowledge flows will eventually occur but at a higher risk of having lower quality. The scenario provides a viable cause for why knowledge loss keeps occurring in the facility development.

We infer from the COT modeling efforts that the lack of FTE's allocation for the project manager's position due to the matrix allocation for different projects is the source for knowledge flows inefficiency. It causes higher communications risk, which causes higher project and functional risks, which eventually cause the facility development process to fail. We find task interdependency aggravating the complex state of knowledge flows in the facility development life cycle process because one source of problem has rippling effects over other workflows because of the existence of their interdependency links. The model-building process and results validated retrospectively our COT case for all ethnographic constructs except knowledge form when we compare to known facts regarding the housing development. We are unable to use neither the COT model nor the ethnography study to firmly measure knowledge flows, although we can visually observe the changes of explicit knowledge flows in the critical path when exceptions occur. Our proposal that higher task interdependencies between multiple workflows will lower the efficiency of knowledge flows when the organization has discontinuous memberships still stands. However, we require further study on how we can proceed further. We discuss below whether the four ethnographic constructs are comprehensive for our further study in view of the COT findings.

6. Discussion

Cohen and Levinthal [32] state that the knowledge absorptive capacity of a firm is based on its absorptive capacity above its prior knowledge. In addition, Kogut and Zander [3] state that the absorptive capacity is the ability of an organization to recognize the value of new, external information; assimilate it; and apply it to commercial ends. We define knowledge absorptive capacity as the ability of an organization to maintain prior knowledge, absorb new knowledge, and recognize the value of new knowledge for its strategic use. Knowledge flow is the process by which knowledge transfer occurs from one entity to another. In an enterprise, efficient diffusion of knowledge promotes higher absorptive knowledge capacity at the enterprise. It relies on the enterprise's organizational structure, process, technology, and operating environment, which Burton and Obel [5] posit can influence the information-processing capability of an enterprise. The information-performance, in turn, affects the enterprise's organizational performance [34].

We started this study with four operating environment constructs of the facility development domain from an earlier ethnography study. They are *multiple concurrent and sequential workflows, discontinuous participation*, *task interdependency*, and *knowledge form*. In this discussion section, we attempt to analyze whether these constructs are comprehensive to cover the nature of facility development operating environment while enabling us to study the affects of knowledge flows on organizational performance in discontinuous participatory enterprises.

Burton and Obel [5] list organization context as one of the contingency factors that affects organizational workflow [17]. They propose four dimensions in a four-variable list of characteristics or attributes to describe the environmental context for enterprises. Those environmental characteristics are *equivocality*, *uncertainty*, *environmental complexity*, and *hostility*. The first three characteristics describe the facility development domain well. The multiple concurrent and sequential workflows form the complexity nature of the work process. The quality performance of the team members affects the project and functional risks of the process. We also note the varied frequencies of task interdependencies among the different workflows. When a process has many interdependent links, we notice the affects on other workflows when an exception originated in one. The task interdependencies in the COT model support the uncertainty and equivocality nature of the work process. Nissen's [20] *Vertical and Horizontal Processes Model* characterizes the powerful interaction between such workflows in an enterprise. However, Nissen's dynamic knowledge-flow model stops at conveying the interdependencies of information processing requirements between some tasks in concurrent workflow processes, and it does not examine explicitly the environment within which an organization operates. We propose combining the multiple concurrent and sequential workflows construct with task interdependency construct to form a simpler *work complexity construct*.

The knowledge of the firm increases when organizations learn new skills by recombining their current capabilities [3]. Carlile and Rebentisch [26] argue that organizational learning is a social process with multiple actors possessing unique knowledge and interests. Given the nature of this collective, but yet dependent, they argue that structure organizational learning cannot be simply understood as an aggregation of individual learning, or taken to the next level, at the organization level. While agreeing with Carlile and Rebentisch that aggregation is too simple approach to explain a firm's knowledge absorptive capacity, we argue that discontinuous participants do impose a different outcome on the firm's overall knowledge absorptive capacity and influences the overall organization performance. Hence, the importance to take into account the discontinuous participatory nature of the enterprise that may disrupt knowledge absorption by team participants. SimVision® does not model knowledge flow directly, and its information-processing capability devoid the direct measurement of tacit knowledge flows in a program. Further study requires a COT tool that would perform horizontal information-processing simulation, either complementing SimVision® or as an integrated COT tool. Utilization of *Transactive Memory Theory* ([24]; [33]), a psycho-social network theory, is emerging as a promising vehicle in capturing knowledge flows by way of identifying information allocation and retrieval nature among participants of an organization. We propose extending the discontinuous participation construct to capture the nature of knowledge transaction among team members within one organization in a workflow, and including team members from other workflows within the same process. We propose to call this construct the *team knowledge transaction construct*. This construct should capture the increase or reduction of total organization knowledge when team members move in or out of an organizational structure. As we have seen in the COT case earlier, any inefficiency flow of knowledge, albeit in the form of communication response, does affect the functional and project risks of an organization.

The knowledge form construct is the most important aspect of our study, but it is still yet measurable after the COT modeling efforts. It describes the forces that move knowledge from individual to the enterprise. As aforesaid, Nissen provides discrete qualitative categories for potential operationalization of knowledge flow in enterprise. We maintain his four knowledge flow dimensions which are type of knowledge (tacit versus explicit), level of socialization associated with the knowledge (individual, group, organization, and inter-organization), activities of knowledge work (create, share, apply, etc.), and flow time. However, we propose renaming the knowledge form construct to *knowledge flows construct.*

Upon the conclusion of our COT efforts, we recommend work complexity, team knowledge transaction, and knowledge flows as key constructs to study the impacts of knowledge flows on organizational performance in enterprises experiencing discontinuous participation. These constructs merge established organization theories with emerging knowledge flows theories. We recommend the use of another horizontal information-processing COT tool or upgrading SimVision® to proceed further.

7. Conclusion

We build upon an ethnographic study and computational organization theory (COT) to model and analyze discontinuous participation in the domain of facility development. Upon reviewing our original ethnography constructs and integrating the COT results, we are recommending *work complexity*, *team knowledge transaction*, and *knowledge flow* as more comprehensive constructs to describe the nature of knowledge flows that would impact organizational performance in discontinuous participatory enterprises. The constructs merge well-established organization theory with emerging dynamic knowledge flows theory. We find organizational design characteristics such as task interdependency affect flows of tacit knowledge and hence work performance in the enterprise. We recommend further testing of these constructs either by way of using another COT tool that would complement SimVision®'s lack of transactive memory-processing capability or by upgrading its current code. This paper presents our initial efforts towards extending organization theory to address the dynamics of knowledge flows when designing organizations with discontinuous participation. Ensuring efficient knowledge flows in dynamic organizations will contribute towards improving the successful completion of facility development projects.

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