Emergence of the Governance Structure for Information Integration across Governmental Agencies: A System Dynamics Approach

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ABSTRACT
The purpose of this paper is to describe a dynamic theory of the socio-technical processes involved in the definition of an Integration Information problem in New York State (NYS). In April 2003, the Criminal Justice Information Technology (CJIT) group of NYS was tasked with developing a framework to give users of criminal justice data and information systems "one-stop shopping" access to information needed to accomplish their mission. CJIT collaborated with the Center for Technology in Government (CTG) for an eight-month period during 2003 to accomplish this task. The theory consists of a system dynamics model for understanding the dynamics of the collaboration involved in the problem definition stage of a project. The model was developed in facilitated group modeling sessions with the CTG team. The model is capable to generate interesting scenarios that show the importance of social accumulations in project management. Moreover, the model illustrates a powerful way to use modeling and simulation as theory-building tools.

Categories and Subject Descriptors
K.6.1 Management of Computing And Information Systems---Project and People Management
I.6.3 Simulation and Modeling---Applications
I.6.8 Simulation and Modeling---Continuous

General Terms
Management, Design, Experimentation, Human Factors, Theory.

Keywords
System Dynamics, Simulation, Governance.

1. INTRODUCTION
The purpose of this paper is to describe a dynamic theory of the socio-technical processes involved in the definition of an information integration problem in New York State (NYS). Projects like the one described in this paper is similar to many other programs oriented to improve government services that require from two or more agencies to integrate and share their information resources through the use of Information Technology in order to accomplish their objectives [15]. Such integration efforts involves complex interactions within social and technological contexts. "Organizations must establish and maintain collaborative relationships in which knowledge sharing is critical to solve numerous issues relating to data definitions and structures, diverse database designs, highly variable data quality, and incompatible network infrastructure. These integration processes often involve new work processes and significant organizational change. They are also embedded in larger political and institutional environments which shape their goals and circumscribe their choices" [11].

Managing these Information Technology (IT) projects is a complex task, and many of them fail every year. Of a study of 8,000 projects in 1995, the Standish group found that 30% of them were canceled before completion, and 70% failed to deliver the expected features [41]. The complexity involved in the projects resides in several reasons ranging from a world of human organizations to a technical artifact that must be integrated in it [45]: There exist multiple parties involved, each group of stakeholders holds multiple (sometimes conflicting) concerns, errors during early stages in the project have an important impact in further stages of development, and projects involve multiple, intertwined activities.

The model presented in this paper stresses the importance of the social processes and accumulations and its impact on the success of information integration projects. After this brief introduction, the paper is organized in 6 more sections. The second section constitutes a brief summary of previous research. The third section includes the main rationale of using simulation and details on the specific methods used to build the model presented in sections 4 and 5. Section 6 shows some simulation experiments, and we finish with some conclusions and further research.

2. PREVIOUS RESEARCH
As mentioned above, managing IT projects is a complex task that very frequently ends with schedule and budgetary overruns, or project failure [41, 45]. In spite of the uneven behavior of software projects, there is an observed trend to make government information readily accessible to the public inside and outside government. These trends respond to the interest of government

administration to improve internal efficiency [13], but also respond to a more general trend in government towards managing for results and improving customer satisfaction [5]. Moreover, information is one of the most valuable resources in government. “Information is a major input in government programs. Information is, in fact, a primary product of government activity. Collecting, housing, protecting, and using it well are fundamental responsibilities of the public sector” [3]. Thus, we need to get a better understanding about managing these kind of projects in order to improve the success rate of them.

In order to get a better understanding about IT projects, researchers have focused their efforts in the identification of main risk factors with the purpose of design management strategies to control them. There are several risk factors that appear in a consistent way in different studies. Some of them are, for example, project size, team size, technical complexity, technical newness, application newness, team diversity, team expertise, project leadership, number and diversity of users, or task characteristics [2, 24].

Though the risk management approach could be a great help during project planning, it could have a limited effectiveness during project development because it considers only unidirectional relationships between some conditions and specific measures. An IT project is a complex system, which contains circular relationships that make difficult the decision making process during project development. IT projects involve additional complexities when compared to other kinds of projects. Some important differences are that goals frequently are not clearly defined, projects lack of clear boundaries, projects have a cumulative impact from one stage to another, and frequently have the need to integrate newer with older technologies [27]

There are several tools to manage schedule and resources flow during projects such as PERT, Gantt charts or Critical Path Methods. Though this kind of tools are very helpful to manage the combinatory complexity of projects, that is to say, projects with multiple parallel and sequential activities, they do not consider the complex circular relationships in project nature [42]. Moreovoer, none of these project management tools consider the social factors embedded in the project, and that are recognized as important success factors in the literature.

In this way, IT project management is often counterintuitive in the sense that good intentioned decisions to improve project performance lead to unexpected results [19, 42]. Brook’s law constitutes a good example of the counterintuitive behavior of software project management: “adding resources to a late project makes it even later” [21]. Given its counterintuitive nature, it is very difficult to analyze and predict project performance in response to decisions made by project managers. Computer models, on the contrary, have the processing capability to interrelate many factors simultaneously according to clear established modeler assumptions. As a result, simulation-modeling approaches are gaining increasing interest among academic researchers and practitioners as complementary analysis tools for project management [25].

On the other hand, there is a growing group of researchers interested in understanding IT initiatives from both social and technical perspectives [12, 26, 30, 44]. However, experiences from the field have revealed the need of getting a better understanding of both, the technology and the collaborative processes involved in its development and use, developing models to explain the interactions between social and technical factors, and to guide practice [16]. The development of such models is a difficult task given that IT initiatives are complex phenomena involving the interactions around a particular technology “characterized by ongoing sensemaking among stakeholders, and it can be chaotic, nonlinear, and continuous” [12]. System dynamics models have been proven useful to explain this kind of problems [34]. In fact, System dynamics modeling has been used to simulate and describe the behavior of projects since the early 70’s, and it has been applied to several kind of projects: R&D projects [36, 37], ship building projects [9], and software project management [1].

3. METHODS AND DATA

The model reported here is an integral part of a two-year research program that concentrates on integration activities in two critical policy areas: justice and public health. These areas include a full range of functions across all three levels of government. These are also areas in which significant integration initiatives are underway and available for study. Federal and state government agencies are collaborating in the research, as are organizations of government professionals concerned with information technology.

Understanding and supporting information integration is a multidisciplinary undertaking. The project therefore combines perspectives from organizational behavior, computer and information science, and political science. Two forms of modeling are being used: system dynamics modeling that emphasizes the continuous and non-linear feedback aspects of the process, and social process modeling that emphasizes the way collaboration and shared meanings are developed. These methods build on prior work of the investigators in interorganizational knowledge sharing, collaboration, and government technology innovation.

The model presented in this paper captures the dynamics of the work developed by the New York State Criminal Justice Information Technology Group (CJIT) during 2003. CJIT is comprised of seven New York State criminal justice agencies and the New York State Office of Technology. In April 2003, CJIT group of New York State (NYS) was tasked with developing a framework to fulfill the goal of giving users of criminal justice data and information systems “one-stop shopping” access to the information needed to accomplish their mission. The action research team of the Center for Technology in Government (CTG) collaborated for an eight-month period during 2003 with the CJIT group to accomplish this task.

Following CTG’s approach, the CJIT-CTG team went through a series of conversations to specify the business problem and its context, and to identify feasible solutions and alternatives [14]. As a result, the formation of an Integrated Justice Advisory Board was seen as a critical first step in the establishment of the governance process necessary to achieve the goals of NYS Integrated Justice.

The final result of the team’s work was a set of recommendations relating to the formation and operations of a NYS Integrated Justice Advisory Board. Although ambiguity and a diversity of views characterized the initial working meetings, the team was able to effectively share their understanding of “NYS Integrated Justice”, and to develop a shared vision of the problem, alternative solutions, and strategic priorities.

System dynamics is a modeling technique that has proven useful in theory-building efforts [8, 32, 33]. The basic building blocks of a system dynamics model are accumulations (stocks), activities explaining how the accumulations change over time (rates) and feedback structures (closed causal relationships) [36, 43]. These building blocks are consistent with elements from sociological theory such as Weick's concept of activities, Bourdieu's concept of accumulations, and Giddens' concept of recursive interaction [7]. Moreover, the modeling technique is also consistent with current research in information technology [18, 20, 31, 40].

The mathematical nature of the method forces the analyst to be "quite exact and specific in attempting to specify causal dynamics that accomplish a satisfactory translation between verbal theory and empirical observations" [23]. Dynamic simulation helps to get a better understanding of verbal theories and any unexpected outcome obtained from them, with the potential to inform or improve the activities of both theorists and empirical analysts [32].

The system dynamics model reported in this paper was built using group model building (GMB) techniques [4, 35, 38, 39, 46]. A distinctive characteristic of these GMB sessions was their use as a theory-building method instead of a method to help groups of managers to tackle complex problems. The theory-building process consisted of five GMB sessions of two to three hours from November 2003 to May 2004. The first two sessions focused on developing a dynamic understanding of the project by analyzing patterns of behavior of key variables identified by the group, story telling, and clustering of the main patterns of behavior. During the third meeting the group focused its efforts in identifying the main causal relationships and feedback processes linked to the patterns of behavior and stories from the first two sessions. The team spent the two last sessions experimenting with two versions of a model for refinement and validation purposes. Results of the theory construction process were shared with a panel of information professionals who were involved in system development at all six research sites. These procedures are documented in detail in the literature [29].

4. A THEORY OF INTER-AGENCY INFORMATION INTEGRATION (III)

One of the initial conceptual efforts that the theory building effort yielded reflected the general process that many groups face when they get together for the first time to solve a problem or to develop a project [17, 22]. At the beginning of this specific process, members of the CJIT had different, fuzzy conceptions of the task at hand; its objectives, goals, and the power structure inside and outside the group (see Figure 1). As the group got immersed in the social process associated with the work on the problem, the group got clarity on the problem definition, developing a shared vision and common understanding of Integrated Justice in NYS.

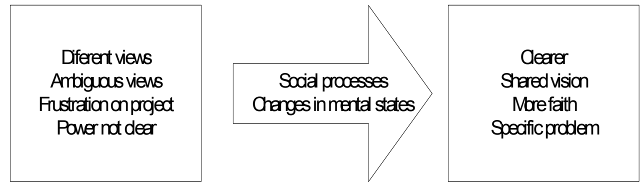

Figure 1. Preliminary Conceptual Icon.

Several pieces of stock-and-flow and feedback structures emerged from the group conversations as the main building blocks of the generic theory of the socio-technical process involved on the clarification of the meaning of Integrated Justice. Figure 2 shows the simplest of them, implying that group activity *created* several kinds of *artifacts* along the process. Moreover, the activity of *creating* artifacts was the result of a certain amount of *effort*, and some *effectiveness* associated with that effort. This common structure helped the group to differentiate among variables affecting the *creating* capacity of CJIT. Some of them could increase (or decrease) this capacity through promoting an increase (or decrease) in the amount of *effort*, and others could improve (or limit) the group *effectiveness*. The accumulation of artifacts could in turn affect some other variables in the process.

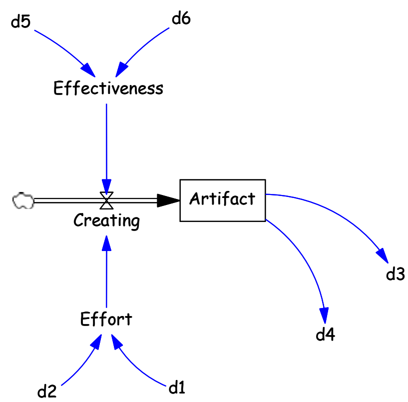

Figure 2. Creating artifacts results from effort and effectiveness.

A second set of generic insights about the process of defining Integrated Justice NY was associated with the idea that CJIT produced not only one kind of artifact, but several of them. Furthermore, these artifacts could be conceptualized as a chain of different group processes that "transformed" artifacts during the project (Figure 3). Along the creation of tangible artifacts, group processes also yielded the creation of several social accumulations such as understanding, trust, or engagement. The effectiveness in the creation of a social accumulation could also depend upon the current state of some other accumulations (i.e. the creation of engagement inside the group could be a function of the level of understanding).

Overlapping the basic stock-and-flow structures of Figure 2 and Figure 3 creates a series of reinforcing and counterbalancing feedback processes associated which each activity or group process in the project (see Figure 4). The three balancing loops in the figure could be considered control feedback processes. The two balancing loops in the bottom of the picture represent increases either in pressure or need to increase effort in a specific process in the project because of the accumulation of tangible artifacts. Increases in the quantity of artifacts 1, for example, create pressure to increase effort in process B. This process exists in many project models, in which accumulation of *work to do* create pressure to process work, reducing the amount of tasks to be done, "pushing" them to the next process. Being a chain of processes, the lack of artifacts 2 creates the need of more effort in process B to create more artifacts for the next process, "pulling" artifacts to the next process. The counterbalancing loop in the upper part of the figure is another control loop representing reductions (or increases) in effectiveness as the group ran out (or accumulates) work to do, assuming processing is easier when the group has a lot of artifacts to work with.

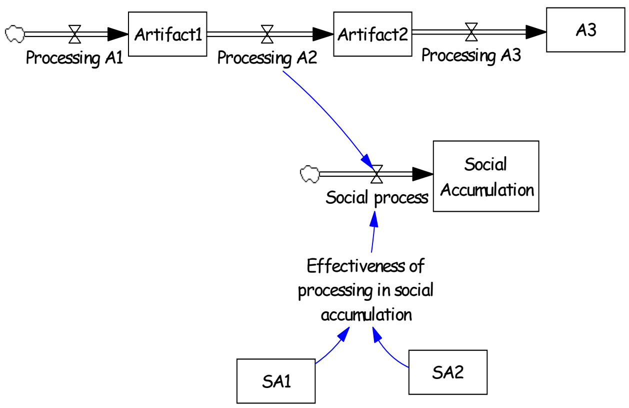

Figure 3. Acting builds social accumulations.

The two reinforcing processes in the figure represent virtuous cycles (or potential traps) in the development of the project. On the upper side of the figure, the group builds effectiveness on the task as group members build social capabilities or gets trapped in the process because of the lack of such capability. Additionally, increases on the social accumulation also have the potential of increasing motivation for devoting more effort to the project. Lack of such accumulation, however, is an additional trap for the group. For example, lack of understanding of the project objectives could prevent group members from investing time on task preventing further development of understanding.

5. DYNAMIC MODEL FOR INTER-AGENCY INFORMATION INTEGRATION

As a result of the theory development process the modeling team selected three kinds of artifacts and four social accumulations to be included in the model of the Justice NY project (see Figure 5). The artifacts consisted of issues brainstormed, clarified, and formalized by the group to be transformed from raw issues to legitimate proposals. For example, if this structure were to be used to represent some form of development of an information system, legitimate proposals might represent portions of code implemented by the organization (that is fully formalized). High quality rendered issues might represent data models or data dictionaries, intermediate products that are necessary to final formalization. The accumulation of Raw issues could include stakeholder maps, preliminary system specifications, or other facts that might occur early on in a system development cycle (a list of model equations can be obtained from the authors).

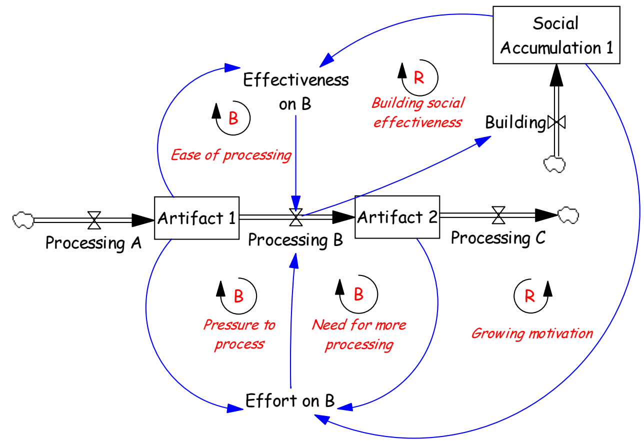

Figure 4. Generic processes creating technical artifacts in a social process.

The main social accumulations considered in this initial theory include two representing individual accumulations (understanding and commitment), and two constituting group accumulations (understanding and engagement). In the final theory as illustrated below, all four of these social accumulations play important roles in facilitating or impeding the creation of artifacts. In turn, these four social accumulations are built as by-products of the process of working on the system. In many cases, project managers are focusing on *Brainstorming*, *Clarifying*, or *Formalizing* processes while at the same time their activities are creating Shared or Individual understanding, Individual commitment, or Group engagement.

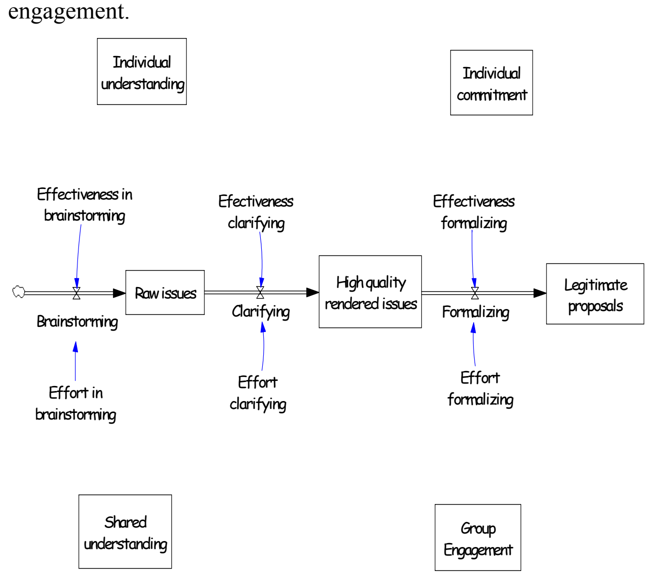

Figure 5. Overview of model stock and flow structure.

The model presents the causal and feedback relationships among these seven key stock variables. The model captures major feedback effects by looking at the causal forces driving *Brainstorming*, *Clarifying*, and *Formalizing*. Another key set of effects centered on processes associated with achieving *legitimacy* and full engagement of the client group. Each of these processes is described in brief below.

5.1 Brainstorming

The work of CJIT started as it met to brainstorm the raw issues and ideas that will be clarified and formalized later on. The existence of an upstream stock of High quality rendered issues or even fully complete Legitimate proposals will influence both the *Ease of brainstorming* and the *Need for brainstorming*. These first order effects shown in Figure 6 serve to initiate a stream of needed Brainstorming and to close down the Brainstorming process once a pool of raw issues have been generated that are in balance with ideas being worked on down stream in the overall work chain. In this theory, a high level of individual understanding on the part of participants on the work team facilitates effective brainstorming. The bottom portion of Figure 6 indicates a final influence on the brainstorming process sometimes caused by confusion. If the individual members of the work team do not share a homogeneous view of the work process (indicated by the Diversity factor in Figure 6) the simple act of brainstorming and placing new ideas on the table can generate confusion for some members of the team. Hence brainstorming and confusing vary together. Confusing the group can decrease shared understanding and over time drop the actual effort devoted to brainstorming.

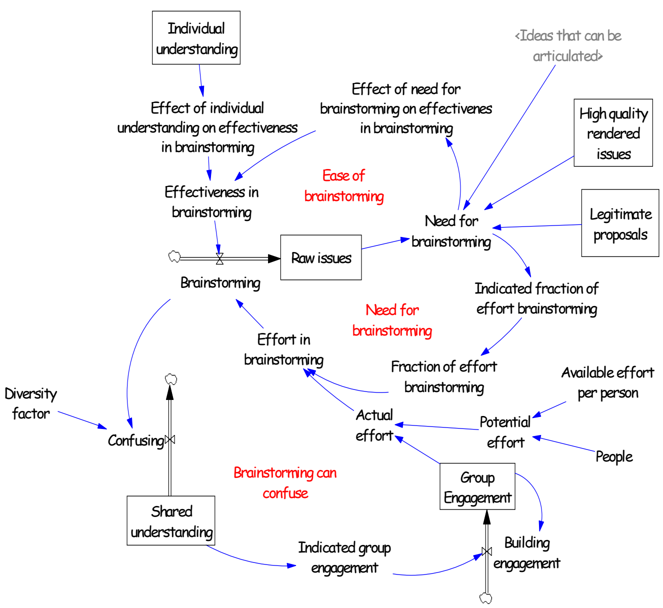

Figure 6. Key structures involved in brainstorming.

5.2 Clarifying

In the theory, the process of *Clarifying* transforms Raw issues into High quality rendered issues. The feedback loops presented in Figure 7 below indicate how the accumulation of artifacts in the system development process interacts with social accumulations to enhance or inhibit this focal clarifying process. As indicated in Figure 7, the simple process of accumulating Raw issues generates two first order controlling pressures. The first is an increasing *Pressure to process* which acts over time to allocate more effort to the clarification process. Similarly, *Pressure for clarifying* created by an accumulation of brainstormed issues works to increase the *Ease of processing*, thereby driving up the effectiveness of overall clarification. Figure 7 indicates two key social processes operating around the clarifying structure in the upper areas of the diagram.

As the total number of ideas being discussed (that is either clarified or formalized) increases, individual and shared understanding also increase. In turn, increases in Shared and Individual understanding touch off reinforcing processes of *Building individual effectiveness* and *Building social effectiveness*. These positive loops can act as virtuous cycles or traps to overall effectiveness in the clarifying process.

Finally, Figure 7 illustrates two feedback effects impacting on overall clarifying processes that involve overall Group engagement. *Engagement enhances (or limits) learning* is a reinforcing cycle involving Shared understanding and Group engagement. Simply put, the model assumes that increasing levels of Shared understanding drive up overall Group engagement which feeds back to enhance (or inhibit) the *future Building of shared understanding*. The final feedback process shown in Figure 7, *Growing Motivation*, indicates that Group Engagement can enhance (or suppress) *Effort clarifying*, thereby closing an additional loop.

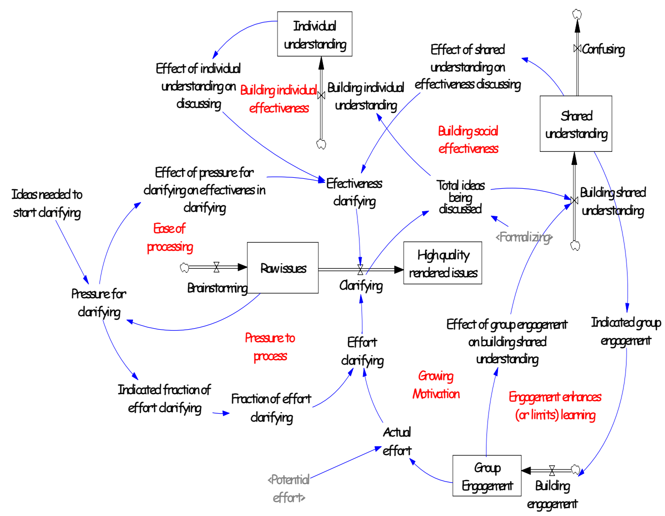

Figure 7. Key structures involved in clarifying.

5.3 Formalizing

The final process of *Formalizing*, as shown in Figure 8, shares much common structure with the *Clarifying* flow as discussed above. *Pressure to process* and *Ease of processing* feedback loops act as first order controls on the formalization process. Similarly, feedback processes involving *Building individual effectiveness* and *Building social effectiveness* can reinforce the effectiveness of the formalizing process. A final set of parallel structures involve *Growing motivation* and a loop in which *Engagement enhances (or limits) learning*.

Figure 8 shows a final feedback process that is not parallel to anything shown in the *Clarifying* structure. The *Ambiguity reduces engagement* senses the final proportion of all work initiated that has been completed and uses it to drive an ambiguity of final product measure. The lowest level of ambiguity results when the most work has been fully completed. The perception of ambiguity is modeled as a weighted average of the *Ambiguity about project products*, and *an Anticipated ambiguity of products*, implemented as a SMOOTH3 function. At the beginning of the project, the Perception of ambiguity starts at zero (equal to the Anticipated ambiguity of products), approaching to the observed

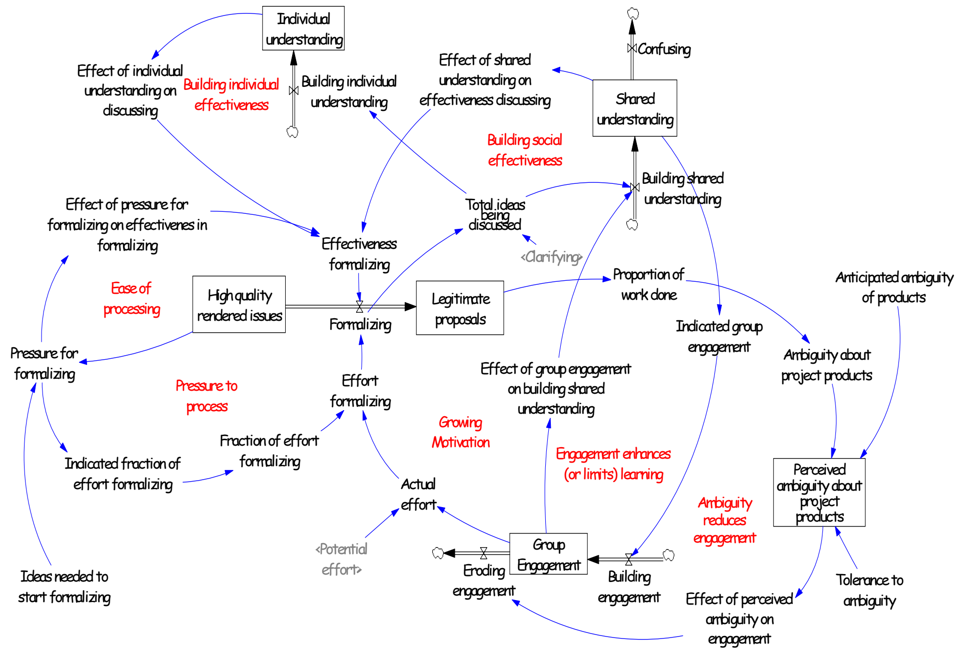

Figure 8. Key structures involved in formalizing.

Ambiguity about project products which results from the proportion of work done. The *Tolerance to ambiguity* (measured in Months) represents the number of months that the group can keep doing work without significant progress, thus tolerating a high level of ambiguity. Leaving work unfinished in an ambiguous state can ultimately shut down a process as ambiguity leads to Eroding engagement ultimately shutting down the *Actual effort* being applied to formalizing activities.

5.4 Process legitimacy and group engagement

Figure 9 shows in overview the last feedback effect articulated by the research team. Portions of this key loop, *Legitimacy of the process enhances (or limits) engagement*, have been shown in Figures 7 and 8. In the portions of this loop already presented, Engagement is driven by Shared understanding and acts to *enhance or limit effort* applied to both *Clarifying* and *Formalizing* work. Figure 9 illustrates a number of "soft" variables that the research team posited as playing a key role in achieving Group engagement. The Perceived legitimacy of the process is a dynamic variable that is driven by the Total ideas being discussed in the project, the Level of activity needed to perceive legitimacy, and the Average time to build a perception of legitimacy. Operating as an endogenous process, this loop says that open and prolonged group activity works with a delay to build a solid sense of process legitimacy.

A second set of factors assumed to be exogenous also impact Perceived legitimacy of the process. The Exercise of group influence plays off against the Exercise of power by a strong or appointed leader of the group in determining overall process legitimacy. The presence of neutral facilitation by an external actor such as CTG can tip this delicate balance between group influences on the process and the exercise of power in the process. Moving both Group engagement and Perceived legitimacy of the process over a critical tipping point was found to be a prerequisite of success in both model simulations as well as in observations of the several projects studied in this research.

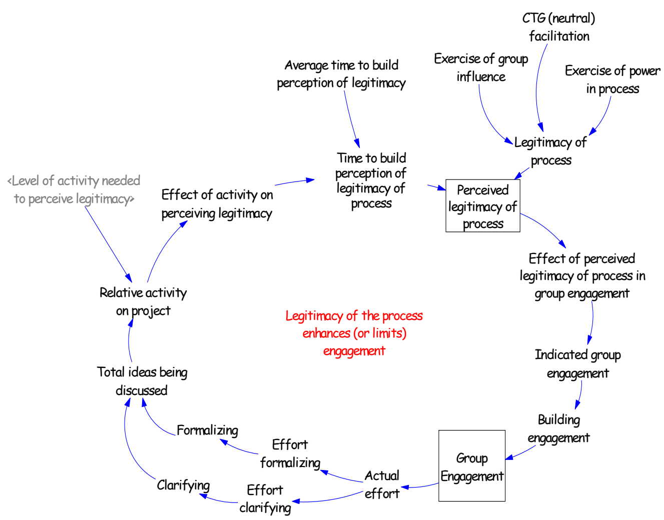

Figure 9. Process legitimacy and group engagement.

6. MODEL BEHAVIOR

The system structure illustrated in Figures Figure 5 through Figure above represents a logically complete theory of a set of technical and social interactions that can create both successful and failing inter-agency integrated information projects. The import of this theory is that it can explain, within a single framework, common processes that can drive projects either to succeed or to fail. A simulation of these results is presented below.

6.1 Scenarios

The modeling team identified 12 key scenario parameters (see

Table 1). Four of them are related to initial conditions in the social accumulations: initial group engagement, initial individual commitment, initial individual understanding, and diversity factor. Four more parameters test for differences in initial conditions in the legitimacy of the process: initial legitimacy, exercise of group influence, CTG (neutral) facilitation, and exercise of power in process. Two parameters can implement changes in assumptions concerning tolerance to ambiguity: anticipated ambiguity of products, and tolerance to ambiguity. Finally, two parameters implement changes in assumptions about flow of work: ideas needed to start clarifying, and ideas needed to start formalizing.

Table 1. Parameter values defining selected scenarios

Scenario Parameter	Run			
	Base	**Not neutral facilita.**	**Innova. Tech.**	**Small toleran. ambig.**
Initial group engagement [0,1]	0.7	0.7	0.7	0.7
Diversity factor [0,1]	0.5	0.5	0.5	0.5
Initial individual understanding [0,1]	0.7	0.7	***0.25***	0.7
Initial individual commitment [0,1]	0.7	0.7	0.7	0.7
Initial legitimacy [0,1]	0.1	0.1	0.1	0.1
Exercise of group influence [0,1]	1.0	1.0	1.0	1.0
Exercise of power on process [0,1]	1.0	1.0	1.0	1.0
CTG (neutral) facilitation [0,1]	0.8	***0.2***	0.8	0.8
Anticipated ambiguity of products [0,1]	0.0	0.0	0.0	0.0
Tolerance to ambiguity (0,n)	10.0	10.0	10.0	***3.0***
Ideas needed to start clarifying (0,n)	20.0	20.0	20.0	20.0
Ideas needed to start formalizing (0,n)	20.0	20.0	20.0	20.0

In principle, a wide variety of scenarios can be run in the simulation model developed in this research. Table 1 illustrates three simple scenarios that were created by changing just one parameter in the simulation at a time. In addition to showing changes needed to implement these three scenarios, Table 1 gives the values for a dozen of the key assumed values in the final simulation. Many of the variables are dimensionless scaled from 0 to 1. For example Initial group engagement could range from none to a maximally engaged group at the start of the project with a value of 1. For the base run, Initial group engagement is set moderately high at .7. Tolerance to ambiguity is set at 10 in this simulation runs except for the Small tolerance to ambiguity scenario where it is set to only 3. By comparing this scenario run to the base run, the user can see the "pure" effect of the Tolerance to ambiguity parameter. Finally the Ideas needed to start clarifying and formalizing set a scale factor for the model—in each case 20 ideas are enough to trigger clarifying and formalizing activities within the simulation. These assumptions do not change in any of the scenarios reported in this paper.

The Not neutral facilitation scenario is exactly the same as the base run except that the strength of CTG (neutral) facilitation drops from .8 to .2, testing the impact of neutral facilitation on the process legitimizing loop as shown in Figure 9. The innovative technology scenario is implemented by dropping Initial individual understanding from an assumed value of .7 to .25, thereby creating a situation where individuals involved in the project begin their work with less base-level comprehension of the technology being used in the project. Finally, the small tolerance to ambiguity scenario is implemented by reducing the number of months that the group can tolerate with high level of ambiguity (small progress) to 3 months.

Simulations implementing these three scenarios and the base run are presented in Figures 10 through 16 below.

6.2 Base Run

Figure 10 shows the three technical accumulations in the base run, which illustrates a successful project spanning a period of 10 months. The stock of Raw issues jumps to nearly 20 by month one and tails off after that as clarifying and formalizing processes move raw issues forward to successful completion. High quality rendered issues peak between months 4 and 5 representing an orderly progression of accomplishment on the overall project. Finally, in this successful project, the number of Legitimate proposals rises through S-shaped growth to a final value of 40 at month 10.

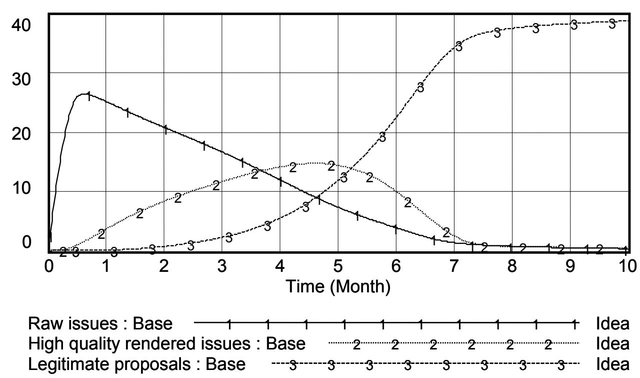

Figure 10. Technical accumulations in the base run.

Figure 11 shows the behavior of the social accumulations in the base run. In this run, Group engagement, Individual commitment, and Individual understanding all start at a high initial value of .7. Shared understanding starts out relatively low at .3 representing the assumption that the key task facing the system development group is developing such a shared understanding.

As shown in Figure 11, feedback processes in the base run lead to a rapid initial fall off in group engagement as well as individual commitment. The loop responsible for this fall is the loop of *Legitimacy of the process*. The project is not making satisfactory progress on clarifying issues and formalizing proposals to keep these levels high. However, as progress is made and the process is perceived as legitimate, Individual commitment makes a come back and the decline in Group engagement halts. Strong growth in individual understanding near the beginning of the project fuels the recovery of the social accumulations. Importantly, after a slight initial decline (caused by the confusion that emerges during brainstorming), shared understanding rises steadily through the base run. The dynamics of these social accumulations can vary dramatically over the three scenarios causing both project failure and overall success.

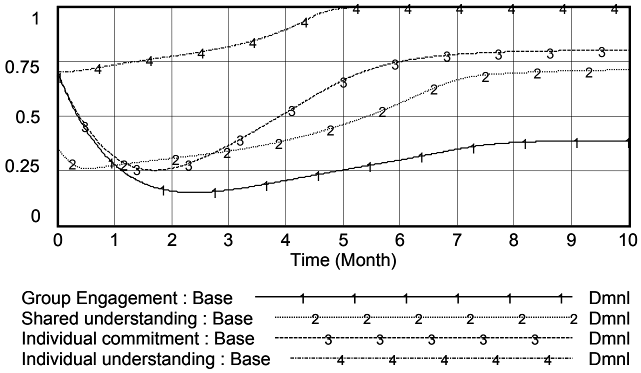

Figure 11. Social accumulations in the base run.

6.3 Comparative Runs

Figure 12 contrasts a successful base run against three scenarios, all of which have difficulty achieving a high level of Legitimate proposals at the end of 10 months. Although in the three scenarios the low level of legitimate proposals can be traced to low levels of group engagement (see Figure 13), three different feedback processes are responsible for the low levels of engagement in each scenario.

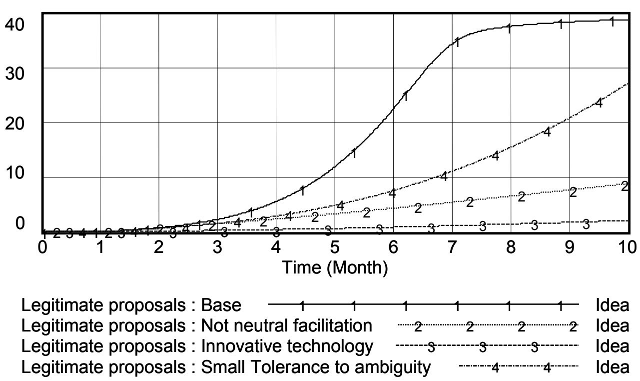

Figure 12. Comparative plot of legitimate proposals across scenarios.

In the Small Tolerance to ambiguity run engagement does not accumulate as fast as in the base run because of the erosion process depicted in Figure 8. The higher levels of perceived ambiguity caused by the smaller Tolerance to ambiguity increase the erosion of group engagement making Engagement to grow slower. The Not neutral facilitation run fails to take off because the Legitimacy of the process is being disrupted by the Exercise of power in the process as shown and discussed in Figure 9. The lack of legitimacy also prevents the group to engage in the project. Finally, the Innovative technology run fails to achieve success because individual understanding fails to take off and subsequently suppresses shared understanding of how the system will work as a whole. The lack of shared understanding prevents the group to engage in the whole process as shown in Figures 6 through 8. As second order effects, low levels of individual and shared understanding disrupt brainstorming and clarifying at the front end of the system as well as formalizing near the back end of the system.

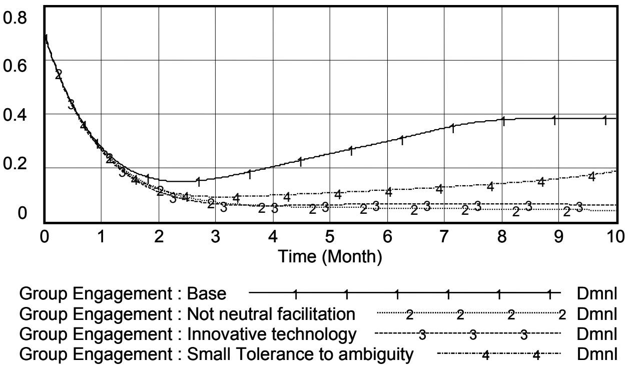

Figure 13. Comparative plot of group engagement across the scenarios.

A key feature to note in Figures 12 and 13 is that the same hypothesized causal structure can drive both project success and failure. However, the model also illustrates multiple distinct modes of failure as feedback loops at both the front end of the system and the back end of the system must work in unison to create an overall successful project.

Figure 14 shows a comparative plot of the behavior of Shared understanding across the four scenarios. The initial value of Shared understanding is a Function of Individual Understanding and the Diversity factor. In this way, the difference in the initial conditions of Individual understanding in the Innovative technology scenario explains the difference in the initial values of Shared Understanding. All runs show a small decrease in Shared Understanding in the initial month of the project. This reduction in understanding is caused by the initial confusion caused by brainstorming individual (and different) views of the project in the brainstorming phase (see Figure 6).

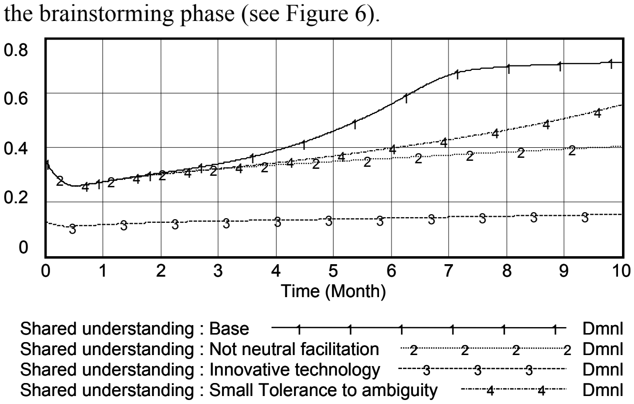

Figure 14. Comparative plot of shared understanding across the scenarios.

Shared understanding builds as the group engages in the discussion of different ideas related to the project (clarifying and formalizing). Similarly, individual understanding grows as the committed individual gets involved in the conversation. In the Innovative technology scenario, Individual understanding does not take of (see Figure 15) because of a reinforcing trap existing between individual commitment and individual understanding. Individuals in the group do not understand the technology, promoting then low levels of individual commitment. Low levels of commitment in turn limit their capacity to learn and build individual effectiveness. The small effectiveness of the group affects the amount of ideas discussed limiting their capability to build shared understanding (Figure 14). Lower levels of Shared understanding in the Not neutral facilitation and Small tolerance to ambiguity scenarios can be traced to low levels of engagement. These low levels of engagement are explained by different feedback processes as described in previous paragraphs.

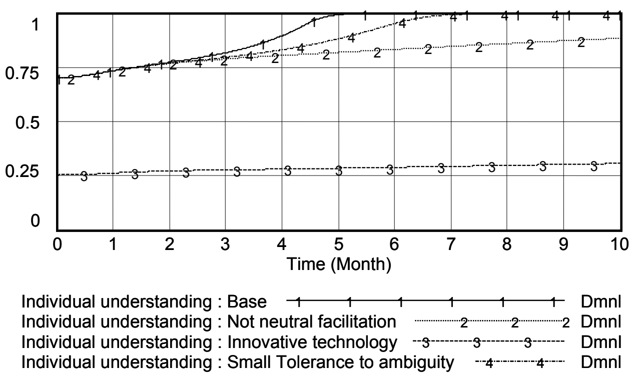

Figure 15. Comparative plot of individual understanding across scenarios.

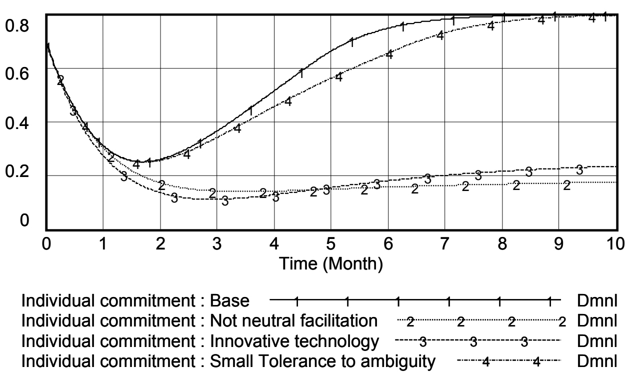

Figure 16. Comparative plot of Individual commitment across the scenarios.

Figures 15 and 16 present comparative graphs of the behavior of Individual Understanding and Individual commitment. In the scenario of innovative technology, individual understanding does not grow because of the trap involving individual understanding and individual commitment described in the previous paragraph. In the case of Not neutral facilitation, individual understanding grows slower and individual commitment stays low because of the lack of legitimacy of the process (see Figure 9). In the Small tolerance to ambiguity, the behavior is similar to the base run, but it took longer to build both individual commitment and understanding. Both behaviors can be explained because of the erosion of engagement caused by the small tolerance to ambiguity.

7. FINAL COMMENTS

The model presented in this paper constitutes a dynamic theory to increase understanding of collaboration in intergovernmental settings. The model builds upon previous modeling efforts, and other theory development on collaboration and innovation dynamics [6, 7, 10, 28].

The model is capable to generate interesting behaviors with reasonable changes in the initial values of some parameters. Moreover, the modeling tool is highly consistent with the literature describing socio-technical processes, which describe them as recursive interactions among technical and social elements, thus full of feedback processes. The model illustrates a powerful way to use group model building and simulation as theory-building tools.

The basic building blocks that emerged during the project constitute steps towards a theory capable to explain beyond the several cases upon which this formal model is based.

Moreover, the model presented in the paper shows the impact of social processes and accumulations on the technical components of an information integration projects. Project managers need to develop tools and techniques to follow-up on these key factors for project success. Simulation models like the one presented here can be useful tools to this purpose.

8. ACKNOWLEDGMENTS

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