

VDT Computational Emulation Models of Organizations: *State of the Art and Practice*

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The Virtual Design Team (VDT) research was initiated in the late 1980s with the goal of developing new micro-organization theory and embedding it in software tools that could be used to design organizations in the same way that engineers design bridges, semiconductors or airplanes - by modeling, analyzing and evaluating multiple virtual prototypes of the system to be designed in a computer.

We recognized from the outset that this was a significant challenge. Micro-theory and analysis tools that embed the theory for designing bridges and airplanes rest on well-understood principles of physics, and involve continuous variables with interval and ratio metrics, and materials whose properties are relatively easy to control and calibrate. These analysis problems yielded to mathematical modeling using systems of differential equations, although solving the large systems of equations for a complex building or airplane could quickly become intractable. Subsequently, applied mathematics techniques for approximating differential equations and plentiful, cheap computing power allowed the models to be computerized so that more complex systems could be analyzed and designed. The approach used to develop this engineering science and technology was to embed well-understood micro-theory into the models and attempt to capture the interactions between elemental parts of a model through constraints (such as constraints that maintain consistency between the deflected positions of adjacent element edges in a finite element model). The result was increasingly accurate predictions of both micro and macro-behavior of many kinds of engineered systems. For many kinds of bridges, deflections under a variety of loading conditions can now be predicted to finer tolerances than the bridge can be constructed to!

Organization theories to date, in contrast, are characterized by nominal and ordinal variables, and poor reproducibility for measuring even these variables. Verbal theories incorporating nominal and ordinal variables create a significant degree of linguistic ambiguity, so that experimental results can not be reliably replicated and different theories are difficult to reconcile or disprove. In the late 1980s, our research group concluded that attempts to model organizations computationally could benefit greatly from the use of non-numerical or "symbolic" representation and reasoning techniques emerging from computer science research on artificial intelligence. Early experiments convinced us and other researchers (e.g., Masuch and Lapotin 89) that this was a fruitful modeling approach.

In scoping out the kinds of organizations that we would model, we picked project teams performing routine design or product development work. For this class of organizations, all work is knowledge work so that an information processing abstraction (Galbraith 77) could potentially be used. Galbraith's "information demand, capacity and throughput" model can be viewed as an analog to Newton's Laws of Motion in Physics, a simple and useful first order approximation. Second, goals and means are both clear and relatively uncontested for these organizations, so that

we could finesse many of the most difficult "organizational chemistry" modeling problems inherent in the kinds of organizations that sociologists have usually studied—mental health, educational and governmental organizations. By operationalizing and extending Galbraith's information processing abstraction in the Virtual Design Team (VDT) computational model, and focusing on the easy corner of the space of all organizations, we developed several versions of VDT (Cohen, Christiansen, Thomsen,) and validated their representation, reasoning and usefulness using the trajectory shown in Figure 1 (Levitt et al, 94; Kunz et al., 98; Thomsen et al, 98).

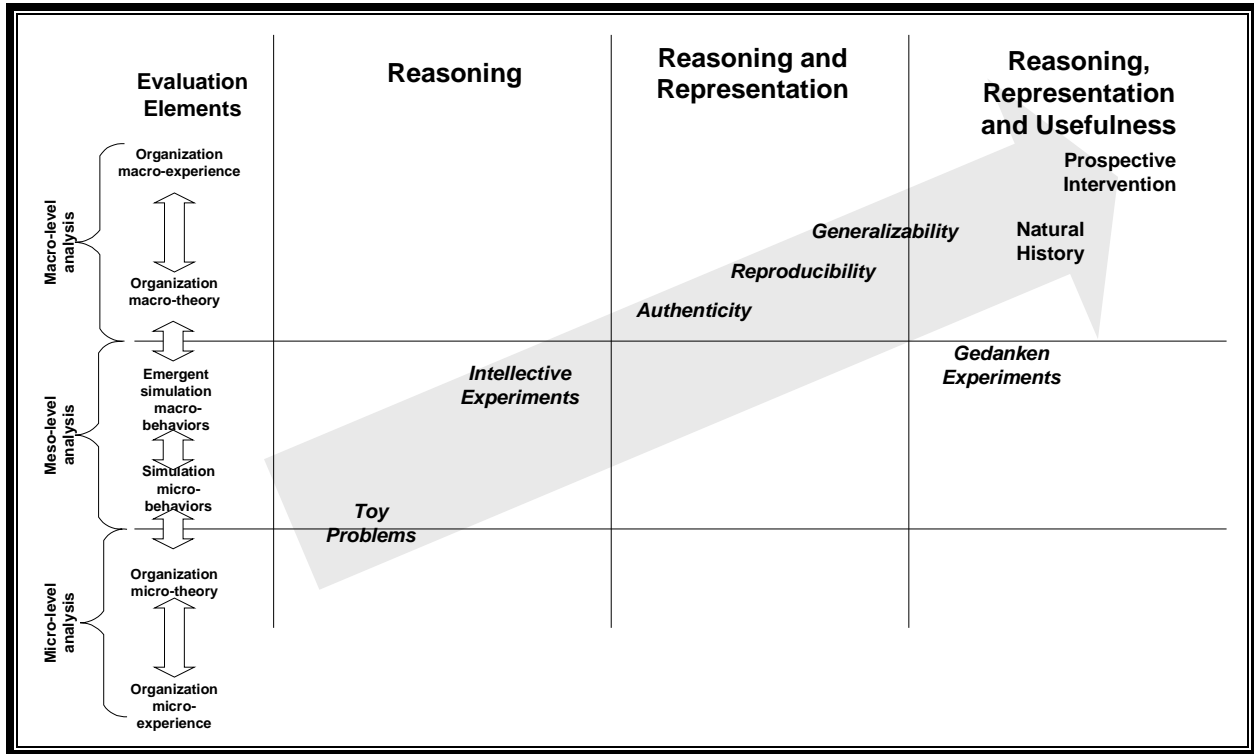


Figure 1. Evaluation Steps for Computational Emulation Models

Moving through the steps of validation, we developed sufficient confidence in the predictions of our theory and tools that managers in several companies are now redesigning their project work processes and organizations prospectively, based on the predictions of SimVision™, a commercial implementation of the VDT model by Vité Corporation. Our VDT theory and analysis tools for project organizations have thus enabled true "organizational engineering" of project teams with congruent goals and relatively routine—albeit complex and fast-paced—design or product development work.

Our intention was always to start with the "organizational information flow physics" and then progressively add elements of "organizational chemistry" to the modeling framework. This would allow us to move out of the easy corner of the organizational space and address a wider range of tasks and organizations. It is useful at this point to position our completed and ongoing versions of VDT in the space of organizations and modeling issues (See Figure 2).

Overview of the Virtual Design Team (VDT) Research Program

The Cohen/Christiansen VDT-2 framework has been fully validated through all of the steps shown in Figure 1. VDT-2 is a reasonable model of project work for which: (1) All activities in the project can be predefined; (2) the organization is static, and all activities are pre-assigned to actors in the static organization; (3) exceptions to activities can be viewed as resulting in extra work volume for the predefined activities to be carried out by the pre-assigned actors; and (4) actors are assumed to have congruent goals. These conditions fit many kinds of design and product development work. VDT-2 has been commercialized as SimVision™, and is in use by companies in a variety of industries for designing their project work processes and organizations www.vite.com.

Thomsen's VDT-3 extends the range of work processes that can be modeled, to encompass less routine design or product development work, in which tasks are still predefined, but there can be flexibility in how they are executed. Actors can have incongruent goals causing them to disagree about how best to execute activities in the project plan. Goal incongruity levels between pairs of actors effect vertical and horizontal communication patterns. VDT-3 has been validated through "gedanken" experiments—thought experiments, in which the model's predictions are compared to managers' predictions of results. It has not yet been prospectively validated—where its prospective predictions are tested against subsequent real project performance data.

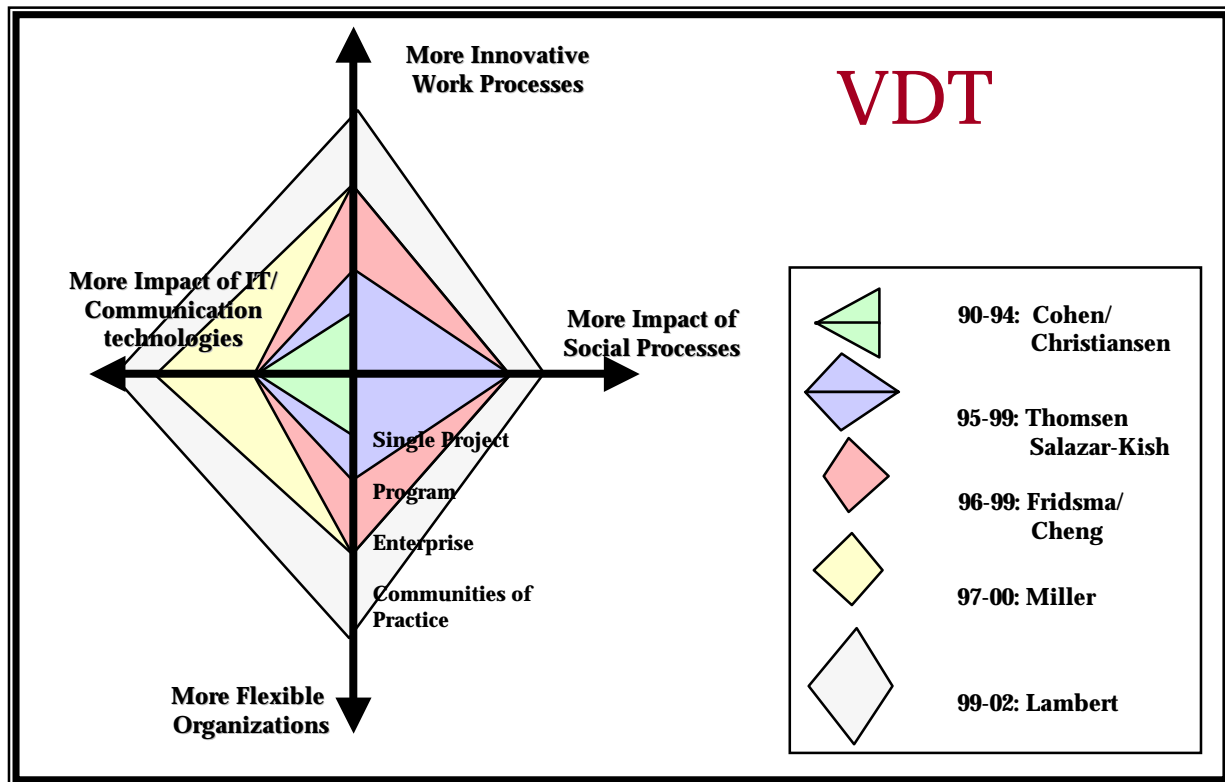


Figure 2. VDT Research Trajectory

Fridsma's VDT-4 is an attempt to move aggressively beyond the previous VDT limits on work process routineness and static organizational structure. He modeled the highly non-routine work

involved in health care delivery for bone marrow transplants and similar complex, multi-specialty medical protocols. For this purpose, we had to relax the constraint that all activities and assignments are rigidly prespecified. Diagnosis activities indicate needed repair activities, and any side effects must be diagnosed and treated contingently. This required significant extensions to the VDT-3 framework. Fridsma (98) extended the information processing micro-theory in VDT-3 to include a variety of more complex exceptions that can cause activities to be added, resequenced, deleted or reassigned, and actors to be dynamically added to the organization and assigned activities as needed. Referring to Figure 1, this extended framework has been implemented and internally validated on "toy problems". The model's predictions are currently being retrospective validated against empirical data in several clinical settings.

VDT-2,3 and 4 implement a simple model of communication tools that transmit information between actors' in-trays. Miller's VDT-5 attempts to extend the tool model to include the interactions between task, tool and organization for more complex collaboration technologies that effect not only communication of information between actors, but also the speed and accuracy of information processing by actors working together. Miller is developing the micro-theory to describe how attributes of tools, tasks, actors and organization structure interact, based on extant micro-theory in the CSCW and HCI literatures. He has selected the "canonical" micro-behaviors to implement as extensions to VDT-3 or VDT-4, and we will now implement them and begin testing their implementation on toy problems. We will then proceed with intellectual simulations and other kinds of validation as the model develops more fully and is refined.

A longer range goal of our work is to begin modeling even more flexible organizations that can be viewed as dynamically shifting "communities of practice," in which actors can communicate with anyone they choose inside or outside the organization their local "organization". Software development teams and some consulting organizations are already beginning to approximate this organizational form. Theories based on concepts such as Public Goods or reciprocity can be used to describe how these links form and persist or dissolve in cyberspace. We received a NSF KDI research grant to work with colleagues from USC, Carnegie Mellon and the University of Illinois in this exciting new area.

This summary of the state of the art and of the practice of our VDT emulation models should give the reader a feel for how powerful and flexible the information processing view of organizations appears to be. We have demonstrated that VDT provides an excellent first order theory to employ as the basis for building models that can predict the flow of complex, value-adding knowledge work through organizations. Moreover we have shown that the VDT methodology and software tools can help managers proactively to diagnose and address information bottlenecks, delays and quality problems arising from failed communication attempts in the course of executing fast-track projects.

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