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The Virtual Team Alliance (VTA): Extending Galbraith's Information-Processing Model to Account for Goal Incongruency*

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Abstract

This paper introduces a new computational organizational analysis and design model, called the Virtual Team Alliance (VTA), that builds on the Virtual Design Team (VDT) (Jin and Levitt, 1996). VTA extends Galbraith's framework implemented in VDT in two ways: (1) it addresses less routine tasks with some flexibility in how they are performed, and (2) it treats project participants as teleological professionals with potentially incongruent goals. Because tasks in the VTA model are flexible, differences in goals may influence which solution approach project participants prefer; thus, goal incongruency can have profound implications for the performance of project teams. We describe how VTA actors comprise a complex system that is endowed with fragments of canonical information-processing micro-behavior. The canonical micro-behaviors in VTA include exception generation, monitoring, selective delegation of authority, searching for alternatives, clarifying goals, steamrolling, and politicking. The VTA model simulates the micro-level communication and coordination behavior of actors within the organization, including the impact of goal incongruency between individual actors, in order to determine the emergent, aggregate project behavior and performance. To Galbraith's sociological analysis, based on information-processing "organizational physics," we add new "organizational chemistry" notions based on social psychological and economic agency theories.

Keywords: agency theory, computational organizational design, contingency theory, goal incongruency, information processing, professionals, project organizations, semi-routine tasks

1. Introduction

Within the growing Computational Organizational Science (COS) community, there has been some progress in using computers to model and analyze today's increasingly agile

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organizations executing interdependent and concurrent knowledge work (e.g., Carley and Lin, 1995; Jin and Levitt, 1996; Wong and Burton, 2000, Carroll and Burton, 2000). Researchers are attempting to advance organizational analysis and design from its current holistic and heuristic approach to one of "model-based reasoning." Organizational analysis tools such as the Virtual Design Team (VDT) model participants as information-processing entities with skill sets and experience and explicitly model lateral interdependencies between activities. VDT offers powerful new capabilities for modeling and analyzing fast-paced work processes and the projects that execute them. However, VDT does not include variables, which may be critical in multi-disciplinary and multi-organizational (cultural), agile project organizations. VDT assumes that all project participants have congruent goals, and it makes assumptions about the routineness of the activities themselves that make it applicable only to relatively routine work processes. VDT is based on the premise that coordination work takes time. Coordination work delays project completion, increases costs, and affects work process quality. For tasks in which coordination is crucial, empirical evidence abounds that, even though coordination can contribute to overloading actors, coordination may also result in better solutions in terms of cost and duration (Ghiselli and Lodahl, 1958; Hall, 1982; Hoffman, 1959; Hoffman and Maier, 1961; Janis, 1972; Nemeth, 1985). Building off the VDT framework, the primary contribution of this paper is a new computational organizational analysis tool, the Virtual Team Alliance (VTA) that test theories and previous empirical findings (Thomsen et al., 1999) in a more complex setting. VTA extends Galbraith's framework to model the behavior of project participants as teleological professionals with potentially incongruent goals and to address less routine tasks with some flexibility in how they are performed; therefore, goal incongruency matters.

Within the page limits of a single journal article, we cannot satisfactorily both explain VTA's generative mechanisms derived from social scientific theories and present substantive validation of VTA's emergent behavior against empirical date collected on a series of case studies. In a companion paper, "A Proposed Trajectory of Validation Experiments for Computational Emulation Models of Organizations" (Thomsen et al., 1999), we describe in detail VTA's external validation strategy and how we performed the validation on a number of case studies conducted over a three-year period.

In this paper, we apply VTA to a number of small synthetic test cases—"toy" organizations—simple enough models that they could be analyzed manually. Based on "canonical" micro-behaviors of actors (monitoring, selective delegation of authority, exception generation, searching for alternatives, goal clarification, steamrolling, and politicking), we compare the model's emergent behavior according to the predictions of established organizational micro-behavioral theory.

After reviewing our model's foundation, we present the representational constructs pertinent to our model. Next, we provide an extensive description of the canonical micro-behavior underlying our computational model and present results from computational synthetic experiments to validate VTA's micro-behavior against the predictions of the underlying organizational theories. The paper concludes with a summary of our practical and theoretical contributions, the limitations of our model, and our suggestions for future work.

2. The Virtual Team Alliance (VTA) Computational Model of Project Teams

2.1. Foundation-VDT: An Information-Processing Framework for Simulation

Organizational contingency theory and the literature it has spawned on organizational design represent one of the most prominent theoretical approaches to understanding organizational performance (Pfeffer, 1996, p. 70). The organizational contingency perspective is founded on two chief precepts (Galbraith, 1973, p. 2). The first principle is that there is no one best way to organize. In other words, the suitability of an organization's structural arrangement is contingent on a number of factors called contingency factors. Contingency factors can, for example, be environmental complexity (Jurkovich, 1974; Tung, 1979) and environmental uncertainty (Duncan, 1972; Lawerence and Lorsch, 1967). Differences in structural configurations will be observed for different contingency factors (Donaldson, 1985). The second principle is that all ways of organizing are not equally effective. Specifically, organizations that demonstrate structures that fit the requirements of their environment will be more effective than organizations, which do not (Burton and Obel, 1995; Pfeffer, 1982, p.148).

Following Galbraith's (1973, 1977) information-processing view of contingency theory, researchers at Stanford University created the Virtual Design Team (Christiansen, 1993; Cohen, 1992; Jin and Levitt, 1996). In the VDT simulation engine, organizations are conceptualized as a web of communication channels. Information is processed at the nodes or actors (i.e., project participants), and different types of communications (exceptions, decisions, information exchanges) are passed between the nodes through a variety of communication tools (e.g., email, fax, phone, etc.). In this way, the emergent behavior of an organization carrying out a particular work process can be simulated to assess organizational performance. A particular organization and work process will require more or less communication, leading to more or less primary work, coordination work and rework for actors, and ultimately to reliable predictions of project cost, schedule and process quality.

There are three principal representational components to a VDT model. First, there are actors, modeled as information-processing units, who perform tasks within the organization. There is only an abstract, statistical representation of the problem-solving or cognitive functioning of these actors—each actor has an in-box in which new tasks arrive, and a set of attention rules to determine which task to do next. Primary work, communication, and decision making all consume the actor's limited time/attention. A stochastic, object-oriented, discrete event-driven simulation engine controls tasks, performed by these actors.

Second, the interdependent actors are imbedded within an organizational hierarchy, which defines supervisor relationships and how exceptions to routine tasks are handled. The structure of this hierarchy defines the organizational framework in which the actors reside and the reporting and coordination structures that are present in the organization to resolve problems.

Finally, VDT has a rich representation of the work process within the organization. Activities are assigned to actors who are responsible for the successful completion of the tasks within those activities. Actors communicate with each other for two reasons. First, actors communicate in response to exceptions that are generated from processing tasks

in activities. Second, actors exchange information about their processing of reciprocally interdependent tasks.

The VDT model is attractive because the process description holds a central place in the framework, and it is around these activities that the actors and their hierarchical reporting structures are framed. The project schedule becomes the process around which the work of the individuals within the organizations is executed and coordinated.

2.2. VTA—Representational Constructs

The project management literature (e.g., Kerzner, 1997) posits cost, duration, and quality as the goals of a project. An actor's best way to serve the project is therefore to focus on the key goals of cost, duration, and quality and *not* on personal goals.[1] This perspective is at odds with the view in mainstream economics that professionals engage in rational calculation for maximum self-interest (Bonner, 1995). However, Kerzener's view has widespread support in the literature on professions, which holds that professionals broadly suppress the assumption of self-interest in favor of greater emphasis on altruism (Chiles and McMackin, 1996; Ghoshal and Moran, 1996; Nass, 1986).

Cost, duration, and quality are reciprocal constraints, since maximizing one tends to cause a diminishment in one or both of the other variables as long as the organizational slack is at a minimum level (March and Simon, 1993). Because of professionals' local expertise and social embeddedness in the institutional infrastructure of their respective "communities," they will most likely prioritize these goals differently. We refer to the difference in ranking of these three criteria as *goal incongruency* between actors. When actors in an organization favor the adoption of different solutions with which to meet common requirements, we say that a *task conflict* has occurred. Actors' preferences among solutions may differ significantly enough that task conflicts need to be constructively resolved by collaborative negotiation or by hierarchical decision making.

Differences of opinion occur not only between team members in the problem-solving process, but between project members and their supervisors. The explicit or implicit goal ranking of the supervisors, encoded within assigned work packages, may be different from those of the actors working on finding solutions to the work packages. These differences in managerial expectations vs. subordinates' aspirations affect the level of compliance with the project plan's recommendations. Deviations from the original project plan may give rise to more coordination and communication among members of the project team and can therefore lengthen the total project duration and increase cost.

One area that demonstrates a classic example of goal incongruency is the relationship between the engineers involved with the design and the business-oriented actors responsible for procurement. Traditionally, engineers want to deliver quality specifications and requirements before submitting this information to procurement. Thus, there is a reluctance to provide information early. However, the actors responsible for procurement must procure early enough to deliver the required component on time, and so they want to receive specifications as early as possible.

In introducing actor goals to our model, however, we wish to avoid the complexity of a full-fledged decision-theoretic or utility-based representation (Howard and Matheson, 1983).

Models of multi-criteria decision making and collective choice presume that all alternatives for all requirements can be elaborated and ordered with respect to goal functions or utility functions which adopt higher values for better alternatives (Tanguiane, 1990). This turned out to be a practically impossible task on our two case studies (Thomsen et al., 1999). Our approach is descriptive rather than normative—we are interested in behavioral changes within the organization in response to goal incongruencies between actors, not in finding the technical solution that optimizes some collective utility function.

The extent to which goal incongruency will lead to task conflict, and actors' behavioral response, depends on a number of contingency factors. Below, we will describe the major moderating factors that directly mediate the effects of goal incongruency.

2.2.1. Activity Flexibility. Brehmer (1976), as well as others (Gladstein, 1984; Van de ven and Ferry, 1980), suggested that the activity the group performs influences the relationship between conflict and performance. The flexibility of an activity refers to the size of the space of feasible solutions that can satisfy the activity. The more alternatives that exist for fulfilling an activity, the more flexible it is. Given a fixed level of goal incongruency, the effect of that goal incongruency will be less for inflexible activities than in highly flexible ones. The lack of distinct alternatives will reduce the probability that goal incongruency will lead to a conflict of desired alternatives. Even though two parties may have different goals, the limited range of possible choices will mitigate the potential for disagreements over alternatives. In contrast, two incongruent parties are more likely to desire different solutions if the solution space is large, since each party has a greater probability of finding a solution that differentially meets his or her particular preferences. Hence, the effect of goal incongruency increases with the flexibility of the activities being performed.

2.2.2. Activity Interdependence. Goal incongruency between two parties will only have a direct effect on actors' behaviors if they are reciprocally interdependent (Thompson, 1967). If the work of one of two parties were completely independent of the work of the other, the actors' incongruent goals would be inconsequential. Thus, high levels of interaction and interdependence intensify the impact of goal incongruency (Gladstein, 1984; Schmidt and Kochan, 1972). A recent study by Jehn (1995) confirmed that conflict had a more profound effect on group performance when members of the group were interdependent. For instance, the problem of goal incongruency is exacerbated in large engineering projects by the sheer complexity of modern engineering artifacts. The need for high levels of interaction among diverse groups (e.g., disciplines, departments, subcontractors) prohibits organizations from simply decomposing tasks and responsibilities and assigning them to strictly delineated departments or groups (Simon, 1996). Consequently, not only must organizations deal effectively with goal incongruency problems arising within supervisor-subordinate relationships but they must also negotiate goal incongruency problems arising in lateral relationships between peers working on interdependent activities.

2.2.3. Disparity in Actor Competence. Large disparities in the competence levels of interdependent actors will cause an actor who is aware of his or her greater expertise in a certain area to avoid wasting a scarce resource—time—in an extended conflict with a less competent actor. The actor with higher expertise simply appeals to a higher authority

(Pfeffer, 1981). We refer to this canonical micro-behavioral process as "steamrolling." Equally competent actors, on the other hand, will be less certain of the superiority of their own solutions and will be more amenable to finding a mutually acceptable solution by means of discussion.

2.2.4. Team Experience. The amount of experience that a team has working together can have a profound effect on the behavior of the group. Smith et al. (1994) found that team members with a long tenure together will not only have spent more time with one another, which facilitates greater social interaction and cohesion, but they will also have a greater shared understanding of their organization than team members with a shorter tenure. Such teams will be more likely to comprehend the specific idiosyncrasies, strengths, and weaknesses of their organizations. This common basis of understanding accelerates decision-making (Stinchcombe, 1965) and further enhances integration and communication. Ouchi (1980) noted that groups with more experience working together will have a more thorough appreciation of how the organization operates, which promotes team interaction and reduces the need for explicit communication.

Another consequence of team experience is that highly experienced teams are more likely to collaborate with one another in making deals and agreements involving future obligations. Since parties lack direct knowledge of the future behaviors of others, they will rely on past behavior to gain insight into probable future behavior (March, 1995). Hence, within teams whose members have had significant experience working with one another, there will be a higher probability for interdependent actors to attempt to save the scarce resource of time by compromising, and thus avoiding protracted discussions to resolve conflicts (Pfeffer, 1981).

2.2.5. Preference for Micro-Management. Building on Mintzberg's (1973) categorization as well as other theories of leadership, Burton and Obel (1995) demonstrated that leadership styles can be assigned one of two categories based on how managers process information and make decisions. The difference between the two categories is rooted in whether or not a manager has a preference for micro-management (i.e., the habit of becoming heavily involved in the day-to-day affairs and activities of subordinates). The effect of goal incongruency on vertical relationships either will be magnified or mitigated, depending on the leadership style of the manager involved. "Micro-managers" will react more strongly to goal incongruency with their subordinates than non-micro-managers. Such managers, for example, will engage in greater "monitoring" and are likely to appropriate decision-making power away from the subordinate, i.e., micro-managers "selectively delegate authority."

In Sections 2.3, 2.4, 2.5, and 2.6 we describe in detail how VTA actors comprise a complex system that is endowed with fragments of canonical information-processing micro-behavior. We apply VTA to the "synthetic organization" illustrated in figure 1. We perform seven synthetic experiments to validate VTA's seven canonical interaction micro-behaviors (exception generation, selective delegation of authority, monitoring, steamrolling, politicking, searching for alternatives and goal clarification) internally by activating one at time (figure 1).

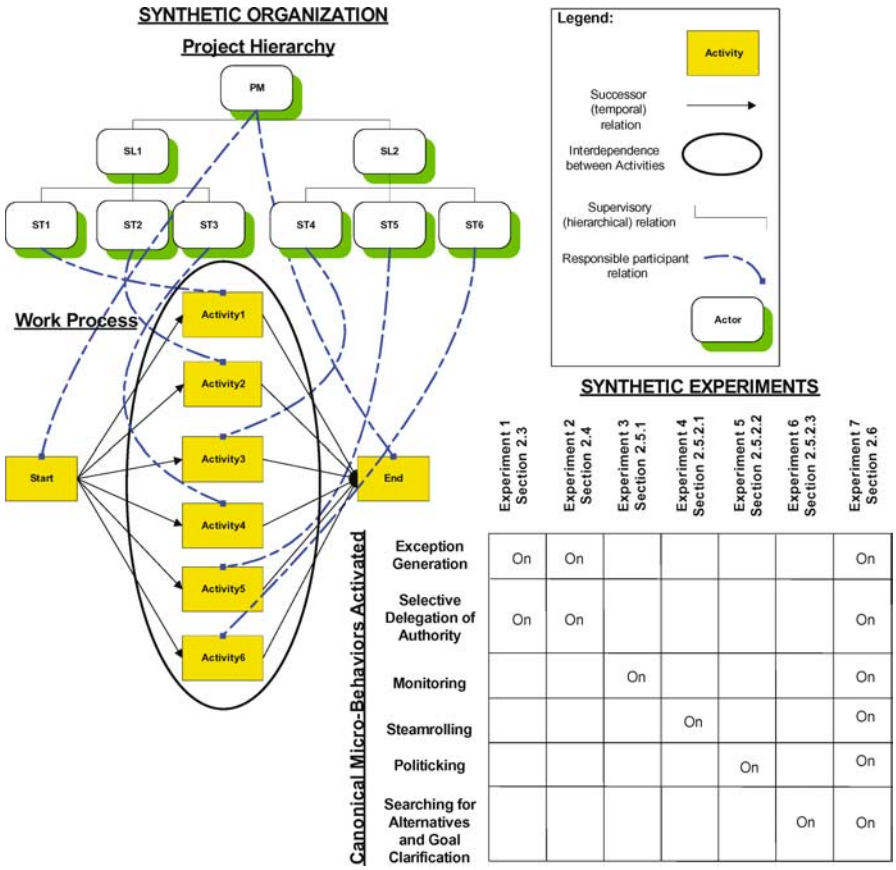

Figure 1. An Overview of the Synthetic Organization and the Synthetic Experiments we used for Internal Validation. The upper left part of the figure shows the work process and the project hierarchy of the synthetic organization. In our conceptual model, a project includes actors (rounded rectangles) and the activities (rectangles)—that are interrelated. That is, each project participant fills a position in the project organizational hierarchy and works on one or more activities. The table in the lower right part of the figure shows the VTA canonical micro-behaviors in response to goal incongruency, in which experiments they are internally validated, and the subsection in which the experiment is discussed.

2.3. VTA-Exception Generation

Any time that the information available to the responsible actor is less than the information needed to execute the sub-activity, an exception is generated (Galbraith, 1973). The probability of exception generation depends on the attributes of the activity (and therefore the sub-activity), activity complexity, activity flexibility, skill requirement, and interdependence strength between activities as well as an actor's attributes—goal priorities and skills.

As each sub-activity is executed by the simulator, the goal-oriented subordinate responsible for activity may generate exceptions to the project plan since it is boundedly rational (Simon, 1956). Exceptions are one of two types—technical errors (TE) and

non-conformances (NC). Technical errors are errors arising from a technical oversight, technical incompetence, or any number of mistakes that might have been avoided had the subordinate been more circumspect or technically proficient. Non-conformances are exceptions that arise directly from goal incongruencies between the manager and the subordinate. They are not incorrect from a technical standpoint (i.e., the final product will not be defective if the non-conformance is not remediated); rather, they do not conform to the approach that the manager had prescribed or desired.

The chance that a technical error will be generated is based on the complexity of the activity as well as the actor-activity skill match. Figure 2 shows that the chance that a subordinate will generate a non-conformance is based on the level of goal incongruency between the supervisor and the subordinate and the activity flexibility. If the exception is a non-conformance, its probability of being a productive non-conformance (PNC) is determined by consideration of the difference in skill between the subordinate and the supervisor. A relatively unskilled supervisor will encounter more productive NCs from a highly skilled subordinate than *vice versa*.

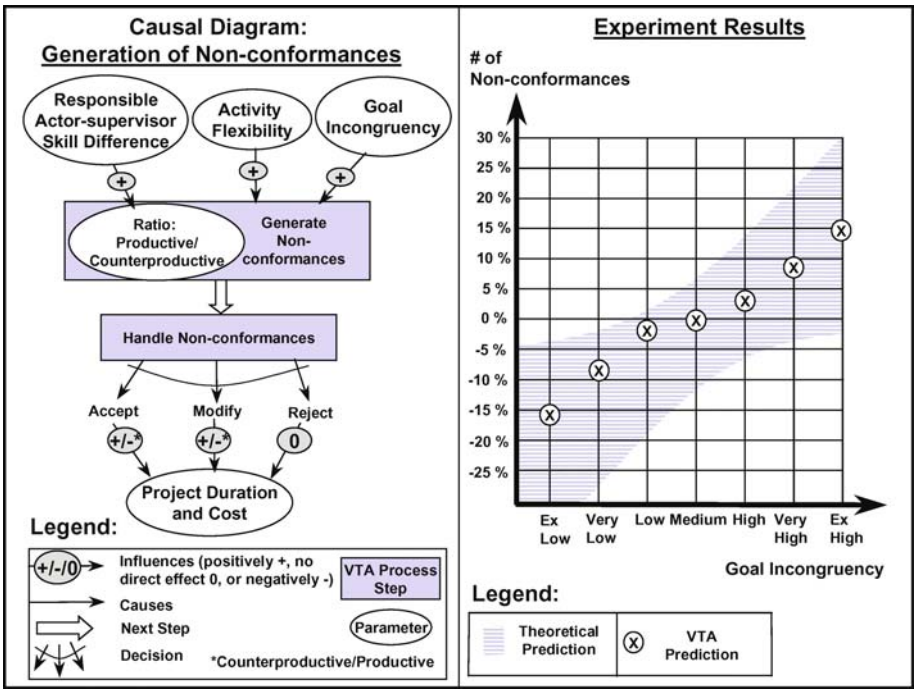

Figure 2. Generation of Non-conformances. The effect of responsible actor-supervisor skill difference, activity flexibility, and goal incongruency on the generation of non-conformances (NC). Activity flexibility and goal incongruency between the supervisor and subordinate determine whether a NC is generated. Once generated, the responsible actor-supervisor skill difference determines the effect that the NC exception is likely to have on project duration and cost. The right part of the figure shows the results from our simulation analysis. Only the exception generation and selective delegation of authority micro-behavioral processes were activated. Simulation results agree qualitatively with organizational contingency theory and they are stable.

The exception is forwarded to the appropriate supervisor who decides how to deal with the exception. In the cases of TE and counterproductive non-conformances, such decisions involve reworking portions of the activity that failed. In the case of PNCs, such decisions involve reducing portions of the primary work volume of the activity in which the PNC was generated. Ignoring/rejecting an exception is acceptable as long as the decision-maker has made an evaluation of the consequences of the decision. However, as soon as the decision-maker becomes overloaded, it may not have a chance to detect the exception or get to the decision. In this case, the actor waiting for the decision proceeds by "default delegation."

If a large number of technical errors or non-conformances are undetected or not attended to, decision-making quality will tend to suffer. Correction and reworking of technical errors and accepting and modifying counterproductive non-conformances will increase decision-making quality, but at the immediate expense of cost and time. In contrast to the negative effects of technical errors and counterproductive non-conformances, productive non-conformances will allow the project to terminate more quickly and efficiently, given that they are not eliminated through rejection (i.e., a productive non-conformance can only be beneficial if the non-conformance is accepted and allowed to stand).

2.4. VTA-Selective Delegation of Authority

Selective authority delegation refers to the process by which managers determine how much decision-making power to grant to subordinates. High goal incongruency levels will lead managers to demand that a greater proportion of exceptions be reported to them for decision making, while low goal incongruency levels will encourage managers to allow subordinates to handle exceptions on their own. Low levels of authority delegation will, in turn, effectively increase the level of centralization in regard to local decision-making within the organization and provide managers with greater control over the workflow.

As a rule, the perception of high levels of goal incongruency, as well as a propensity for micro-involvement on the part of the manager, will cause a manager to delegate less authority to subordinates (Burton and Obel, 1995) (figure 3).

Based on Simon's (1997) theory that the cognitive limitations of human actors will cause them to be more likely to identify with the goals for which they are most directly responsible, higher-level actors are assumed to be motivated by project-level goals rather than requirements for activities. By virtue of their global perspective on the project, managers have a greater awareness of the ramifications that a failure in one activity could have for other interdependent activities. Hence, higher-level actors in our model tend to decide to perform rework, rather than to "quick-fix" or ignore the error when errors are detected, and *vice versa*.[2]

2.5. VTA-Information Exchange

In this section, we describe a total of five well-validated canonical interaction micro-behavioral processes in response to goal incongruency: one for vertical relationships and four for lateral relationships. Each response is not necessarily exclusive of the others, and

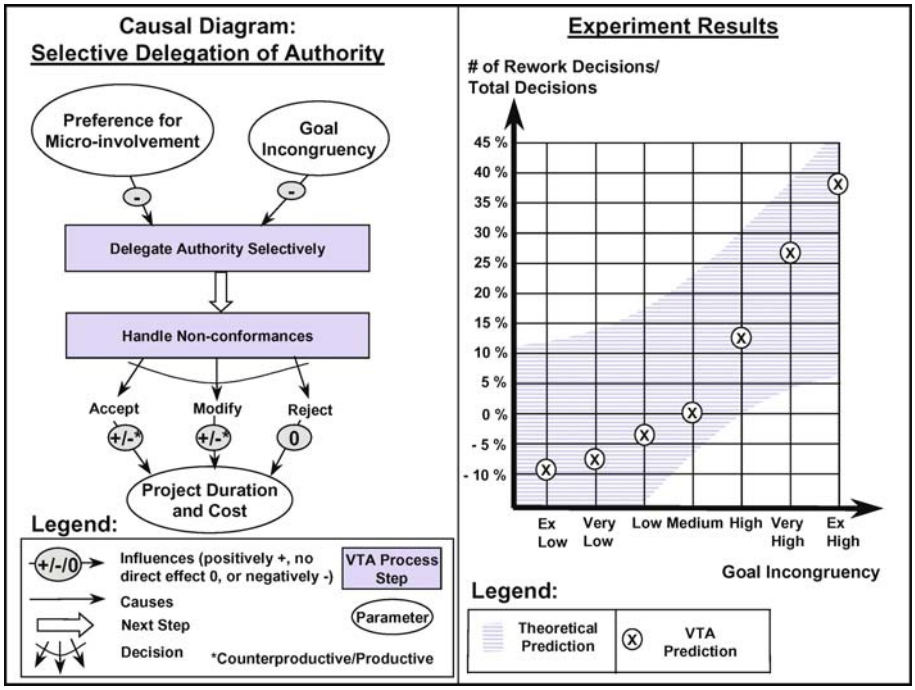

Figure 3. Selective Delegation of Authority. Preference for micro-involvement and goal incongruency determine the distribution of authority in each vertical chain of command. The right part of the figure shows the results from our simulation analysis. Only the exception generation and selective delegation of authority micro-behavioral processes were activated. Simulation results agree qualitatively with organizational contingency theory and they are stable.

the extent to which each one is invoked is contingent on the level of goal incongruency as well as other organizational factors.

2.5.1. Monitoring. Given that our model is based on an information-processing view of organizations, we represent all managerial control mechanisms through the processes of monitoring and the aforementioned selective authority delegation (Eisenhardt, 1989). Our model calculates the level of monitoring and delegated authority for each hierarchical dyad relationship by first considering the overall level of monitoring and the degree to which decision-making is centralized and then by locally modifying these initial values for each dyad relationship. This modification is based on the characteristics of individual actors—i.e., the manager's preference for micro-involvement (Burton and Obel, 1995)—as well as the level of goal incongruency within each relationship.

Monitoring in our model incorporates all the specific activities involved in the use of control mechanisms, including the transmission of information concerning behavioral observations, evaluations, and prescriptions. It is a cyclic process in which managers periodically administer new prescriptions to subordinates and request progress reports on the status of work packages. Subordinates, in turn, send reports and questions up to supervisors. The

number of managerial prescriptions that are issued will affect how much latitude subordinates have in terms of deviating from managerial expectations. As more prescriptions are sent down the hierarchy and attended to by subordinates, the probability that a subordinate will generate an exception will decrease. When subordinates do not attend to managerial prescriptions, however, the probability that they generate an exception will increase rather than decrease, since the subordinate will not be aware of the new prescription and may inadvertently deviate from it. In a similar vein, as more reports and questions are channeled up the hierarchy by subordinates and attended to by managers, managers will become more aware of the status of work packages. Attended-to-reports will result in a greater probability that exceptions will be detected. However, when managers are overworked and do not attend to reports, the probability of exception detection will decrease.

As a rule, the perception of high levels of goal incongruency, as well as a propensity for micro-involvement on the part of the manager, will cause a manager to engage in more extensive monitoring, while perceived concurrence will result in a lessening of the intensity of monitoring.

Figure 4 illustrates how we have implemented monitoring. At the completion of each sub-activity, the subordinate might send a report to the supervisor based on the goal

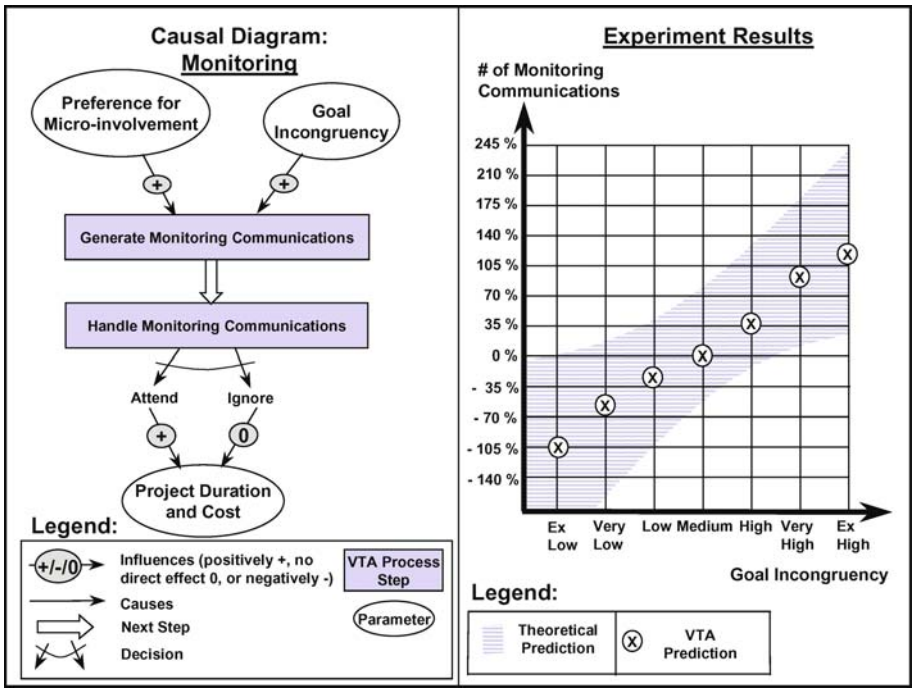

Figure 4. *Monitoring.* Preference for micro-involvement and goal incongruency determines the level of monitoring in each vertical dyad. The right part of the figure shows the results from our simulation analysis. Only the monitoring micro-behavioral processes were activated. Simulation results agree qualitatively with organizational contingency theory and they are stable.

incongruency between the subordinate and supervisor as well as on the supervisor's preference for micro-management. The supervisor may or may not attend to the report based on the supervisor's current backlog. If the supervisor attends to the report, the supervisor will reply to the subordinate, whose likelihood for attending to the reply is based on its own attention allocation. Moreover, each time that a manager attends to a report from a subordinate, the manager might send a message up to its supervisor based on the goal incongruency between itself and the next-level supervisor as well as on the supervisor's preference for micro-management. Attending to reports increases the probability that exceptions will be detected. Thus, monitoring requires time on the part of the supervisors and subordinates. Monitoring items must be initiated, attended to, and responded to. However, monitoring generally leads to an increase in decision-making quality, since more exceptions are detected and handled properly. On the other hand, this increase may be offset by a decrease in coordination quality if the hierarchy becomes overloaded with monitoring communications. It is clear that there will be some optimal level of monitoring—too little may result in an excess of exceptions as a consequence of goal incongruency, and too much may overload actors to the point that they become seriously backlogged. Amount of monitoring is especially a concern for supervisors with a large span of control.

2.5.2. Peer Communication. A comprehensive model of organizational behavior needs to consider the lateral interaction among project members, as well as the interactions between managers and subordinates. In the following, we have identified four responses that peer actors can make in reacting to goal incongruency—steamrolling, politicking, searching for alternatives, and clarification of goals.

New data from experiments in social psychology indicate that an intermediate level of goal incongruency may have potentially positive effects on group problem-solving performance (e.g., Amason, 1996; Jehn, 1995; Pelled, 1996; Watson et al., 1993; Weick, 1979). On a micro-organizational level, theorists hypothesize that goal incongruency confers two distinct advantages. It forces actors to consider a wider range of possible solutions to a problem, which increases the likelihood that a more ideal solution will be found. We refer to this canonical micro-behavior as "searching for alternatives." Moreover, goal incongruency leads to a greater understanding and clarification of the trade-offs associated with each solution under consideration and encourages actors to formalize their knowledge of these trade-offs implicitly or explicitly into a "goal trade-off table." We refer to this canonical micro-behavior as "goal clarification." Shared goal trade-off beliefs among project participants can be viewed as a common set of values or a shared culture. The existence of shared values or culture is now widely viewed to increase efficiency by serving as a guidepost or touchstone that allows actors to make decisions more quickly and consistently when similar problems arise further downstream (Kunda, 1992).

The homogeneity vs. heterogeneity of participants in a working group affects performance through goal incongruency. One study by Wagner et al. (1984) found that group heterogeneity was correlated with a decrease in interpersonal communication. Observations by Pfeffer (1981) indicate that heterogeneity within groups can give rise to behaviors of a political nature. Drawing on March and Simon (1993, pp. 149–152), we see that such

behaviors may include the practice of "politicking," in which one party compromises on one solution in order to elicit another party's compromise on another solution.

Empirical research on construction projects has demonstrated that the apparent dysfunctionality of politicking can, in fact, be highly functional (Kreiner, 1976), particularly in situations in which both parties have the best interests of the organization in mind. Consequently, they can avoid extended communication and negotiation.

Research by Pfeffer (1981) indicates that the phenomena of steamrolling (as mentioned in Section 2.2) and politicking will not be evident to any significant degree in groups with no goal incongruency. Searching for alternatives or goal clarification, however, will still occur to some extent even in the absence of goal incongruency, since searching for solutions and communicating with interdependent actors are requisite behaviors for performing any activity. As goal incongruency increases, though, all four behaviors will become increasingly manifest. Consequently, the relative proportion of steamrolling and politicking behavior to searching for alternatives and goal clarification will be greater at higher levels of goal incongruency than at lower levels.

2.5.2.1. Steamrolling. Steamrolling is a process in which one actor appeals to a higher authority to force some other actor to perform an action. In our model, steamrolling occurs only within interdependent relationships and is most prevalent in relationships with high goal incongruency. In an interdependent relationship, there is a probability that one actor will appeal to the supervisor through an external counterproductive non-conformance exception (i.e., an exception that affects an activity other than the one in which it was generated) to force an interdependent actor to perform additional work. This probability increases with the level of goal incongruency between the two interdependent actors, to reflect the greater propensity for steamrolling in disharmonious relationships. If the manager agrees with the subordinate (i.e., if there is a low level of goal incongruency between the subordinate and his or her manager), then the actor that is the victim of the steamrolling will be forced to undertake additional work. In addition, the disparity in competence between interdependent actors affects the likelihood of steamrolling. Their skill levels and the amount of experience they have had performing activities similar to the current one are the yardstick by which competence is measured. If the disparity is large and one actor is more competent than the other, the more competent actor will have greater confidence in the merit of its own solution. The more competent actor will be less inclined to spend time working with the less competent actor to find another solution or to examine carefully the advantages and disadvantages of each proposed solution. Rather, it will be more likely to try to save time by simply steamrolling the other actor to facilitate quick acceptance of its solution (figure 5). In contrast, if the disparity in actor competencies is small, the actors are more likely to engage in searching for additional solutions and in clarifying goals in order to arrive at a satisfactory decision. Also, each actor is more likely to give greater weight to the opinions of the other and will be less certain that his or her own solution is categorically better than the other's.

2.5.2.2. Politicking. Politicking is the process by which one actor persuades another interdependent actor to accept its solution in return for a promise to accept the other's solution in the future. Politicking can occur only when social exchange processes come into play, i.e.,

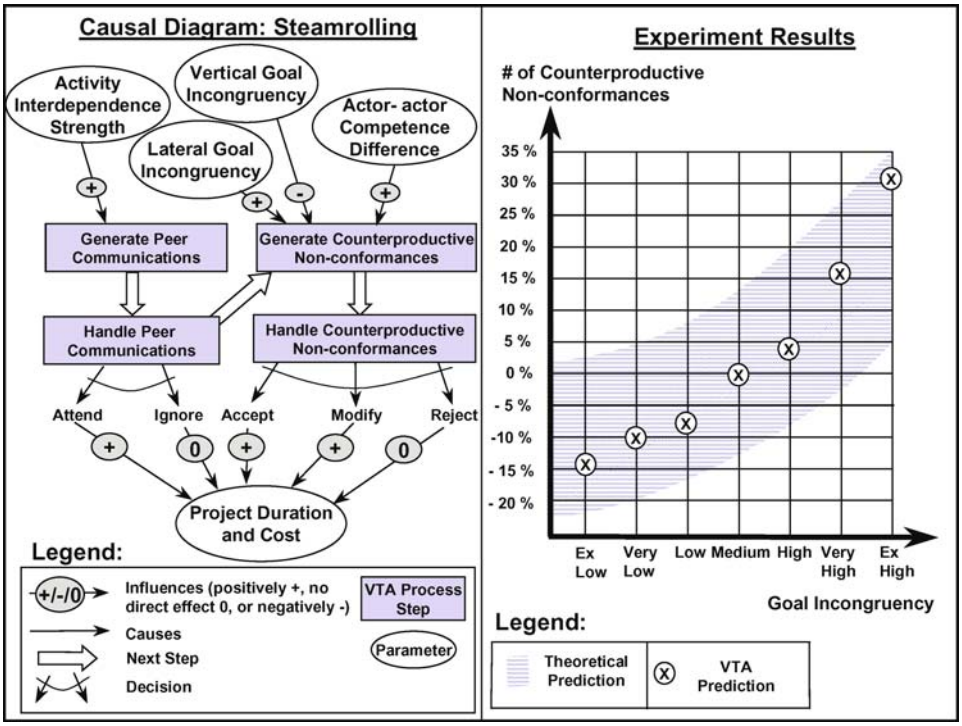

Figure 5. Steamrolling. The left part of the figure shows how we implemented steamrolling behavior in VTA. The right part of the figure shows the results from our simulation analysis. In this test case only the steamrolling micro-behavioral processes were activated. Simulation results agree qualitatively with organizational contingency theory and they are stable.

when actors expect to interact with one another repeatedly over extended periods of time, exchanging favors and obligations. Hence, the degree to which politicking processes are expected to take place in a project team depends on the amount of time that the members of the team have been working together (in our model, given by the "team experience" variable). A long history of association and collaboration is necessary for actors to trust one another to return favors.

Team experience lessens the need for explicit coordination between actors because they have learned to anticipate one another's needs or demands and can coordinate more tacitly. The benefits of high team experience will be most pronounced when there are low levels of goal incongruency between actors. As the level of goal incongruency increases within highly experienced teams, though, members will begin to resort to alternative means of resolving differences in order to get things done and to avoid being stalemated indefinitely in time-consuming arguments. Politicking will become more apparent, and although it will reduce the volume of communication produced by the higher levels of goal incongruency, it will occur at the expense of finding better solutions. Hence, high team experience combined with high goal incongruency will increase the probability of counterproductive

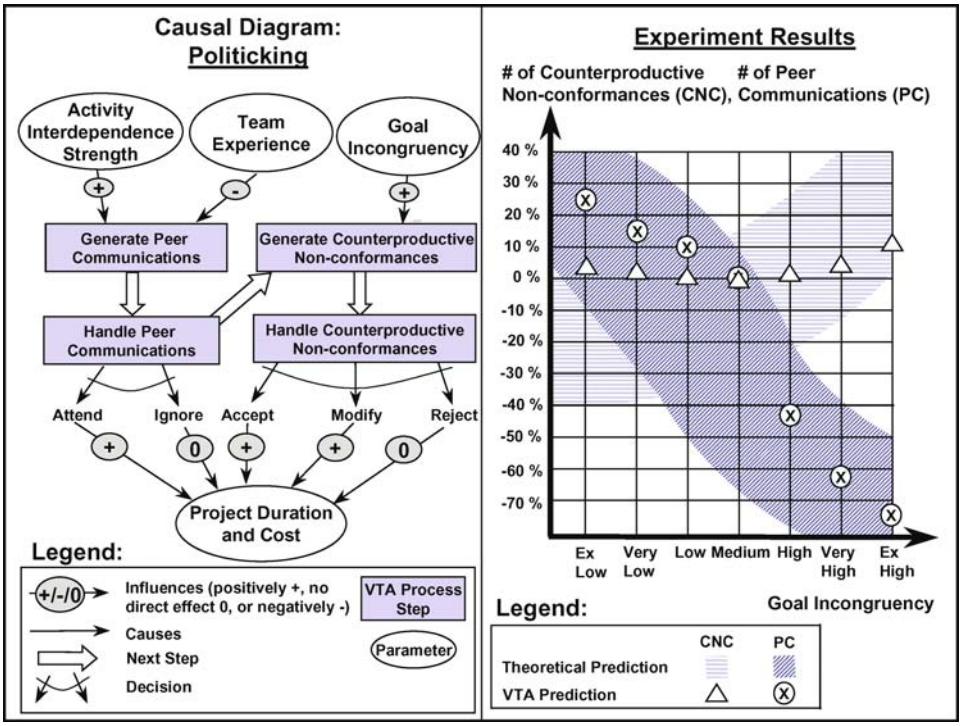

Figure 6. Politicking. The left part of the figure shows how we implemented politicking behavior in VTA. The right part of the figure shows the results from our simulation analysis. In this test case, only the politicking micro-behavioral processes were activated. Simulation results for both counterproductive non-conformances and peer communications agree qualitatively with organizational contingency theory and they are stable.

non-conformances being generated in addition to reducing the probability of peer communications being generated. For a given level of team experience, the number of peer communications will decrease and the number of counterproductive non-conformances will increase for higher levels of goal incongruency (figure 6).

2.5.2.3. Searching for Alternatives and Goal Clarification. In our model, the processes of searching for alternatives and goal clarification are considered to have the same effect on organizational behavior. Searching for alternatives necessitates increased communication between actors working on interdependent activities as they collaborate with one another in generating new solutions and seek to reconcile their differences to arrive at a solution which is mutually acceptable. Goal clarification likewise increases the volumes of communications as actors attempt to develop some sense of the costs and benefits associated with each solution. Hence, in an information-processing framework in which the content of activities is abstracted from the model, the effects of these two processes are the same.

Goal incongruency will force actors to consider a wider range of possible alternatives in order to find a mutually acceptable solution to the problems at hand. The more alternatives

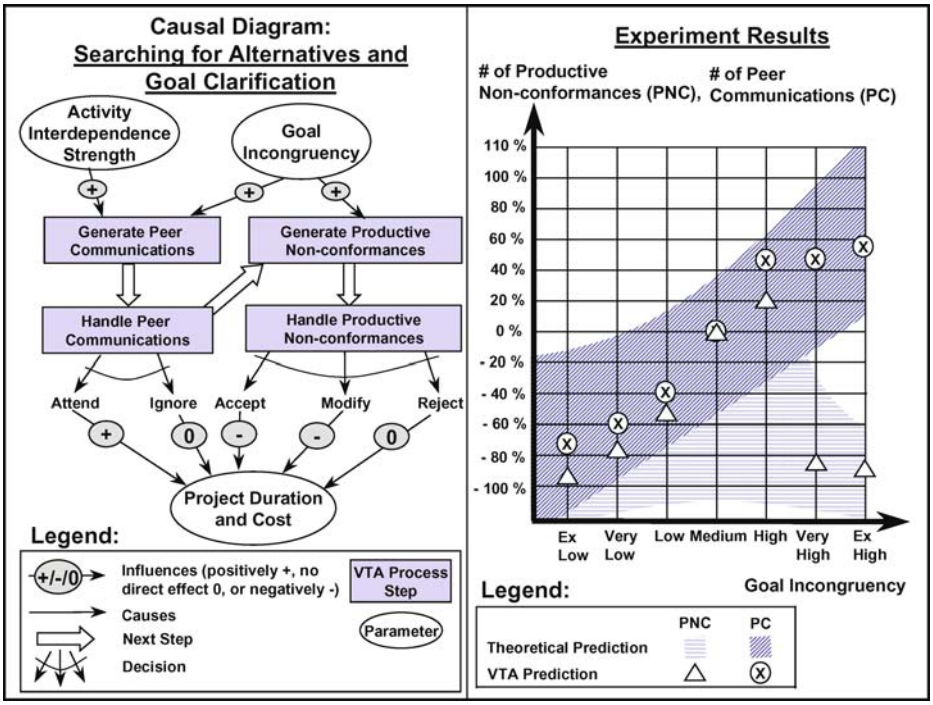

Figure 7. Searching for Alternatives and Goal Clarification. The left part of the figure illustrates how we implemented the "searching for alternatives and goal clarification" behavior in VTA. The right part of the figure shows the results from our simulation analysis. In this test case only the searching for alternatives and goal clarification micro-behavioral processes were activated. Simulation results agree qualitatively with organizational contingency theory and they are stable.

that are evaluated the higher the likelihood that a more ideal solution will be found. Goal incongruency will lead to a greater understanding and clarification of trade-offs associated with the solutions under consideration. The immediate effect of searching for alternatives and goal clarification in our model is to increase the volume of communication (figure 7). When communications are well attended to, the number productive non-conformance will increase because of the gain in time afforded by more efficient decision-making and the increased likelihood that the collaborating actors will derive a more globally productive solution. However, at very high level of goal incongruency the number of productive non-conformances will decrease because the interdependent actors are less likely to find mutually productive solutions (figure 7). The increase in peer communications and the upside-down u-shaped effect on number of productive non-conformances is commensurate with the flexibility of the activities in question. Greater activity flexibility means that there is a broader space of alternatives that must be searched through, and more goals to clarify, while lower activity flexibility indicates that there is a smaller solution space and fewer goals need to be considered. The effects of goal incongruency on peer communications and productive non-conformances are intensified for higher levels of activity flexibility.

The effect of the increase in communication volume depends on how well those communications are attended to. When communications aimed at resolving goal incongruency by searching for alternatives or clarifying goals are not attended to by the recipient actor, actors will be more likely to select alternatives that are not mutually satisfying. The process of developing a shared view of goal trade-offs will be interrupted.

2.6. The Emergent Macro-Behavior of VTA

We have presented our model for investigating the emergent effects of goal incongruencies between individual or group actors on project team performance. To determine the usefulness of this model, we need extensive external validation. Our companion paper, "A Proposed Trajectory of Validation Experiments for Computational Emulation Models of Organizations" (Thomsen et al., 1999), discusses results of the experiments that were conducted to validate the VTA model on real-world project organizations.

However, we want to illustrate how we validated VTA's emergent macro-behavior internally according to the predictions of established organizational macro-theory. Organizational theory qualitatively predicts that goal incongruency can increase the diversity of behavioral repertoires available to the project to meet the requirements imposed by the environment. It can, therefore, improve the project performance, e.g., reduce project cost and duration (Weick, 1979). At the same time, organization theory indicates that too much goal incongruency can lead to time-consuming arguments, thus undermining project performance, e.g., increasing project cost and duration (March and Simon, 1993). Hence, organization theory predicts a curvilinear u-shaped relationship between goal incongruency and project cost and duration (figure 8).

3. Discussion

Semi-routine, fast-paced projects with interdependent and concurrent activities and professional project participants from multiple organizations create unique management challenges. Computational organizational modeling affords us with opportunities to both understand and respond to these complex challenges.

Relying on our actor and work process assumptions, we focused on augmenting the information-processing behavior within the VDT discrete-event simulator framework by adding behaviors related to actors with incongruent goals executing activities with some flexibility. We then performed synthetic experiments to illustrate and validate each of the canonical micro-behaviors of our extended computational model and their combined effects on emergent project performance. We found that our information-processing operationalization of exception generation, monitoring, selective delegation of authority, searching for alternatives, clarifying goals, steamrolling, and politicking agreed qualitatively with the micro-theoretical predictions. We validated the model's emergent macro-behavior according to the predictions of established organizational macro-theory, and found qualitative consistency here as well. Our micro-contingency model extends information-processing organization theory by introducing and operationalizing the effects of contingency factors such as activity flexibility, interdependence between activities, etc. External validation discussed

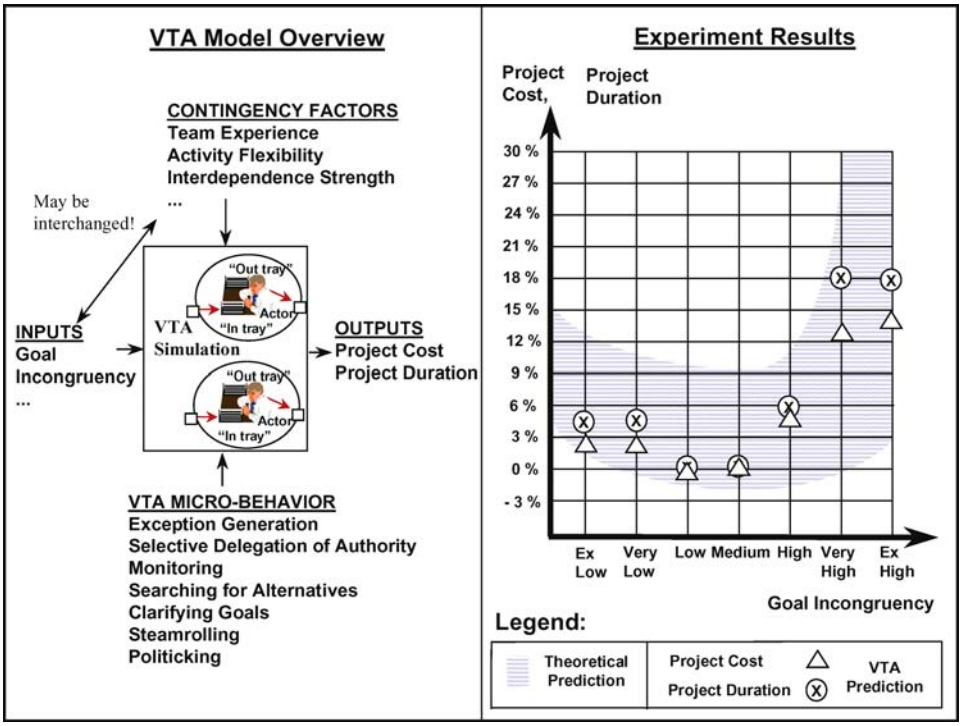

Figure 8. An Overview of the VTA Model and Emergent Simulation Results. The right part of the figure shows the results from a simple experiment on the same synthetic organization that we used in the experiments above. In this experiment, all seven micro-behavior processes were activated. Simulation results agree qualitatively with organizational theory and are stable, with a coefficient of variation (CV) between 1 and 5 percent for all settings.

in a companion paper (Thomsen et al., 1999) introduces new findings and suggests a new set of contingent propositions about the effects of goal incongruency on organizational performance.

3.1. Contributions

The dominant approach for studying performance in multi- constituency project teams has been grounded in the transaction-cost framework (Williamson, 1979). This theory focuses on the relationship among consumers and suppliers and the contracts, which regulate their transactions. In this paper, we have chosen to focus on the constituents of a project team. By simulating actors executing micro-behavior interactions, VTA generates emergent system-level behavior that advances the science and "engineering" of semi-routine, fast-paced project organizations.

Relying on organizational theories developed in the 1970s when speed and flexibility were less relevant for organizational success than they presently are for firms, organizational

simulations have been used in the organizational sciences to improve the design of real-world projects that perform *idealized, routine* work processes. We relax these limiting assumptions, and combine field insights with economic agency theory and sociological and social psychological theories of organizational design to describe rich repertoires of canonical micro-behavior in real-world, fast-paced product development projects. In the VTA model, actors are endowed with fragments of canonical micro-behavior, and then assembled into networks of activities and actors to represent real-world activities and organizations.

The less routine nature of fast-paced work processes means that decision making requires *judgment* (Thompson and Tuden, 1959) and *interpretation* (Pava, 1983) by the professionals who carry it out. We therefore represent project participants, actors, as teleological professionals with potentially incongruent goals. In addition, our work process representation captures the fact that less routine work includes flexibility that may result in more complex exceptions than the sort characterized by Galbraith (1977).

In developing the conceptual extensions for VTA, we have extended existing contingency theory (Thompson, 1967) and Galbraith's information-processing theory (Galbraith, 1973, 1977). We claim that these extensions create a new theoretical basis for our model of semi-routine, fast-paced projects consisting of professionals from multiple disciplines. Galbraith and other contingency theorists focus on organizational behavior at the level of the organization itself, and do not concern themselves with the internal dynamics of the organization. Goal incongruency, however, surfaces in the dyadic relationships between individual actors, and it is only at this level that one can apply the findings garnered from economic agency theory and social psychology about the potentially positive as well as negative effects of goal incongruency. Given our need to create a model for goal incongruency that considers its local influence on the internal micro-behavior of individual actors within organizations, we have extended contingency theory to develop a micro-contingency model of goal incongruency and organizational behavior. Our VTA model takes the relationship between pairs of actors as the fundamental unit of analysis.

Within the larger framework provided by Galbraith's information-processing model, we incorporate and operationalize behavioral and organizational theories, which analyze goal incongruency behavior at the level of individual actors and relationships. These theories cover the behavior of actors embedded in vertical dyadic relationships in the organizational hierarchy, as well as the behavior of peer actors working on interdependent activities. We depict organizational actors as relatively simple, goal-oriented, information processors and communicators with finite or "boundedly rational" capacity (March and Simon, 1993). Their work is choreographed by

- relatively abstract, flexible, sequentially and reciprocally interdependent inform ation-processing activities assigned to them (Thompson, 1967), and
- organizational structures that reactively handle exceptions from pre-planned activities in the spirit of Galbraith (1973, 1977) and proactively monitor the behavior of subordinates (Ouchi, 1979; Eisenhardt, 1985).

The past VDT work operationalized aspects of Galbraith's information-processing view of organizations. VTA extends Galbraith's framework to address less routine activities with

some flexibility in how they are performed. Since activities are now flexible, differences in goals may influence which solutions project participants prefer, so that goal incongruency matters. VTA integrates economic agency theories about supervisor-subordinate behavior and social psychological theories about peer-to-peer behavior with respect to information processing in the presence of goal incongruency. To Galbraith's sociological analysis, based on "organizational physics," we add new social psychological and economic agency notions of "organizational chemistry."

3.2. Limitations and Future Work

To be amenable to analysis in our framework, a semi-routine, fast-paced project should first have relatively clear objectives. Second, project managers should understand work processes well enough so they can relate requirements to processes and assign pre-specified activities to different, specialized individuals. Third, the interactions among project participants responsible for activities must be derivable from requirements. Fourth, we model exceptions to pre-specified activities by adding or subtracting work to these activities. While these assumptions do not apply to all projects or organizations, they apply well to many engineering design and product-development activities as well as organizations that are moving to organize their ongoing work processes as "projects" (Hammer and Champy, 1993; Davidow and Malone, 1992).

Our model is not applicable to contingent work processes, such as those often found in engineering maintenance and medical service activities. Diagnostic and repair activities are by their nature conditional. Depending on the results of the diagnosis, completely different repair strategies should be used. To simulate the way an organization would perform these activities within a particular setting, we would have to develop an enriched set of micro-behavior to model the conditional aspects of these activities and to determine new product and process quality evaluation metrics (Fridsma and Thomsen, 1998).

Procurement presents a classical organizational goal dilemma: an engineer may want to hold on to a design to improve its quality, but schedule pressures encourage releasing the design to procurement as early as possible. In the traditional aerospace industry procurement model, manufacturing could accommodate design changes relatively easily when design and manufacturing were done by the same organization. With manufacturing by outside contractors becoming more frequent, engineering change orders often become more formal, expensive and time-consuming. The agile organization creates greater tension regarding time-quality trade-offs. We can represent such tensions through goal incongruency between project participants. However, in our model, goal incongruency is static. That is, there is no change in goal incongruencies over the course of the project. Such a view of goal incongruency, however, is at odds with actual behavior, since people adopt different goals over time. For example, engineering professionals customarily prefer to attend to activities "on the critical path;" and the critical path can change several times during a project. A more detailed model of goal incongruency would account for learning and adaptation by individuals and view goal incongruencies as dynamic variables. The fundamental tenet of goal-driven learning is that learning is largely an active and strategic process. The learner attempts to identify and satisfy its information needs in the context of its activities and goals,

its prior knowledge, its capabilities, and environmental opportunities for learning. We would need to add to the simulator dynamic goal modification methods that allow actors to adjust their goals during a simulation, based on factors such as activity status on the critical path or changing estimates of activity risk.

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Notes

1. In addition to a project's requirements, there are a number of overriding project goals that constrain the range of feasible or acceptable potential solution approaches to meet project requirements. Important project goals typically are "completing tasks on time," "staying within budget," and "striving for high task quality." Project goals are differentially impacted by alternative solution approaches. Project participants can have different personal goals and preferences. Thus, they may prioritize project goals differently and hence may favor different solution approaches to meet given requirements.
2. *Note*: This cultural assumption that higher level engineering managers are more likely than their subordinates to rework all errors had to be flipped when we modeled a software development team. In this case the programmers wanted to fix all bugs, whereas the project manager was willing to ship the software with known, non-serious bugs to meet the promised release date.

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