Simulating Environment Contingencies Using SimVision®[1]

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Abstract

In product development life cycle, specifically the facility development life cycle, utilization of tacit knowledge is critical during the earlier Feasibility and Entitlements phases. Tacit knowledge is the 'know how' that is not explicitly available to an enterprise. Since knowledge flows enable workflows, they are essential to organizational performance wherever knowledge and information work is involved. But the design of knowledge flows and workflows depends upon the environment in which an organization operates, and the design space of alternate organizations is large. In order to inform organizational design, we employ a computational organization theory tool that can simulate the environmental contingencies inherent in the facility development life cycle process. Building upon ethnography to understand the facility development life cycle processes, we combine case study research with computational methods to extend knowledge-flow theory. This paper presents how we develop our case study model using an agent-based computational organization theory tool, SimVision®, to represent the environment contingencies of a facility development project and inform the design of organizational knowledge flows.

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Simulating Environment Contingencies Using SimVision®

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In product development life cycle, specifically the facility development life cycle, utilization of tacit knowledge is critical during the earlier Feasibility and Entitlements phases (Ibrahim and Nissen, 2003). Tacit knowledge is the 'know how' that is not explicitly available to an enterprise. Since knowledge flows enable workflows, they are essential to organizational performance wherever knowledge and information work is involved. But the design of knowledge flows and workflows depends upon the environment in which an organization operates, and the design space of alternate organizations is large. In order to inform organizational design, we employ a computational organization theory tool that can simulate the environmental contingencies inherent in the facility development life cycle process. Building upon ethnography to understand the facility development life cycle processes, we combine case study research with computational methods to extend knowledge-flow theory. This paper presents how we develop our case study model using an agent-based computational organization theory tool, SimVision®, to represent the environment contingencies of a facility development project and inform the design of organizational knowledge flows.

Background Problem

At this point it is understood well that knowledge flows enable workflows (Nissen 2004). Hence flows of knowledge are essential to organizational performance wherever knowledge and information work is involved. But organizational knowledge flows can be negative as well as positive; that is, organizations can forget as well as learn, and the environment plays an important role in how well organizations are designed in this regard. As an example from the domain of facility development, facility developers can lose valuable operating revenues for 'forgetting' to deliver an agreed item. In a case of affordable housing studied by the authors, the approved design called for a play structure, but as the design evolved, the play structure became a flat playground area. A few years after the project completion, the funding agency fined the facility developer for not providing a play structure as specified in the (original) approved design. The facility developer was required to build a new play structure or return funds to the agency. In this case, dynamics of the organizational environment—specifically, shifting inter-organizational structure—affected negatively the organization's knowledge flows.

Modeling Knowledge-Flow in Equivocal Environments

From the earliest days of Contingency Theory (Lawrence and Lorsch 1967), organization scholars have understood the central role played by the environment in terms of organizational design and performance. But researchers have yet to agree on what all of the salient environment features are. Carley and Lin (1997) show that task environment characteristics have more effect on performance than information distortion and the organization design. This paper presents the theoretical framework to develop a case study model that supports the facility development life cycle process and environment. We study two driving characteristics of the facility development life cycle: (1) sequential yet interdependent workflow processes, and (2) dynamic organizational structure.

Organizational Behavior Assumptions

We compare our ethnography data with Burton's and Obel's (2003) view and computational implementation of Contingency Theory. Workflow and organizational structure dynamic characteristics are set up in conformance with the key organizational design propositions. Such propositions include that a high complexity, high uncertainty, and high equivocality organization tends to have low formalization, low organizational complexity, and low centralization. There is also tendency of managers to get overloaded in such organizations. This propositional description applies well to the domain of facility development. In such dynamic operating environments, Burton and Obel propose *Ad Hoc* or *Matrix* configurations as the best organizational structures to manage the workflow processes. 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. Its best coordination methods are via planning, integrators, meetings, use of rich media, while its best motivation is to provide result-based incentives.

Knowledge-flow Assumptions

In the domain of facility development, different forms of knowledge dominate at different points in the process. Specifically, tacit knowledge is dominant during the early Feasibility and Entitlements phases, while explicit knowledge is dominant during the later Building Permit, Construction, and Property Management phases. Tacit knowledge (Polanyi, 1967) 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. Nonaka's (1994) dynamic theory of organizational knowledge creation posits that knowledge-flow processes (i.e. transformation of tacit knowledge to explicit knowledge) occur through four knowledge processes in the organization: socialization, internalization, externalization, and combination. Facility developers obtain tacit knowledge by socializing and internalizing the actions and sayings of the local elected officials, and the public that supports them. Facility developers also face complex interaction between knowledge flows and workflows. Nissen's (2002) *Vertical and Horizontal Processes Model* characterizes the powerful interaction between such flows in an enterprise. However, Nissen's dynamic knowledge-flow model stops at conveying the interdependencies of information processing requirements between some tasks in different workflow processes, and it does not examine explicitly the environment within which an organization operates.

Framework For Tracking Dynamic Knowledge-Flow

We build a *Knowledge Group Set* (KGS) unit to explain the interrelated flows of knowledge and work processes in an organization. A KGS unit is a group of processes that requires a team or several matrix teams to accomplish a common goal within a time frame. Each process is independent, but contains several interdependent tasks from another concurrent process within the same time frame. The key is, one or more stable organizational structures persist over a single workflow process. Several workflow processes can form a KGS such as the Feasibility Phase of a facility development life cycle phase consists of Design-Construction and Finance-Asset Management workflows. Referring to Figure 1, we build a KGS unit in three steps: Nissen's (2002) horizontal workflow process is represented by arranging several sequential tasks for a Workflow Process 1; it culminates with a milestone goal (e.g., G1) at the end of the horizontal sequence; and finally, the latest vertical milestone goal shall flow vertically towards the next time frame.

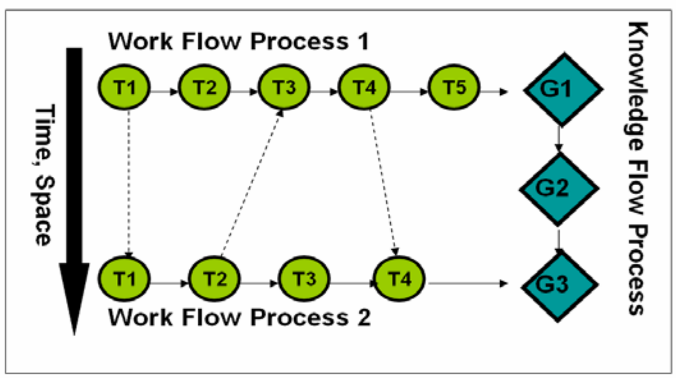

Figure 1: A Knowledge Group Set (KGS) unit consisting of two workflow processes with task interdependency links during a knowledge life cycle period (adapted and revised from Nissen's Horizontal and Vertical Processes Model (2002, Fig. 3))

We can arrange a sequential combination of several KGS units, which forms the Knowledge Group Set Flow Model. One KGS unit represents a facility development life cycle phase. Figure 2 illustrates a Knowledge Group Set Flow Model. As noted above, different workflow processes in a KGS unit (e.g., KGS1 to KGS3) have similar or different combinations of matrix teams working over them. The reason is that a workflow may have more than one matrix responsible for its completion. These are represented by the different squares shown above each workflow. Each KGS unit represents the vertical knowledge-flow goals represented in Nissen's model. In the facility development case, KGS1 represents the Feasibility Phase, KGS2 represents the Entitlements Phase, and KGS3 represents the Building Permit Phase. A workflow in a KGS unit continues to the succeeding KGS unit. As it transits into the next phase, the matrix team combination may change. The goals for Feasibility, Entitlements, and Building Permit Phases are submission for development permit, receipt of the development permit, and construction start respectively. Facility developers achieve these goals as the project progresses through time and space.

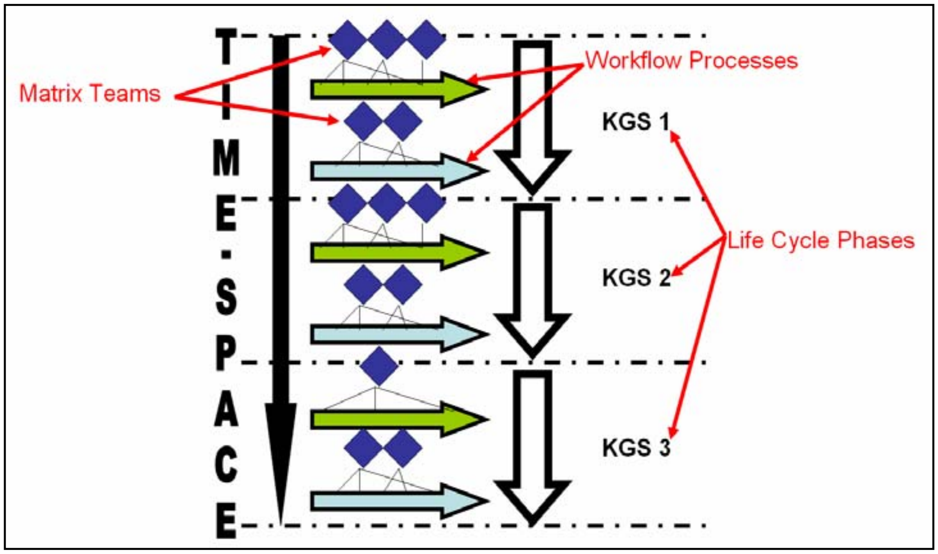

Figure 2: Knowledge Group Set Flow Model during a product development life cycle

Model Development

We use SimVision® to model the pre-construction activities of an affordable housing project. This paper assumes reader familiarity with agent-based modeling in general and SimVision® in particular. Background information can be obtained from Jin and Levitt (1996). SimVision® is an agent-based representation (Cohen, 1992; Kunz et al., 1998) that reflects well-accepted theory of micro-level organizational behaviors (Levitt et al., 1999). The development tasks we model are high-level development processes. For our case study, we represent all such pre-construction activities as one KGS unit. Our case study is a 43-unit, affordable family housing development for farm workers located in the Bay Area. We obtain data by conducting an ethnography survey involving learning from people in their environmental context, i.e. a facility developer enterprise. The major source of our data come from archival data and semi-structured interviews. The owner is a subsidiary of a premier affordable housing developer in the Bay Area, which owns and operates 73 affordable housing projects. This facility development has been in operation since June 2001, but has been plagued with civil and wastewater related problems since construction. We expect the model to identify causes during the pre-construction activities that lead to its current predicament.

The Baseline Model represents a KGS unit. We model the pre-construction activities of the case study with a different organizational structure for each project. At the program level, there are two projects running concurrently: the Design-Construction (Des-Cons) and the Finance-Asset Management (Fin-Assm) projects. They consist of 39 tasks with twelve milestones in both projects. 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 1, 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 *functional* and *project error probabilities* to 0.05. These parameter settings reflect well-established norms for specifying SimVision® models (e.g., see Jin and Levitt 1996). 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 as actors in the projects' position because the roles they play do not change although specific individuals change frequently. We specify the Baseline Model schedule to include indirect work (i.e., coordination, rework, and waiting period) based on the actual schedule and related documents the Project Manager provides. These steps give our model considerable accuracy in terms of representing the organization and process. The Fin-Assm project captures a very complex set of financial activities that include three "soft loan" applications, one permanent/equity financing, and one construction loan application processes. We parameterize this model in similar fashion.

The model illustrates the close task interdependencies between the Des-Cons and Fin-Assm projects by having four *ghost connectors* between them. The *ghost connectors* reflect the flow of knowledge from a preceding task in one workflow to a succeeding task in another 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.

Results and Conclusions

We run Monte Carlo simulations of 100 cases for the Baseline Model in SimVision®. It identified the project manager having a 60-day backlog, and the civil survey is the top critical tasks. The results were confirmed by the project manager for she was so overwhelmed with work. The case study model successfully represents the two characteristics of the facility development life cycle: (1) sequential yet interdependent workflow processes, and (2) dynamic organizational structure over different workflow processes and phases. Among causes for uncertainty and equivocality environment are adding/deleting tasks in a workflow sequence, extending/reducing task or lag durations, and changes due to dynamic organizational structure. These exceptions impact the duration and interdependencies of tasks in different workflow processes. The critical path changes in the workflow processes highlight the uncertainty of the facility development process. We validated the case study model based on Thomsen's et al. (1999) toy problem and intellective validation criteria. There are several limitations to current SimVision® application. First, it does not allow two primary actors assigned to one task, hence, limiting the flexibility to model group matrices at project level. Another is that we can only assign one primary skill to a shared task. These limitations direct us to look at utilizing *Transactive Memory Theory* (Wegner (1987) in Hollingshead, 1998; Lambert and Shaw, 2002) to accommodate the team knowledge transaction construct in our latter knowledge-based organizational performance model. Despite these limitations, the overall results support our base assumptions in building a model that reflects the challenging dynamics of the facility development operating environment.

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