A Dynamic Theory of Collaboration: A Structural Approach to Facilitating Intergovernmental Use of Information Technology

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Abstract

This paper explores the dynamics of trust, collaboration, and knowledge sharing in the context of a multi-governmental, interorganizational project to design and implement a new information system. Drawing on research and a case study of a successful project, the authors construct a system dynamics model and simulate a base case scenario. They then explore several scenarios in which trust, knowledge of other agencies' work, and skill in meeting facilitation are varied, and they theorize about why certain facilitation attributes and objects can effectively build cross-boundary trust and collaboration.

1. Introduction

Trust, knowledge sharing, and collaboration are central elements of effective interorganizational relationships. These elements are particularly important when the interorganizational relationships involve the development of innovation or new business processes. This paper reports on efforts to model the dynamics of trust, knowledge sharing, and collaboration in a such a project, to develop a new information system to be shared across public and private organizations.[1] By constructing a dynamic model we strive to enrich the theoretical and practical understanding of trust, knowledge sharing, and collaboration in the context of interorganizational information technology (IT) intensive projects. The research group at the Center of Technology in Government (CTG) and the modeling group at the Rockefeller College have been working for about a year to develop a model of collaborative processes observed in a particularly successful case. The model presented in this paper constitutes the second iteration of this effort. The exploration has linked operationally the concept of *trust* with *knowledge* of a partner's role and objectives, which emerges through working together in a project. A key assumption in this model, consistent with the case studied, is that learning arises when meeting facilitation effectively combines conversational methods and artifacts (here, project management tools and IT system requirements analysis documentation) as "boundary objects" [9].

Themes of trust, knowledge sharing, and collaboration are closely related in several theoretical perspectives and research streams. The view of trust as a foundation of social order spans several disciplines and levels of analysis [29]. Interpersonal and interorganizational trust is a construct considered an important factor in coordinated and effective interaction in a variety of settings [17, 50], including effective teamwork [25] and interorganizational collaboration [27, 23]. As pointed out by Porter [see 32], however, "Trust …tends to be somewhat like a combination of weather and motherhood; it is widely talked about, and it is widely assumed to be good for organizations. When it comes to specifying what it means in an organizational context, however, vagueness creeps in." Therefore a variety of conceptions of trust help frame that aspect in the model.

A broad-based conceptual approach also informs the model's treatment of knowledge sharing and collaboration. Knowledge sharing can involve explicit forms as well as tacit and embedded forms expressed in action, groups, procedures, and artifacts [11, 52], and may vary considerably across communities of practice [49]. Knowledge may involve different costs and problems of sharing as well [26]. Collaboration across problematic organizational boundaries has been the subject of research and theorizing relevant to this work. Since the case under study involves collaboration in an information technology project, research on project dynamics and work flows inform the modeling as well. This paper contributes to

[1] The research reported here is supported by National Science Foundation grant #SES-9979839. The views and conclusions expressed in this paper are those of the authors alone and do not reflect the views or policies of the National Science Foundation.

0-7695-1874-5/03 $17.00 © 2002 IEEE

understanding of interorganizational collaboration by integrating aspects of trust, knowledge sharing, and project flow in a dynamic framework.

2. The project context

The project on which the model is based was multi-government and interorganizational, consisting of state, county, and city regulatory agencies and the nonprofit and local government service providers that receive financial support from the State. It was designed to develop a new management information system to be shared by the Bureau of Housing Services (State of New York) and state-funded homeless shelter providers. The system is to assist in managing and evaluating client service programs.[2] The Bureau of Housing Services (BHS) determines funding eligibility and need for services and provides case management, direct services, and referrals to outside service providers. Federal, state, and local government programs for the homeless in New York State spend approximately $350 million per year, $130 million of which is to support services to clients. The project work was a collaborative effort involving the BHS, New York City Department of Homeless Services, and provider representatives along with the Center for Technology in Government (CTG). The role of CTG in the project was two-fold: supporting and facilitating the collaboration among the other participants; and providing IT expertise and a development environment for the prototype system.

To be successful, the project required participants from the state agency responsible for shelter oversight to work in a highly collaborative way with managers from a wide range of homeless shelters in New York City, Westchester, and Suffolk counties. Over a 2-plus-year period, the project participants were able to achieve the necessary collaboration and share highly detailed and complex operational knowledge. The result was the design and development of a successful prototype shared information system [14]. To achieve this success, participants confronted and overcame issues of potential misuse of authority, threats to client confidentiality, disparities in business processes, factional views of data elements and their "true" definitions, and lack of standardization in IT platforms.

3. Collaboration, trust, and knowledge sharing: A project perspective

The model explores and represents interactions among collaboration, trust, and knowledge sharing. There is little consensus on the nature of these complex phenomena, let alone a commonly accepted framework to describe how they interact. The model presented here draws on the tradition of system dynamics work in project management to explore the interaction of the organizations involved in the development of the HIMS. A main assumption of the model is that collaborative work is embedded in a series of reinforcing processes associated with learning about one's own and another's role, needs, constraints and objectives in the project work. Representations of collaboration, knowledge sharing, and trust are informed by perspectives reviewed below.

3.1 The project management perspective

Research using system dynamics modeling has provided insights to several issues relevant to the project of interest. Cooper's [13] study of change orders in a ship-building project and Abdel-Hamid's [1] study of a software development effort explicitly portray the creation, identification, and resolution of problems during project work and their effect on the timeliness and quality of the completed project. They also demonstrate that assigning too-few resources to a project at its initiation can result in snowballing needs for resources in the final stages of project work. Repenning [37] and Repenning, Gonçalves, and Black [38] examine allocation of resources to projects in product development when more than one project is underway and conclude that observed biases toward allocating resources to projects whose deadlines are imminent can lead to systematic under-allocation of people to early phases of projects. They suggest that a temporary increase in project workload can "tip" an organization to produce work at a permanently lower level of quality than potentially possible.

3.2 The role of trust

In an interorganizational setting, trust can become a major governance mechanism [2, 35, 36, 1]. Norms of reciprocity and openness can develop as efficient mechanisms for social control and coordinating transactions and decisions necessary for collaboration and knowledge sharing to proceed. Although trust appears as an important concept across fields of anthropology, economics, organizational behavior, psychology, and sociology [43], there is little consensus on types or definitions of trust. Some themes appear repeatedly: vulnerability, risk, and the role of positive expectations or optimistic belief [42]. Trust without uncertainty and risk is not meaningful [43]. Trusting behaviors increase one's vulnerability to the trustee whose behavior is not under

[2] During the course of the innovation project described here the agency name was changed from Bureau of Shelter Services (BSS) to Bureau of Housing Services (BHS). The use of "BHS" in this paper refers to the same agency as the earlier BSS.

the trustor's control [51]. If the trustee abuses this vulnerability, the damage is greater than the benefit if trust is fulfilled. Thus trust can be seen as the expectation that the trustee will not behave opportunistically, even if there are incentives to do so [10, 24, 33].

Several forms of trust can be seen in different relationships [29, 43]. One scheme [42] identifies three forms of trust relevant to this project: *calculus-based trust* (depending on the trustor's capacity to assess trustworthiness [43] and on the trustee's *propensity to trust* [31]); *identity-based trust* (based on emotional or personal attachment formed by long-term reciprocal interaction [28, 53]); and *institution-based trust* (based on institutional factors, such as organizational culture, societal norms, and legal systems that mitigate risk and support trust [30, 53, 44,45]. Each of these forms of trust could be observed in the actions and event in this project, although the model aggregates these notions in each party's trust of the other. Trust has been shown to play a major role in the effectiveness of information sharing and organizational learning [15, 16, 36, 48] and in knowledge and information sharing in interorganizational relationships [7, 24].

3.3 Collaboration and knowledge sharing

Cook and Brown [12] distinguish between *knowledge* as something possessed by individuals or groups versus *knowing* as knowledge-in-practice. Important elements of the knowledge of interest in this project are tacit, embedded in the social context, and much more difficult to transfer [34]. Such knowledge cannot be separated from the work culture and the social construction of the work processes in each of the organizations. Knowledge may also be viewed as an organization-level phenomenon, embedded in organizational forms, social expertise, and as "knowledge-in-practice situated in the historical, socio-material, and cultural context in which it occurs" [11, 20, 49]. Zander and Kogut [52] identified five dimensions of a firm's knowledge: c*odifiability*, *teachability*, *complexity*, *system dependence*, and *product observability*, each of which would be expected to affect transferability and imitability of the knowledge.

System dynamics modeling has been used to explore the role of knowledge in creating collaborative patterns of interaction. Black, Carlile, and Repenning's [5] work with a case study by Barley [3] suggests that relative expertise among workers in different roles dynamically affects which group performs which task, which in turn affects who knows how to do what. Black [4] studied (non)collaboration in new product development and proposed a theory of the effects of location, timing, and artifacts used in cross-departmental interactions on work-related knowledge and project progress. Again, relative expertise plays a significant role in the social processes, or feedback dynamics, that determine whether the interactions across boundaries unfold collaboratively [4]. Relative expertise can change through time, and theories of structuration [6, 21] view social life as unfolding through a recursive process in which accumulated values and properties (sometimes called "capital") of institutions or individuals shape daily activities, which in turn can conserve or transform actors' accumulated capital. System dynamics modeling provides a useful method for representing interactions between activities and actors' accumulations of capital through time.

4. Methods

After two group-modeling sessions [14], the team finished a preliminary model. Using qualitative data from the case, we constructed a refined version of the model to aid analysis of the collaborative dynamics observed and to push forward theorizing about interrelationships between collaboration, trust, knowledge, and the tools used to facilitate communication across boundaries. We used system dynamics [e.g., 46] as the modeling method, as it has proven useful for studying complex feedback systems, where feedback is understood as a closed sequence of causal relationships [39]. The premise is that dynamic behaviors (performance over time) are closely linked to an underlying structure of feedback loops. Articulating and understanding linkages between behavior and structure aids explanation of—and effective intervention in—dynamic, nonlinear processes arising from multiple interrelationships among aspects of a system [19].

As with grounded theory [22, 47], an inductive formal model is constructed by inferring from data some hypotheses about causal relationships that generate a particular pattern of behavior observed in the field. Model-building proceeds iterative by representing hypotheses with connected elements of model structure, simulating the structure, comparing the simulated behavior qualitatively and in degree to the behavior observed in the field, and returning to the data to refine the hypotheses represented in the model by changing its structure. In this sense, a formal model grounded in data is a nontextual expression of a theory of cause-and-effect relationships that systematically produce patterns of behavior observed in the field [4]. We conducted several interviews with CTG staff who had been involved in the original HIMS case, and they confirmed face validity of the variables and interrelationships posited in the model structure and for directional validity of the simulations.

Simulation provides a valuable check on internal consistency [19, 46] of multiple interrelationships in a way text-based arguments cannot. Moreover, simulation permits exploration of a broader range of circumstances than those observed in the field. We used the model to explore the range of outcomes generated by varying the amount of knowledge and trust with which simulated participants begin the project; and varying the effectiveness of boundary objects of CTG's facilitation tools and methods. We reason that if the same interrelationships among knowledge, trust, and collaboration, under different parameter settings, plausibly generate more than one pattern of behavior, then the theory modeled may be useful in explaining more than one dynamic observed in the field.

5. Model description

5.1 Model overview

The model (documentation available from authors Black or Luna) centers on reinforcing dynamics: Working together builds knowledge of one's own work as well as knowledge of the other's work; as one knows the other better, it is possible to trust the other more; and as trust builds, parties share more information, making their collaborative work more effective. In this study, a key to collaborative work lies in the facilitative tools and methods used by the Center for Technology in Government researchers. Stakeholder analyses and facilitated conversations to identify problems and clarify objectives served by the proposed information system, as well as IT requirements analysis and data modeling tools serve as boundary objects [9] to make interdependencies between the parties understandable and concrete and to help find and correct errors in the work done together.

The HIMS project involved one State agency and about 120 local service providers and proceeded through two significant phases of information system development, specification discovery and prototype construction. In the model, however, we make significant simplifying assumptions to aid tractability of the simulated dynamics. We aggregate all the service-provider agencies and represent them as a single Provider. We consider only the first phase of system development, joint specification discovery. (We plan to extend theorizing and modeling to account for more of the project's complexities in future work.) Additionally we represent CTG's facilitation as exogenous parameters affecting the quality and effectiveness of work undertaken together by the State and Provider. Thus this model considers two main participants, the State and the Provider, engaged in the work of developing specifications for the proposed information system, HIMS. It consists of three main parts: a simple project model to represent the dynamics of doing work; the participants' respective accumulations of knowledge of their own and the other's work, and the resulting trust and engagement to continue specification development; and the influences of CTG's facilitative design of the meetings' process and content.

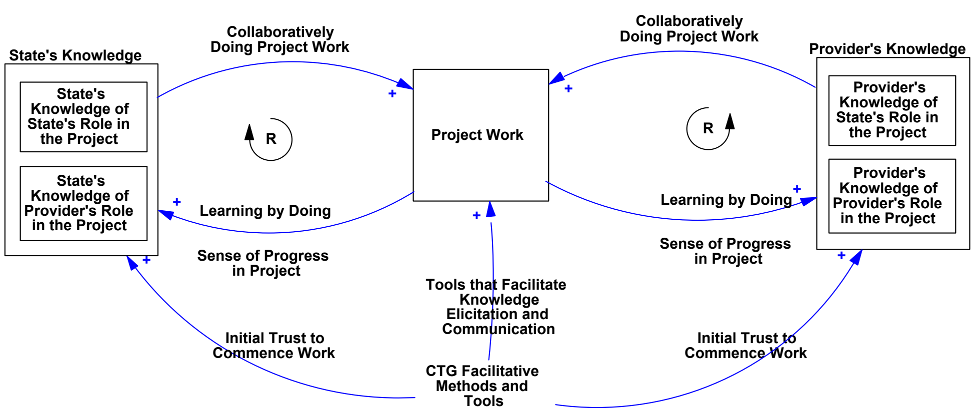

Figure 1: Model overview

5.2 Project work

The model sector representing project work progress is shown as Figure 2. A rich body of system dynamics literature has studied the dynamics of project management [13, 18, 40], and a standard model structure for representing the rudiments of projects has emerged [46], which we adopt here. Project tasks can exist in one of four states: Work to Do, Undiscovered Rework, Known Rework, or Work Really Done. When the specification-development phase begins, no work has yet been done, so all tasks (Project Definition) are in the Work to Do accumulation. As participants perform work—we assume for simplicity that all specification-development work occurs in meetings between the State and Provider—tasks move to the stock Work Really Done, with a probability of 1- Error Fraction. The presence of the Error Fraction indicates that it is impossible to perform all tasks correctly on the first try. Specification-discovery tasks performed incorrectly require rework, and additional meeting-work by the State and the Provider identify which tasks must be redone. Hence as the State and Provider perform Work to Do, tasks enter the accumulation Undiscovered Rework with a probability of Error Fraction. Similarly, redoing problematic tasks can be completed correctly (moving from the accumulation of Known Rework to Work Really Done) or incorrectly (returning to Undiscovered Rework), based on the error fraction.

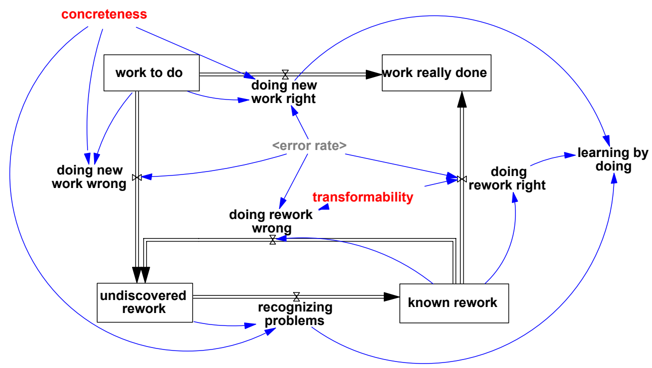

Figure 2: Project work

Participants' Engagement, or willingness to continue working on the project (see below), depends on their sense of progress in the project work. Sense of Progress (Figure 3) emerges from perceptions of the fraction of tasks undertaken *to date* that participants believe they have completed correctly; the fraction of the *entire project* that participants believe has been done correctly; and a sense of how hard the participants have worked lately. These measures provide an optimistic view, reflecting a common bias (observed both in the field and in everyday life) toward believing that any work done is work done correctly, until the need for rework is discovered.

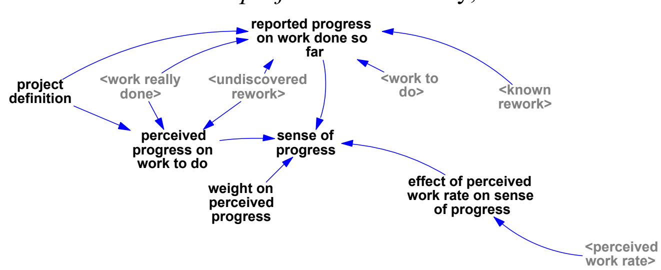

Figure 3: Sense of Progress

5.3 Collaboration, engagement, trust, and knowledge of own and other's work

In the model, collaboration is the sum of participants' engagement. As participants are more engaged and collaborate more, productivity increases. A participant's engagement depends on her sense of progress and her level of trust in the other participant. Trust depends on how much the party knows about the other participant's roles, need, objectives, and constraints relating to the project and its implementation. As participants do the work, they learn more about the possibilities for their own involvement, as well as more about the other's involvement in the project. Therefore the model represents that the State and Provider can each possess two kinds of knowledge, which grow as they interact through the work of creating information system specifications. Each party can accumulate knowledge of her own roles, needs, objectives, and constraints, in the project (State's Knowledge of State's Role in the Project and Provider's Knowledge of Provider's Role in the Project). Each can also accumulate understanding of the other's work in the project (State's Knowledge of Provider's Role in the Project and Provider's Knowledge of the State's Role in the Project). These accumulations (also called "stocks") of knowledge are dimensionless variables (defined over [0,1]). As knowledge of one's own work in the project increases, the probability of error in the project work decreases. When both participants possess a lot of knowledge about their respective roles in the project, the probability of making mistakes as they work together is low.

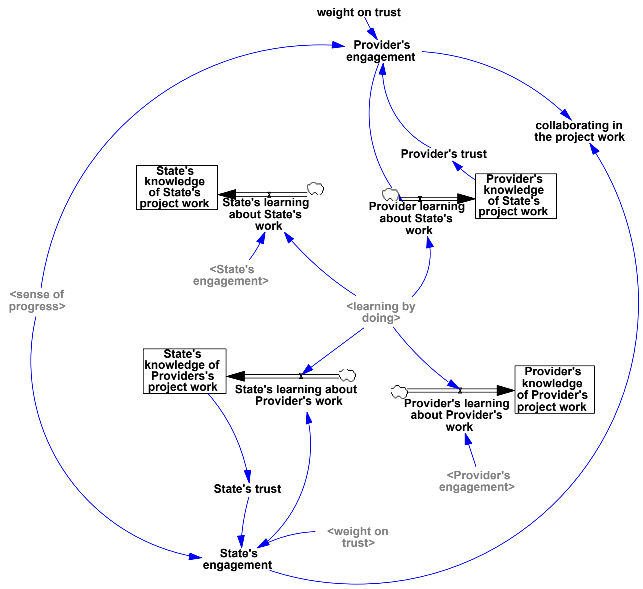

Figure 4: Knowledge, Engagement, and Trust

5.4 CTG facilitative methods and tools

The CTG research team is represented in the model through exogenous parameters influencing the effectiveness of facilitation and communication tools, Concreteness, Transformability, and Potential Accuracy in Representing State's (Provider's) Point of View (all defined on the interval [0,1]). Concreteness [8] refers to the specificity of the conversation and cross-boundary work on specification discovery. Through diagrams and visible note-taking, for example, CTG's facilitative team helps direct the State and Provider identify issues in sharing certain data. In the model, the ability to do new work and to identify problems in work done to date depends on the Concreteness of the artifacts used. Transformability [9] refers to the ability of the State and Provider to address problems identified. If participants are unable to voice their opinions about how the work should be different or if their suggestions for resolving problems are ignored by the other party and the facilitators, then the work is "untransformable" to them (Transformability has a low value). CTG's facilitative methods rest on a philosophy of helping parties be explicit about their concerns and hopes for joint work, so high CTG involvement in a project suggests the parameters Concreteness and Transformability take on high values.

CTG staff do not, however, coerce parties to share information. CTG involvement affects the Potential Accuracy for representing each party's point of view, but the actual accuracy depends also on each party's trust in the other (see Figure 5). As a participant grows to trust the other, she is likely to share more information, increasing the accuracy of the representation of her point of view in the project work. As the accuracy of her point of view increases, the other grows in knowledge of that participant's role in the project.

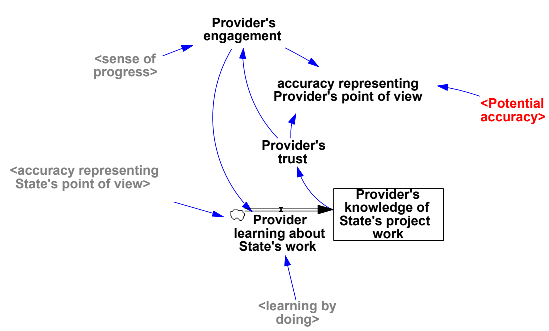

Figure 5: Accuracy in representing a participant's point of view

Proceedings of the 36th Hawaii International Conference on System Sciences (HICSS'03)
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5.6 Summary of model description

The primary feedback loops formed by the connections described above are reinforcing, meaning that they tend to amplify in the future behaviors experienced in the present (see Figure 6, below). The CTG research staff use carefully chosen facilitative methods and tools to increase the clarity and usefulness of communication across the State-Provider boundary. As participants begin to work together and make progress, they become more engaged (R1 and R2) to do the work and in turn learn more about their roles, constraints, objectives, and needs in continuing participation in the project (R3 and R4). By doing work together, they also learn about the other's role in the project and so grow in trust (R5 and R6). As trust increases, each party shares more information, thus clarifying her point of view for the other and so allowing the other to learn more about her objectives and constraints, and thereby trust her more (R7).

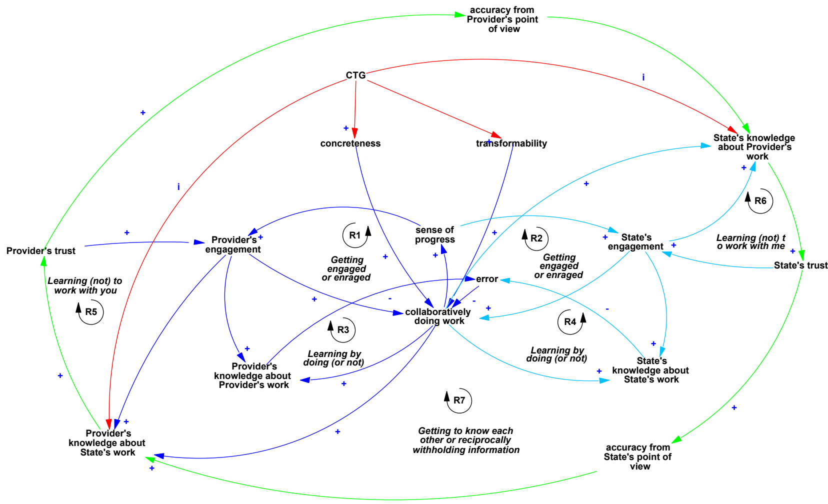


Figure 6: Main reinforcing processes in the model

6. Model simulations

6.1 HIMS simulation

The base scenario represents the specification stage of the development of the HIMS project. The initial parameters were based on qualitative data in the case. Because the CTG team had previous interactions with the State team, State's knowledge about its own objectives and role in the project is initially set to 0.8 and State's knowledge about Provider's work is set to 0.3. On the other hand, the Provider's accumulations of knowledge are initially low (0.1 each). CTG participation and effective facilitation are represented by high values (0.8) in Concreteness, Transformability and Potential Accuracy.

As shown in Figure 7, project work is completed in about 42 months for this scenario (longer than observed in the case under study, which suggests the model can benefit from refinement, though actual project participants confirmed the validity of the causal structure of the model's elements and reinforcing dynamics observed in simulation). During early stages of the project, Work Really Done and Undiscovered Rework grow together. Because the Provider's low initial knowledge creates a high error rate, the accumulation of undiscovered rework is greater than the accumulation of work really done during these first months. The Provider's knowledge of its own role and objectives in the project increases as the collaborative work takes place (see Figure 8a), however, gradually reducing the error rate and increasing the fraction of work done correctly. Undiscovered Rework is identified through reviewing activities, which start when the participants perceive they have undertaken about 20 percent of the project and increases gradually.

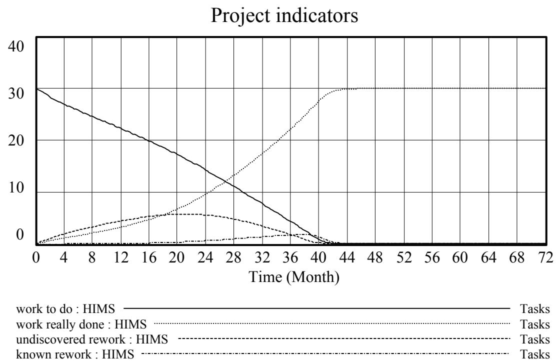
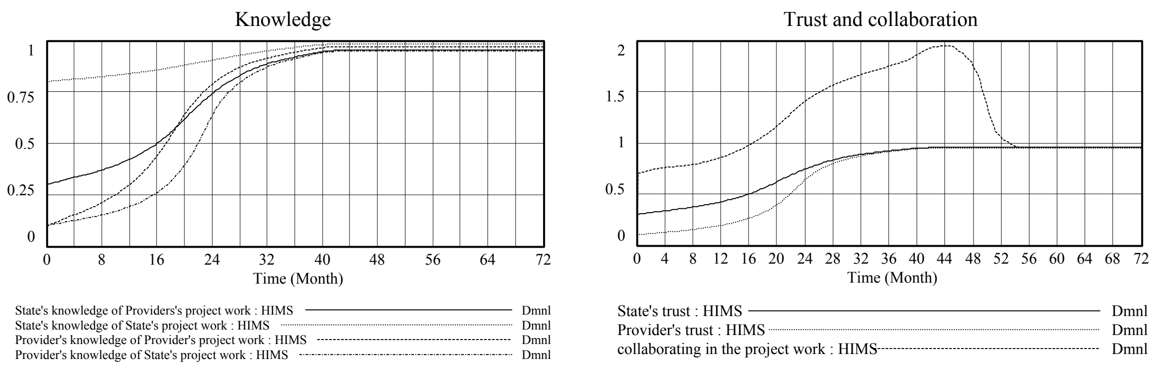


Figure 7: Project work development in the HIMS case

Effective facilitation methods (reflected in high values of Concreteness, Transformability and Potential Accuracy) help the four accumulations of knowledge move from their initial conditions through values close to the maximum (Figure 8a). In this base scenario, all the reinforcing processes depicted in the previous section work in a virtuous manner to promote less error, more engagement, more knowledge and trust along the project development.



(a) (b)

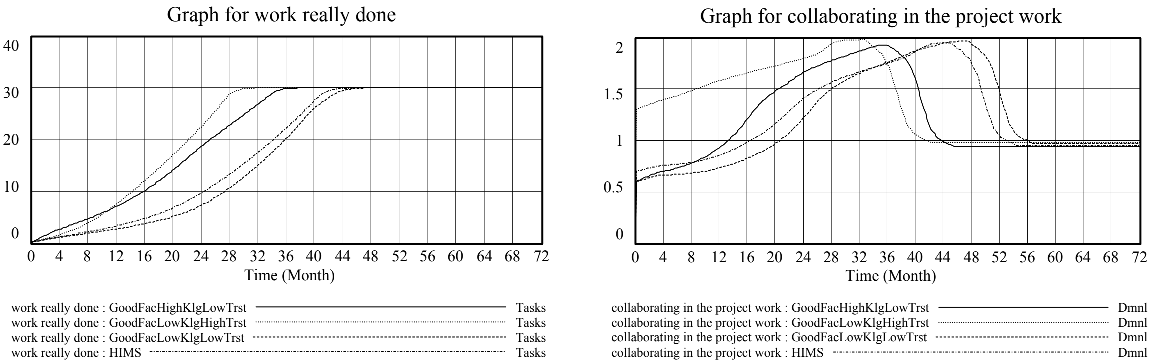
Figure 8: Knowledge levels (a), trust and collaboration (b) on the HIMS model

Figure 8b shows the dynamics of trust and collaboration in the project. State's and Provider's growing pattern of trust is the same qualitatively and quantitatively. Collaborative work is explained partially by these two levels of trust, but it is influenced too by the level of engagement in the project. The collaborative effort is higher than the level of trust while project work is being developed, and decreases to the same value of trust at the end of this project stage. It is possible to interpret this final value of collaborative work as momentum to be carried to the next stages of the project or to different initiatives started by the same partnership.

In order to explore the effectiveness of facilitation design in the promotion of knowledge sharing, collaboration, and trust in the context of a progress, two experiments were designed. In the first, effective facilitation objects were used in scenarios with symmetric but different levels of initial knowledge. That is, high values in Concreteness, Transformability and Potential Accuracy were used in simulations where:

- Both participants begin with high knowledge about their own role in the project but low knowledge about the other participant (reflecting low trust),
- Both participants start with low knowledge about their own role but high knowledge about the other's (reflecting high trust), and
- Both participants begin with low levels in both accumulations of knowledge.

In the second experiment, average facilitation artifacts were tested in the same three scenarios.



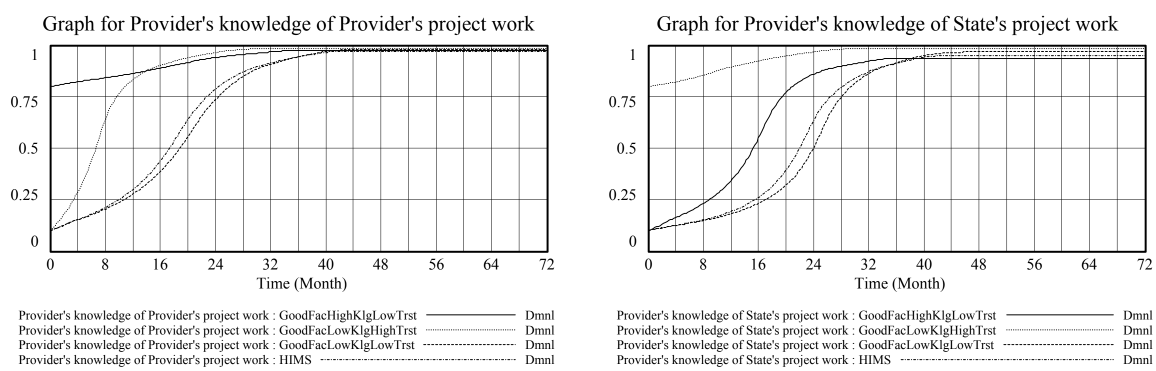
(a) (b)

Figure 9: Work Really Done and Collaboration with several initial knowledge conditions for a good facilitation scenario

6.2 Good facilitation design with several initial knowledge conditions

Figure 9a shows the completion of tasks completed correctly in the three scenarios, comparing them to the base (HIMS) case. In the cases where the two participants started with a high level of knowledge (of any kind), the project work finishes earlier than in the base case, and when both levels of knowledge start low, the work ends a little later than in the base case. An interesting pattern occurs in the cases in which both participants start with one kind of knowledge. Although in the cases in which there is initially a high level of knowledge about their *own* roles and objectives progresses faster than the case in which there is a high level of knowledge about the *other's* role and objectives, in the later cases the project ends earlier. The initial knowledge of their own purposes drives a lower error rate and a faster start-up, but high initial knowledge about the other leads to higher levels of trust and engagement. Being highly engaged makes the learning-by-doing reinforcing processes work faster, promoting quick learning in both participants and early reduction in the error fraction. Higher levels of engagement also promote more intensive collaboration (Figure 9b) and thus an earlier conclusion to the project.

The symmetry of the initial values of the stocks of knowledge makes the State and Provider's knowledge behave identically (figures 10a and 10b). The Provider's knowledge of its own role and objectives (Figure 10a) grows faster in the scenario of high trust and low knowledge for the same reasons described above. Interestingly, in this scenario both Provider and State end up knowing slightly more about themselves (figures 10a and 10b). In this case, low initial values of their own work promote higher error rates at the beginning of the project. The additional collaborative effort created by identifying and solving these additional errors promotes more learning and a higher level of both kinds of knowledge (of their own and the other's work) at the end of the project.



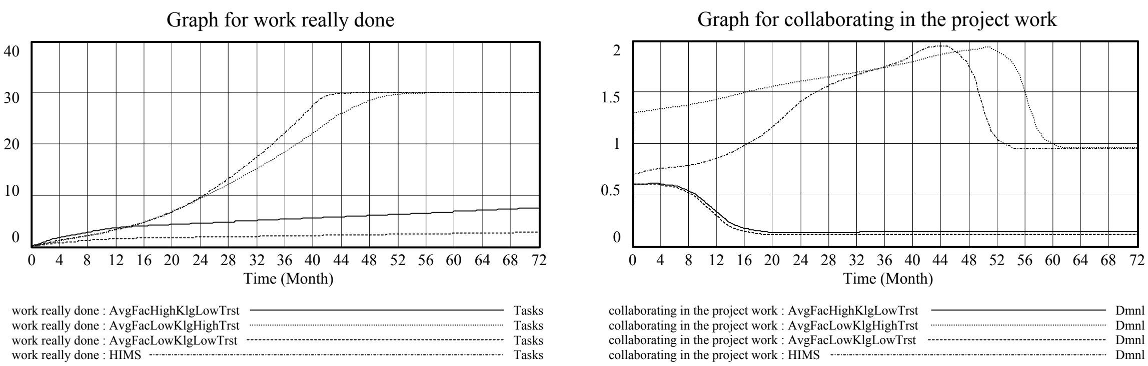
(a) (b)

Figure 10: Comparison of Providers' knowledge of their own work and the State's work on the project under several initial knowledge conditions and good facilitation scenarios

Good facilitation design proves powerful even in the case in which four stocks of knowledge start at a low level. In the three first scenarios, the reinforcing processes in the model behave in a virtuous mode. The initial work and the initial sense of progress promotes increasing engagement, and doing collaborative work drives learning and increases knowledge.

6.3 Average facilitation design with several initial knowledge conditions

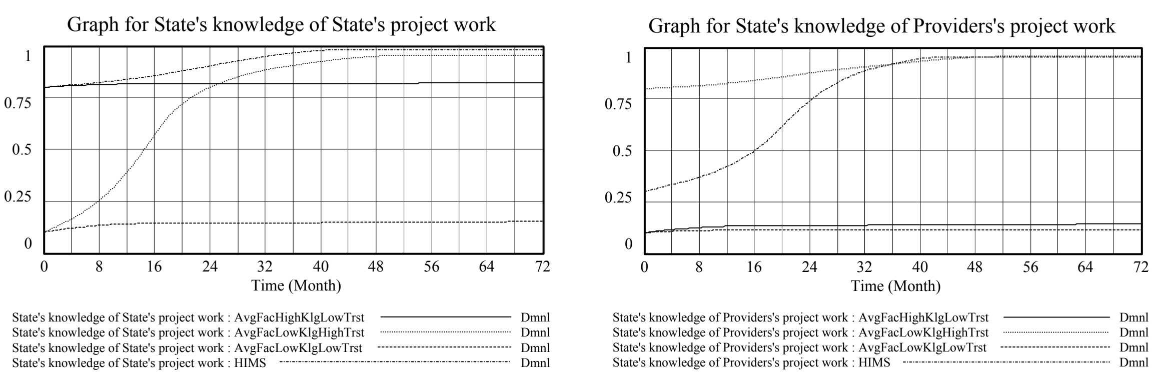
As mentioned above, the second experiment involved the use of the same initial knowledge scenarios with an average facilitation design (0.5 for the initial values of Concreteness, Transformability and Potential Accuracy). In this second set of explorations, the project is completed only in the case where project participants begin with a high level of trust (high knowledge about the other's involvement in the work) (Figure 11a).



(a) (b)

Figure 11: Work Really Done and Collaboration with several initial knowledge conditions for an average facilitation scenario

In both cases where the project is not completed, the reinforcing processes work as a trap, or in a vicious mode. In this way, low levels of initial trust and engagement result in a small amount of collaborative work, leading to a small sense of progress and accomplishment. The lack of achievement makes the participants become even less engaged and spend even less time working in the project (Figure 11b). Additionally, spending a small amount of time doing work collaboratively limits the learning capacity of both participants, maintaining the four knowledge stocks at the same level during the simulation (figures 12a and 12b).



(a) (b)

Figure 12: Comparative of Providers' Knowledge of their own work and the state work on the project under several initial knowledge conditions and average facilitation scenarios

These simulations reveal that a half-competent facilitation design can contribute to either success or failure and highlight the importance of trust. When facilitation methods are not strong, project success hinges more critically on beginning with "the right team." Pre-project activities, in which participants initiate learning about the other's needs and objectives may also be important determinants of project success or failure.

7. Discussion

IT inherently crosses boundaries and therefore requires collaboration. This paper integrates research on trust and collaboration with the rational design of IT development methods to provide a more robust understanding of what causes success and failure in IT projects. It suggests a theoretical grounding for why IT tools and methods can work, that development tools may serve as boundary objects, helping build knowledge of one's own and others' work and trust to share information productively.

Scholars and practitioners agree that cross-boundary collaboration unfolds as a dynamic process, with interdependent factors that can change through time. This paper takes a step toward a dynamic theory of collaboration by representing key interrelationships that determine whether and why collaboration evolves in the context of a case study of intergovernmental use of information technology.

We propose that successful intergovernmental collaboration attends to knowledge management and knowledge representation in cross-boundary meetings. This paper provides a structural approach to explaining successful and failed outcomes of collaborative efforts.

8. Future research

This second iteration in modeling cross-boundary collaboration in IT-intensive projects suggests several paths for future work in modeling and theorizing about cross-boundary collaboration. Conducting validation interviews with individuals from agencies involved in the HIMS collaboration can help refine the model. While it is challenging to derive direct empirical measures of "knowledge" or "collaboration," future work may include use of survey instruments or structured interviews of participants in similar interagency collaborative efforts to assess relative knowledge and willingness to collaborate at different points in the project process.

A critical limitation of the model is the assumption that knowledge of the other leads to trust, rather than distrust; we can describe how dynamics that include distrust might unfold in these kind of settings. CTG's facilitation design is represented as exogenous inputs to the model (parameter values for Concreteness, Transformability and Potential Accuracy). Another iteration of the work can consider the dynamics of CTG's learning about the needs and objectives of project participants, and participants' learning how to design facilitation of their own work. Representing multiple service-providing agencies poses another way to develop the model. While simulating a range of circumstances not observed in the field suggests that the model-theory can be useful in explaining more processes and outcomes than the one documented in the HIMS case, examining the theory's explanatory power in other cases can provide further validation or disconfirmation of the model. Another path to future work can explore the range of dynamics possible when cross-boundary collaboration reveals a range of benefits and costs (perhaps asymmetric) for each party. Finally, the theory as modeled can be enhanced by including more phases of the IT development and implementation process to understand better the challenges of scale-up dynamics across phases.

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