Complex Contracted Governmental Projects and the Challenge of Shared Understanding

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Abstract:

Recent studies have revealed a wide range of factors that contribute to failure in complex, governmental projects based on multi-party contracts. A major argument is that in complex projects, there are more opportunities for different self-interested parties to exploit the contract, and therefore project failure is likely. The inherent assumption of this argument is that organizations normally lack shared incentives to pursue mutual benefits. We relax this assumption in this multi-method approach investigating the complex nature of governmental projects in the aerospace industries. First, based on analyses of data from 30 semi-structured interviews, we report a case study that identifies five primary causes of miscommunication as viewed by project participants. Then, drawing on theories of interaction and informed by communication patterns observed in the data, we build a simulation model that represents characteristics of communication across organizational boundaries and conduct a set of additional analyses that explores how communication patterns, not financial incentives, contribute to project failure. The findings show that delays in the iterative nature of communicating in complex projects can impede shared understanding, and therefore drive project failure, even if the organizations truly seek to perform effectively for their mutual benefit. The simulation analyses suggest that there is an optimal level for how fast an organization should respond to other parties, which interacts with the level of communication clarity. The implications are that efforts to build shared financial incentives for project outcomes will be insufficient to achieve successful collective action from complex contracting, and attention should be also paid to creating incentives, processes, and skills to improve communication skills and patterns and so increase shared understanding across organizations throughout projects.

KEYWORDS: Shared understanding, complex projects, contracting, collaboration, aerospace

INTRODUCTION

Governments acquire their complex cutting-edge infrastructures such as aerospace equipment, defense facilities, high-tech IT systems, and transportation facilities mostly by contracting large projects to multiple contractors and subcontractors. These complex innovative projects differ from other collaborative efforts because at the outset actors lack an understanding of the problems they will encounter as they work to create an end-product that has not been achieved before (Brown, Potoski, & Van Slyke, 2008, 2010; Doughtery 1992; Edmondson and Nembhard 2009; Bechky, 2003). For example, in many aerospace projects, the end-product is unique, expensive, and never built previously. Therefore at project initiation there may be agreement on primary performance specifications but no clear agreement on many physical and operating characteristics of the future product. Challenges of communication in cross functional teams (Majchrzak, More, and Faraj, 2012; Edmondson and Nembhard 2009; Bechky, 2003), difficulties in measuring performance (Young, 2007) and the existence of limited possible vendors that can perform the job add to complexities of the projects (Brown et al., 2010). Furthermore, such projects are most often organized in hierarchical levels involving projects organizations with differing expertise, values, assumptions, and work processes exacerbating uncertainties in planning at project outset. These challenges often lead to inefficiency, scope creep, cost overrun, and project breakdown (Melese et al. 2007).

Improving government performance in contracting complex projects can be a significant source for cost saving. Zhang et al. (2003) provide a wide range of evidence for scope escalation in governmental IT projects including different projects in the California Department of Motor Vehicles (cost of $49.4 million for a project before it was abandoned), and the California Department of Social Services (a project cancellation after a delay of 26 months and $270 million cost overrun estimation which was 357% above the initial plan) (Zhang, Keil, Rai, & Mann, 2003).

Another salient example is the IT-based baggage handling system at Denver International Airport, delivered with significantly reduced capability 16 months late and with cost overruns of $2 billion (Montealegre & Keil, 2000).

A dominant perspective for explaining contract failure in complex projects is based on the principal-agent model of rational, self-interested players with conflicting interests. Based on this perspective three major reasons for failure in complex projects can be offered. First, in complex projects buyers and sellers are not able to clearly define project terms as they lack information about and experience with the innovative end-product (Brown et al. 2008, 2010). Thus, even though contracts seek to specify terms precisely, the emerging project contains ambiguities about the projects and costs that will be resolved only as the work progresses. In such a condition, interpretation of contracts is often subjective and prone to biases and disagreements (Solan, Rosenblatt, & Osherson, 2008). Second, once the project starts, as some ambiguities are resolved, switching to a new buyer or seller is costly or impossible for both parties, and they become locked-in to the project (Brown et al. 2010). Third, in the presence of project ambiguities, both parties, especially contractors, can engage in games (Courty & Marschke, 2004) that further exploit ambiguities in pursuit of greater individual gain, which culminates in a prisoner-dilemma equilibrium of lose-lose (Brown et al., 2008, 2010).

While insightful, these studies are premised on the assumption that the organizations have an incentive to exploit project ambiguities and maximize their profits. The evidence for the tendency to take advantage of project ambiguities is usually supported by one party's reflection on the other parties' behavior (Brown et al., 2010) with negative attributions dominating (Argyris, 1990). This study offers a different explanation for failure in complex multi-organizational projects.

In this paper, we study shared understanding in multi-organizational and governmental complex projects. We undertake a multi-method approach to the problem and conduct two complementary studies of inter-organizational shared understanding in the context of governmental aerospace projects. In the first study, we analyze data from 30 semi-structured interviews, and investigate the on-the-ground processes of interagency, cross-boundary collaborations in the projects, coding the data for causal explanations offered for lack of shared understanding across organizations. Then, in the second study, in line with Davis et al., (2007) we further develop our theory by building a small simulation model that represents the nature of communication in multi-organizational projects and conduct what-if analyses, testing both subjects' explanations for miscommunications and researchers' hypotheses about what can improve cross-organizational shared understanding. The study offers insights into critical aspects of the emergent nature of inter-organizational collaborative capacity. The offered investigation is unique in the sense that it shows there is a source for failure in complex projects which is rooted in the structure of cross-boundary communication in innovative projects. That implies that building shared financial incentives will be insufficient to achieve successful collective action from complex contracting, and attention should be also paid to creating incentives to advance processes and skills to increase communication clarity and improve communication pacing.

DIFFERENT SOURCES OF COMPLEXITY

Complex products range from aerospace equipment and sophisticated transportation facilities to energy production facilities such as nuclear plants. Often these products apply technologies in new ways to accomplish their objectives. Due to the extensive and varieties of level of expertise needed, governments usually use the general contractor approach in which a private organization takes the responsibility of breaking down the project to several sub-projects then assigned to different sub-contractors (Brown et al., 2008). However, due to ambiguities that exist from the beginning of these projects, having a complete and clear contract with the general contractor is not likely (Melese et al., 2007). The need for close collaboration throughout the contract period as well as performance measurement difficulties, typical of collaborative projects (Gibbons & Henderson, 2012; Courty & Marschke, 2004), add another layer of challenges to managing complex projects.

Brown et al. (2010) study contracting in a major acquisition program to upgrade and integrate sea assets in a government program, an example of a complex project. Through case analysis, they develop a theory of complex project failure as resulting from project uncertainties. First, they argue that in complex projects buyers and sellers are unable to clearly and completely define exchange terms at the outset because both agent and principal lack information about the end product. These inherent uncertainties, when combined with complex project characteristics, affect project performance. For example, once a buyer decides to work with a contractor, the investment flows to a specific contractor, and switching to another company in the middle of the project requires significant re-investment. Likewise, the seller has only one buyer for the complicated customized product. Further, the buyer and seller need to conduct an asset-specific investment, and their expenditures do not have economic value outside the product being produced. Therefore, in complex projects the buyer and seller become locked-in through interdependencies in the project process and content and cannot switch to other sellers or buyers. This gives both parties sufficient incentives to take advantage of the uncertainties inherent in incomplete contracts. In such a situation, both parties try to pursue greater individual gains at the expense of almost certainly smaller mutual payoffs. Such perfunctory behaviors, ultimately, lead the project to a lose-lose equilibrium—i.e., project failure.

Further, due to the iterative nature of a complex project and the need for learning, researching, and making sense of the project as it evolves, collective learning is necessary. In other words, a single organization cannot finish a complex project on its own without communicating with the project officers about the characteristics of the product emerging through the project’s work. A collective learning process in collaborations involves acquiring new understanding through diverse actions, assessing outcomes, and disseminating new knowledge across individuals. Examples of contexts in which aligning different players to create a shared understanding of a project or a policy is critical include governmental projects in the health sector (Daley, 2009), the environmental sector (Daley, 2009), scientific projects (Ambos & Birkinshaw, 2010), and construction projects with multiple contractors (Franco, Cushman, & Rosenhead, 2004). Based on a review of 137 cases of collaborative governance across a range of policy sectors, Ansell and Gash (2008) claim that encouraging face-to-face dialogue, trust building, and the development of commitment and shared understanding is crucial in inter-organizational collaborations (Ansell & Gash, 2008).

However, communication in projects that cross organizational and regional boundaries is complex in itself (Bechky, 2003). These projects usually involve organizations that specialize in different expertise and disciplines. Even meeting face-to-face, people from different technical disciplines and in different organizations have different dimensions of concern and work from different assumptions, use different language and have different objectives (Strauss, 1985) and may have trouble creating shared meaning. These differences can be exacerbated when there is no shared organizational culture to fill in or correct communication breakdowns that occur (Schein, 1996). Organizations participating in complex governmental projects almost certainly have differing values, goals, and work processes and may consider themselves part of different societal sectors (profit versus nonprofit, military versus nonmilitary, public versus private), and the contracting process does not permit explicit acknowledgement of these differences or resolution of their implications. Therefore, specifically investigating communications in complex projects is needed to understand why large governmental projects fail and how they can succeed.

In one of the few studies with this focus, Greer et al. (2006) investigate shared understanding, and the absence of it, in a multi-organizational complex project. They focused on communication breakdowns that the field site subjects called “disconnects,” latent differences in understanding of the work to be done among program participants, at the team, group, or organizational level, that, when recognized, would cause significant rework, schedule slips, reputation damage, and cost overruns. Their analyses suggest that the greatest leverage in reducing disconnects relates to increasing expertise, improving communication clarity, and accelerating the pace of assessing impacts from changes in other organizations' understandings and actions.

In this study, we build on the literature of shared understanding and meaning construction as applied to multi-organizational contexts. We examine governmental complex projects with a special focus on communication across boundaries, and investigate further the reasons for disconnects in these projects. We draw on two complementary studies. First, in Study 1, we examine the processes and challenges of building shared understanding in governmental complex projects in a specific case in the aerospace industry conducted by two of the authors. Then, in Study 2, we follow the methodological path suggested by Davis et al. (2007) and investigate the role of different factors in contributing to disconnects in inter-organizational collaboration through building and analyzing a simulation model.

STUDY 1: SHARED UNDERSTANDING IN COMPLEX PROJECTS

Study 1 Method

The empirical context giving rise to this study was a very large, government-initiated software-intensive aerospace development program whose focus was on, not “make-to-order” demands, but rather “research-to-order” and “engineer-to-order” work. The specific project studied in our research involved a large-scale program that spanned more than a decade with a final price tag in the billions of dollars.

The organization with which we primarily worked was a Federally Funded Research and Development Center (FFRDC) that receives federal funds to provide research and scientific and technical assistance to the specific U.S. government agencies. The purpose of this FFRDC agency is to provide long-term scientific, technical, and independent contracting support to the uniformed military officers who bear ultimate project management responsibility. Uniformed military officers typically rotate into a position for several years to manage a project whose full lifespan typically began before their tour of duty and continues after their tour is complete. In these circumstances, an FFRDC provides continuity and support to multiple scientific, engineering, and contracting functions of the System Program Office (SPO), the entity charged with managing the development and acquisition of complex, innovative goods.

In the project under study (as in most similar large-scale projects), the SPO worked with a network of contractors (KTRs) normally organized and coordinated by a prime contractor working with subcontractors often widely dispersed around the country or in some cases across the globe. This organizational structure implies that multiple organizations involved must integrate knowledge from multiple disciplines, often crossing organizational, geographic, and societal sector boundaries, to accomplish large-scale implementation of innovative technologies. The presenting problem from SPO supervising the project was to reduce “disconnects” in understanding the scope of work among the multiple organizations working in the roles of SPO, prime contractor, subcontractors and vendors--specifically, “How does system engineering identify a 'disconnect,' and what do we do when we find one?” In law, recent research has termed “undetected indeterminacy” in contracts as “pernicious ambiguity” (Solan et al., 2008). In the extreme, “disconnects” lead to Nunn-McCurdy breaches (Nunn-McCurdy Amendment, H.Rept. 97-311, Department of Defense Authorization Act, 1982) requiring Congressional investigations of causes of cost and schedule overruns and quality shortfalls in governmental work.

Data collection was conducted as a part of a larger project and included 30 semi-structured interviews (Eisenhardt, 1989; Merton, Lowenthal, & Kendall, 1990) of individuals involved at various levels of technical and organizational responsibility in the SPO. Interviewees' years of experience in the SPO ranged from one to more than 20 years, and interviews lasted from 45 minutes to 2-1/4 hours. For organizational confidentiality reasons, the interviews were not recorded; instead, two researchers took copious notes at each interview, which they then reviewed in detail with a third researcher. The research team conducted qualitative analysis and grounded theory-building (Glaser & Strauss, 1967) to distill key categories and constructs causally related, in interviewees' minds, to the problem of disconnects. In keeping with Eisenhardt's (1989) view of case studies and Glaser and Strauss's (1967) advocated method of grounded theory-building, data collection and qualitative analyses overlapped. As analyses of the data proceeded iteratively, discussions of research-in-progress with individuals and small groups in the SPO stimulated individuals' providing additional data, which were then used to check, corroborate, disconfirm, and/or add depth to the emerging picture (Andersen et al., 2012). In addition, we attended to the decision-making cycles (Boyd, 1992; Mintzberg & Westley, 2001) of each organization involved in the innovative work.

Study 1 Results

Analyses of interview data revealed causal explanations for disconnects that centered on five central propositions (interviewees' explanations 1-5) all dealing with communication clarity and delays in project management and contracting. Here we explain these themes and offer representative excerpts from interview data and analyses.

Interviewees' Explanation 1: System Program Officer representatives and contractors cannot communicate.

The causal rationale for poor communication causing disconnects may be described this way: Requirements are vaguely documented because of inadequate communication capabilities. Poorly written requirements lead to ambiguities in recognizing requirement interdependencies and in even recognizing when a requirement is changing (in this project, as in many governmental contracts, requirements changes involve formal change board processes). In discussing implications and feasibility of changes, communications are hindered by poor meeting processes, information overloads, and gaps between the informal networks of people doing work and the formal communications about changes. These can culminate in work—and work to implement changes—that proceeds until one part of the project system recognizes a gap between what it understood to be in the formally articulated scope of work and the activities it is observing, and a disconnect is exposed.

We noted that each party not only used different language (or the same language but intending different meanings), but also each used different durations for attending to and interpreting communications from collaborating organizations and for implementing actions based on new communications. Cued further by interviewees' attributions of "slowness," we began to explore explicitly the delays in observing and orienting, deciding and acting in the subsequent simulation analyses. Overall we distilled several subthemes from the interviews, which centered on challenges in *writing clear requirements*, in *communicating effectively in large organizations*, and in *creating a culture of open communication*. We describe these in more detail in the following propositions as a way to convey the rich substance and nuance of communications within the SPO and between the SPO and prime contractor organization.

The challenges in writing clear requirements arose from multiple sources. Informants acknowledged that work often proceeded before requirements for the work were clearly documented. One spoke of "building components with PowerPoint docs for specs"; another said, "If you can't describe it, how do you know it's a [requirement] change?" Another asserted that rework resulted from unclear requirements: "The 80 percent technical deferrals are because of vague requirements." One interviewee said that garbled, unclear writing is a widespread problem across the organizations involved. Project participants also said that there is not shared understanding among individuals and organizations of what a contract requirement *is*, as distinct from a user need. This leads to further ambiguities related to dependencies among requirements and challenges in identifying how a change in one requirement affects other requirements and the product specifications overall. Members of the System Program Office were not the only ones alleged to struggle with clear writing. A contractor reported that "RFP [Requests for Proposals] responses [written by prospective contracting organizations] are…poorly defined."

Interviewees described problems effectively communicating in large organizations. Common to many organizations, these included email overload and many overlapping but incomplete communication mechanisms, ineffective meetings and/or ineffective participation. But they also pointed to inadequate, un-shared technologies for communicating, absence of clarity on terminology, and breakdowns between salient informal communication networks and the extensive processes of formal communications within meetings. One asserted that "people know their job, [but] they just don't document [the work]," and another said that "too many ad hoc groups causes the formal organization to be chaotic." A notable refrain in this theme concerned the slowness of information circulation in a "huge" organization.

In different contexts, multiple interviewees expressed concerns about "adversarial" views of other organizations and a related reluctance to ask questions. "People need to admit they don't know," said one; "How do you know that your understanding of a requirement is right or wrong?" said another. One interviewee said that cross-organizational teams were good if well implemented, "but without give and take, problems are not allowed to surface." Some attributed challenges in *creating a culture of open communication* to "shifting philosophies" in how the government works with contractors as well as migration from engineers and users developing requirements in partnership to design engineers "telling the users."

Interviewees' Explanation 2: Changing requirements cause disconnects.

Interviewees reasoned from their experiences that requirements changes cause disconnects because, when there is a change to a requirement that is part of a complex set of interdependent requirements, the change can seldom be implemented without fairly comprehensive exploration of what else in the work-in-process is affected by the change. This exploration crosses not only functional divisions of work, but also cross-hierarchical and cross-organizational communications. Every organizational boundary crossed requires more time to coordinate communication among the necessary people. And the longer it takes to process and approve a change, the more that the project risks stalling, proceeding with work on the change while the communication processes lags behind, or proceeding with work under existing requirements until given explicit approval to update the requirements with the change. Any of these three risky approaches can lead to disconnects, suddenly recognized gaps between the expected and actual project schedule and scope of work.

Informants described many reasons for requirements changes, in which we recognized five themes. One, related to interviewees' explanation 1, above, was that under-articulated initial requirements and vague subsequent specifications necessitated *engineer's "filling in" gaps* in the texts and numbers given to them. There were "no formal specs until the [product] was almost complete," one interviewee offered. A second theme centered on the fact that Presidential directives can, mid-project, evoke *mandated new capabilities and new constituencies*. Many constituencies, an interviewee said, were "throwing requirements grenades." Multiplying constituencies further exacerbated delays with the change-coordination and change-approval process. Some stakeholders "during the 'coordination cycle' want no compromise in many cases," one informant asserted. Another said it is not clear "how to balance the constituency needs and contractual constraints when a change is proposed."

A third theme focused on *requirement interdependency* (there is no clear process to "explicitly link requirement dependencies") *and intertwining requirement interdependence with stakeholder groups* (there is little guidance on "how to make explicit tradeoffs among constituencies"). Fourth, interviewees described *evolving expectations for performance and accurac*y in the product's output, beyond what was described in the specifications. "There is a floating goal on accuracy that gets higher and higher," an interviewee asserted. Another said he wished he knew "the marginal cost of an accuracy improvement over time." Finally, informants explained that *relations between requirement changes and their implementations and project funding* were ambiguous. One interviewee described a need to "establish funding for changes," while another said funding was needed even to investigate prospectively effects of proposed changes.   "Funding allocated to change implementation" was a problem, one said, while another said it was ambiguous "how budgets affect need and requirement partitioning," though there is an acknowledged (if ill-defined) relationship.

Interviewees' Explanation 3: The System Program Office lacks expertise.

The informants' causal explanation of how disconnects arise from lack of expertise in the System Program Office is along the following lines. Inexperience among recently rotated military personnel meant that decision makers at times did not understand the contexts for certain activities and communications, and so they could misinterpret the technical as well as procedural significance of communications. Through their subsequent action or inaction on information, work on the contract could proceed (or stall) without other project participants becoming aware. By the time a gap between work proceeding and work understood to be necessary was recognized, a disconnect had arisen.

One theme that emerged from analyses described the *gap in new personnel's immediate expectations for responsibility and the one- to two-year up-to-speed time needed* to be effective on such a technically and organizationally complex project. A telling remark was, "Poor Lt. X couldn't tell that what the contractor gave him was crap." Another interviewee said, "People don't really know everything they should [technically] and they misunderstand intent." One theme centered on *lack of training and knowledge related to processes and procedures* and the inordinate time (80 percent, according to one interviewee's estimate) that explanation of processes and contexts consumed when scarce resources might be allocated to performing the technical work. Not understanding the difference between a waiver and a deviation, or the difference between a notification and approval, had led to inappropriate actions. Because officers "can't keep it all straight," they must look to others for help in understanding the process. "The process is not broken if you don't use it," said an interviewee commenting on the lack of process training.

A third theme in expertise lamented the *loss of both managerial and technical knowledge in recent years*, as the government made efforts to streamline its workforce, leading to a vacuum in understanding of the history and context for long-duration project work and to ineffective transfers of technical knowledge. Overlapping with a theme of the poor communication, above, was the interviewee comment "New people don't ask many questions about what is best."

Interviewees' Explanation 4: People are too slow *in making sense of proposed changes*.

As indicated above, in large governmental projects the processes for exploring implications of a proposed change to requirements and for gaining formal approval is complicated and time-consuming. People we interviewed reasoned that the very slowness of the change coordination and approval processes created disconnects because information moved at different paces through different parts of organizations, and people often acted on the information received, even if it hadn't received formal approval or been integrated into a revised contract. This led to multiple undesirable situations, including the contractor and subcontractors "working at risk" on a change that could eventually be rejected by decision makers in the formal Change Control Board processes. Additionally, a disconnect could emerge when work proceeded according to informal agreements (garnered through the informal exploration and coordination process that precedes the formal change proposal) that were subsequently inadequately documented. A related situation could arise from the informal exploration efforts not recognizing all of the parties that should be consulted, so that only at high-level formal meetings of the Change Control Board would the un-alignment among organizations' work appear. Each of these situations had led to disconnects in project scope, schedule, and/or budget.

Informants' comments clustered into four factors that contribute to very slow processing and orienting of information. The first was that the *change process and procedures* related to communicating requests for requirements changes were *not standardized or not followed*. Every change document "has its own story," one interviewee said. Another said, "There is [a lot] of deviation from the process." One interviewee wryly assessed "it's not exactly a seamless process." "Everything is a surprise," said another, "not a process of 'no surprises.'" One summarized it as "an undesigned process." Multiple people interviewed expressed that the organizations spend large amounts of time addressing process problems and non-standard operating procedures.

A second and related factor centered on the *quality of documents in the change-request and –approval process*. An interviewee said, "There is no standard format or structure to present to the CCB [Change Control Board]." Others described delays caused by many different formats for documents and deliverables. One interviewee said the contractor's and governments change management "shops" used different formats and were "literally not on the same page." "The process is slowed by non-technical issues—typos, acronyms…, table formatting, etc., described an informant. The communication process could be accelerated, said one, if they improved the quality of documents and reduced “admin crap.”

The sheer *numbers of people required by procedures to be involved in the change process* formed a third factor slowing the pace of assimilating information. “I wish I knew how many people only have ‘checking’ responsibility in the process,” said an interviewee. Reducing administrative overhead in the change information process could speed up the processing of changes, several asserted. One wondered “how the number of people checking affects the process efficiency and velocity.” Others summarized their concerns as wanting the organizations to focus attention on improving “the efficiency of the change processes.”

A fourth factor related to slow information-processing and contributing to disconnects stemmed from *agreements reached during informal explorations* among parties engaged in the work which were not documented formally and incorporated into the formal contract-amendment process. “Contractors agree to a change but don’t put it in a [change document] and people don’t catch it 'til later,” an interviewee said. Another said, the “contractor is not implementing changes or [is] rejecting [working group]-approved changes.” Another asserted that the [working group documents] “don’t document action items on each comment, so what people say or commit to is not documented.” One informant summarized the problem as “how to track compliance to non-contractual agreements made during the change process.” Inadequately documented informal agreements also related to challenges with the change process itself. “It’s hard to track who requested a particular change,” said an interviewee. Describing a series of specification change notifications, one said, “The last one was number 11, then we receive one for number 15—what happened to 12 through 14?”

Throughout these four themes, informants emphasized the slowness in *processing and making sense of information*—while slowness in acting on decisions was viewed as a distinct problem that also contributed to disconnects. "My complaint is with second-tier processes to get answers to good questions," an interviewee said, characterizing a problem with multiple layers of communication. Another said, "An item is coming to the Change Control Board multiple times while work continued at risk."

Interviewees' Explanation 5: People, especially in the System Program Office, are too slow *to act on proposed changes*.

In discussing concerns with pacing, informants broadly agreed and consistently hypothesized that if the System Program Office's processes for *acting* on proposed and approved changes were accelerated, disconnects would be mitigated, reduced or eliminated. Even when information was communicated and assessed, slow decision making and action on those decisions led people in different parts of the project "system" to act at different paces on the same or related information. One interviewee said his group should be called "reverse engineering" because "50 percent of the changes [received] are already in progress with the contractor." One described work as being "gated" by the Change Control Board process. "It is a slow process with extensive contractor input." "Many [change documents] are "behind the game," described an interviewee. "The contractor has already started, and we never do things the 'normal' way." Several interviewees said that the formal change approval process was so slow that "the change is changed" before it is place in a formal contract revision. When people working in different parts of the project act at different paces, it places some "always in reaction mode," according to one. "By the time it gets to the [authorizing board], the contractor has done most of the work," said another. One authorizing person's effort to "fast track" and bypass some of the change processes had led to yet more time being consumed to untangle what work had been done "in parallel" with the change process—another disconnect.

STUDY 2: A SIMULATION MODEL OF COMMUNICATION PROCESSES WITHIN THE PROJECT

Study 2 Intent

After conducting the first study, the research team wanted to understand more deeply the role of different characteristics of the communication "system" among organizations, such as delays in inter-organizational interactions. Analyzing the developmental dynamics in inter-organizational cooperation is extremely hard, as multiple and interacting and recursive sub-processes are involved and the interactions are subject to external and internal shocks. We decided to follow Davis et al. (2007) proposal to use a simulation model to develop theories of organizations. We used the core concepts of the mathematical model developed in Greer et al. (2006) and modified the model to a more aggregated and simpler representation of interactions across a government agency and one contractor (two players). The purpose of the simulation model presented below is not to represent the many physical flows and scientific, engineering, and managerial work processes that were involved in the project that we studied. Rather the model's purpose is to parsimoniously and at a high level represent the essential dynamic characteristics of the five informant explanations extracted from the qualitative data analysis. Hence, a successful simulation model should be able to dynamically reproduce project "disconnects"—that is gaps between SPO's and KTR's perception of an implicit variable such as program scope—by relying only on characteristics of the communication process between SPO and KTR. Constructing such a model should allow us to "test" in a simulating model the causal explanations for disconnects that interviewees hypothesized during the qualitative study and so assess their effects on the dynamics of shared understanding and disconnects.

In contrast to Greer et al. (2006), our investigation was directed more toward a normative analysis of the problem in order to find ways that help government performance in complex projects. That is, we were interested in more than how communication failures can cause project disconnects: we also seek to explain how government agencies and partners can improve complex project performance. Specifically we conducted a series of what-if analyses and optimizations to find conditions under which the performance of complex projects can be improved. While capturing the essence of the themes from our first study in the model, we tried to keep our model simple enough to more clearly understand different modes of behavior and policy implications (Ghaffarzadegan, Lyneis, & Richardson, 2011).

Study 2's Model

Briefly, the basic elements of model structure represent a situation in which each organization accumulates its understanding based on its own actions and on the communications it receives from others, who also accumulate their own understandings, influenced in similar ways. The model focuses on the interactions among organizations as they seek to "get on the same page," since organizations cannot directly observe each other's understanding of the work to be done, even when that work is specified "in black and white." This is an explicit representation of Mead's (1934) foundational theory of how meaning is constituted: As individuals accumulate experiences of their own actions and others' communications with them, these experiences affect how they interpret and then adapt to subsequent communications from others and even their own actions (Mead, 1934; Blumer, 1969). We explain the modeling process for one-way communication in a simple project and then expand it to dyadic inter-organizational communications in a complex project.

One-Way Communication in "Simple" Projects: In a simple project, the government would know ex ante about different aspects of the project, and it could communicate to the contractor through mostly a top-down approach. In simple projects many aspects of the end products can be documented in the contract, and detailed needs can be communicated clearly as the project progresses.

In reality, communications are about multiple dimensions (technical, financial, etc.) of the project. For simplicity, however, let's assume in this model communication is about a single dimension, which we call D1. D1 can represent a wide variety of concepts ranging from the scope or cost of the project to intangible and abstract concepts like how similar to earlier equipment the user interface should be. Figure 1 shows the communication between the government's System Program Office (SPO) and the contractor (KTR).

As shown in the figure, the KTR's perception of the SPO's baseline[1] on D1 will change based on the SPO's baseline on D1, the clarity of the SPO's communication to the KTR about the baseline, the KTR's own expertise level in determining what the SPO's communication means, and the delays the KTR experiences in attending to and re-orienting (identifying implications for related work, for example) to the baseline based on the SPO's communication. In other words, although in practice people act as if their own understanding can be unambiguously communicated, rarely do we have perfect and clear communication. Rather, there may be "noise," or distractions, that affect both the communicator's ability to send a clear message to the recipient and the recipient's ability to understand the message. It is expected that the message sender's "clarity of communication" and the message recipient's "expertise level" relate inversely to the level of noise in communication, and as either of these two factors increases, there is less ambiguity in communication.

[1] "Baseline" refers to the aggregate negotiated (and estimated) scope or cost of a project. Informants referred to technical baselines and financial baselines, as well as used the term to indicate the project work in aggregate, as understood at a particular moment in time.

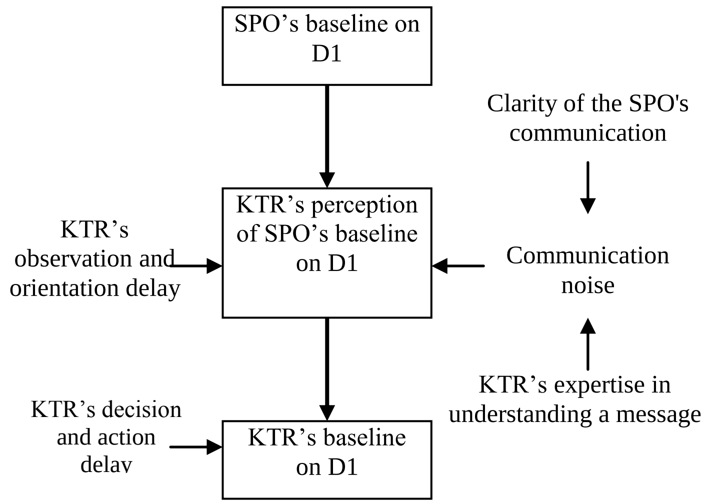


Figure 1 – A one-way unambiguous communication

As the KTR’s perception of the SPO’s baseline changes, the KTR changes its own baseline. The change in the KTR’s baseline is influenced by its perception of the SPO’s baseline and the KTR’s internal delays in deciding how to make sense of and then act on the changes it perceives. This conceptualization of model structure is consistent with the dynamic pacing of an individual’s Observe-Orient-Decide-Act (OODA) loop first articulated by Boyd (1992) and interpreted in terms of organizational decision and action by Haeckel (1999), and Mintzberg and Westley (2001). We provide explanation and mathematical equations in the Appendix.

Complex projects and mutual construction of meanings: As noted above, however, in complex projects, no party has a clear and unambiguous idea of how the end-product will look and function at the beginning of the project. In such a context, the SPO and the KTR must communicate as the work progresses, so there is a dyadic communication structure, i.e. a two-way communication channel which adds feedback to the system. This is imperative especially in innovative projects when no one knows everything about the work to be done, but rather participants make sense of it as the program unfolds and mutually shape others’ understandings of what is possible and practical over time and as the work progresses. Here, in the communication between the KTR and the SPO, as the players seek to understand each other, again, communication can suffer from ambiguity due to difficulties of communication (interviewees' explanations 1 and 3 in Study 1). Figure 2 shows a conceptual model of the structure of a dyadic communication in a complex project, with the SPO's and KTR's baselines on different dimensions of the program, from D1 to D2 to…Dn, being updated through dyadic communications.

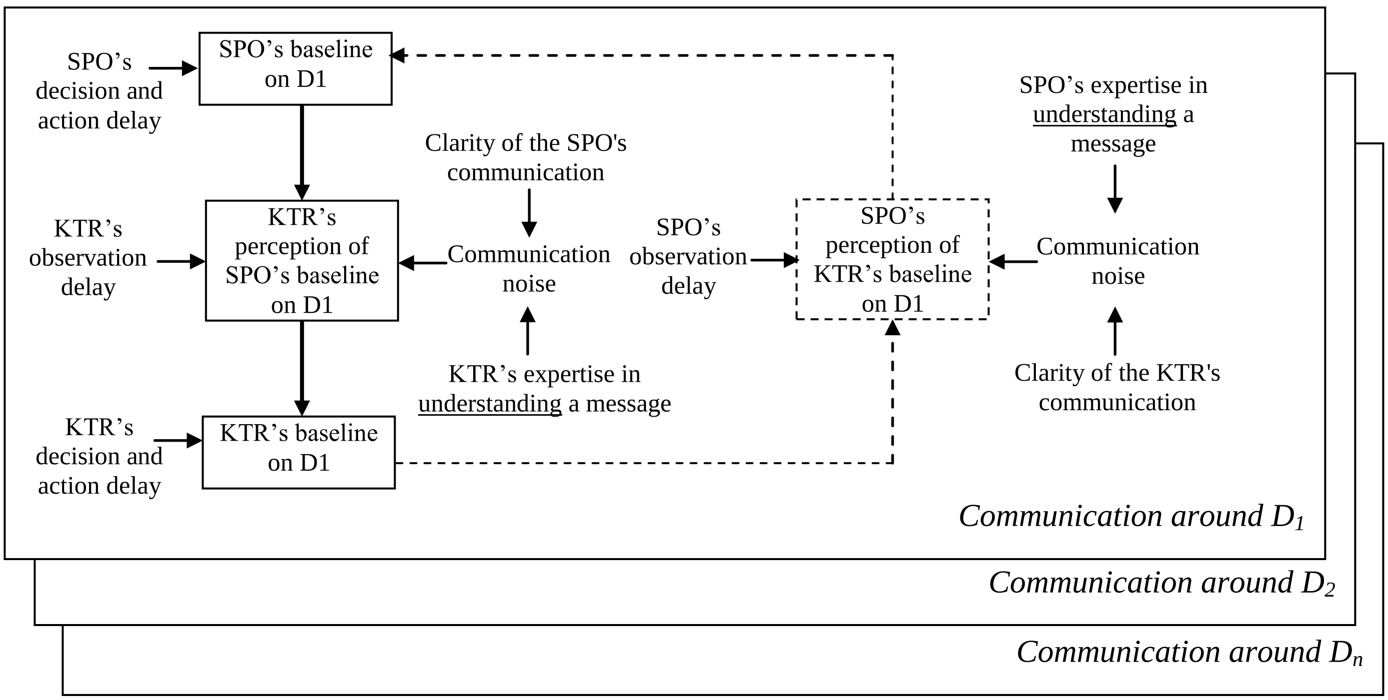


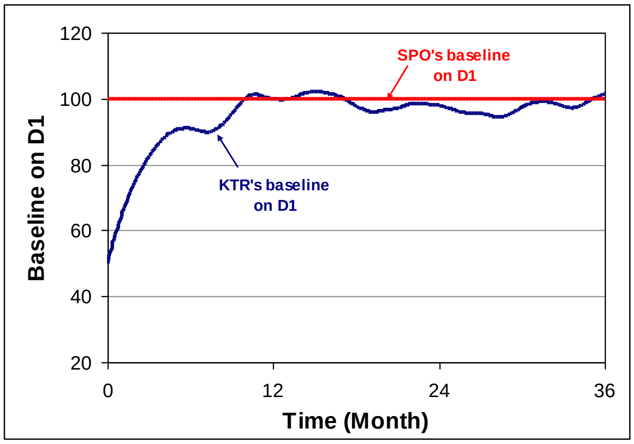
Figure 2 – A dyadic communication in a complex project

As mentioned, in reality there are multiple layers to the conceptual model depicted in Figure 2, and the SPO and KTR should pay attention to many different dimensions of the projects. We formulate the conceptual model as reported in Appendix. The model is parameterized based on the data from the interviews and associated archival data. The project time period is 36 months. The KTR and SPO start from different initial conditions (e.g., different initial understandings of the scope of work to be done), and through interactions their understandings of the program scope can become more similar and in sync—or more disconnected.

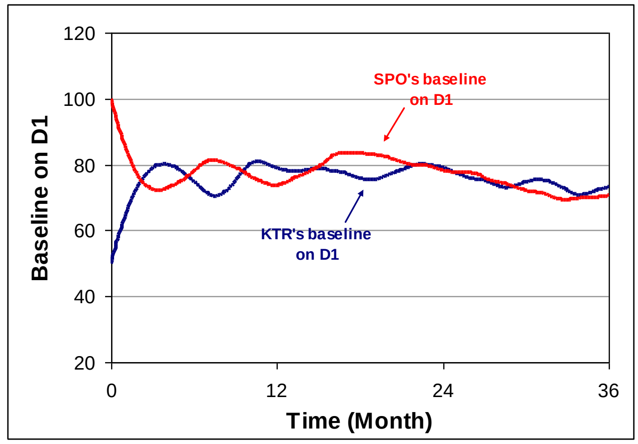
In the following, we report on simulation results under a wide range of scenarios. Because the interviews in Study 1 revealed that many concerns centered on delays (interviewees' explanations 4 and 5) and especially, decision and action delays in government's response to the contractor on proposed changes to requirements (interviewees' explanation 5), our normative analyses focuses more on understanding the effects of delays. First we present a set of base run analyses, and then we report a Monte Carlo simulation analyses on effects of decision and action delay on shared understanding.

Study 2 Results

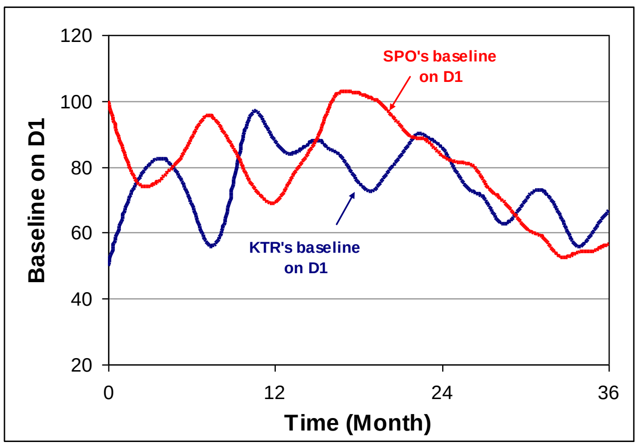
We simulated the model under a wide range of parameters, and Figure 3 shows a sample of the simulation results. In Figure 3a, we see one-way communication in a simple project. In this scenario, the SPO has a clear idea of the desired outcome from the beginning of the project, and the SPO's understanding remains unchanged throughout the project. Assuming the KTR starts from a different initial condition, with some delay, the KTR learns about the SPO's expectations and ultimately aligns its baseline with the SPO's. As the figure shows, in a simple project, assuming sufficient clarity in the project definition and communication, shared understanding can emerge through the project (the parties' baselines converge over time).



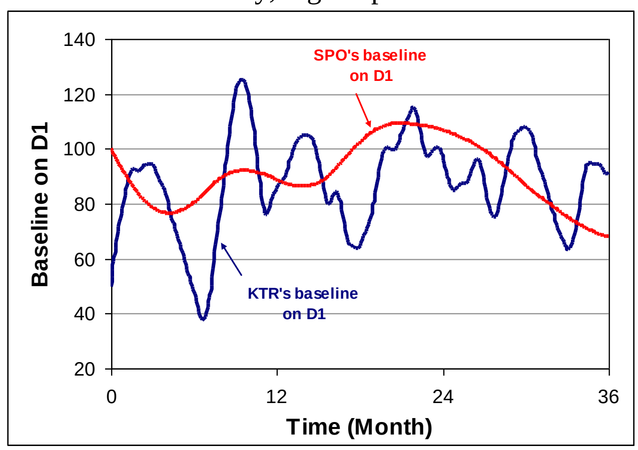
(a) “simple” project: one-way communication



(b) “complex” project: two-way communication, high clarity, high expertise



(c) “complex” project: two-way communication, low clarity, low expertise



(d) “complex” project: two-way communication, low clarity, low expertise, unsynchronized delays

Figure (3): A sample of simulation results for four different scenarios

In figures 3b-3d, we have different scenarios for complex projects in which there is two-way communication, and the SPO and KTR receive feedback from each other’s communications and adjust their expectations of the project scope during the project. In figures 3b and 3c, we represent high and medium levels of communication clarity and expertise level for the SPO and KTR with the organizations having similar delays in orienting and acting on proposed changes; in 3b there is higher level of communication clarity and expertise level, and therefore less divergence in the organizations’ understandings of D1. As we see in both cases, there is oscillation around shared understanding of D1, representing that each party is altering its understanding of project scope in response to communications from the other. As clarity and expertise decrease in Figure 3c, the

SPO's and KTR's baselines differ more during the project and many times diverge; the delta between the baselines indicates lack of shared understanding, or "disconnects."

Finally in Figure 3d, we represent a scenario in which there is a low level of clarity and expertise, similar to 3c, but in this scenario the SPO's and KTR's decision and action delays are different, with the SPO having more inertia (longer delays). As we see in this scenario, the organizations do not show signs of convergence on this specific D1 baseline. Based on our first study, we conclude that conditions represented in 3c and 3d are more common in complex governmental projects, and the risks of disconnects in shared understanding in complex projects is high.

To move toward a normative analysis and examine actions that can help improve shared understanding, we can change different parameters in the model and compare a range of baseline differences between the SPO and KTR. Some of the most important parameters in the model are decision and action delays—that is, how fast the SPO and KTR make decisions and take actions on adjusting the project scope or requirements.

The effect of a decision and action delay does not seem intuitive in the first glance. Delay can be a source of oscillation (Sterman, 2000), and we might expect that by increasing delay, the level of total divergence may increase. Further, we may expect that a player's fast response to a partner's messages (shorter decision and action delay)—as suggested by many people interviewed in Study 1—should result in faster convergence. But experiments with the model do not consistently support this notion. In many cases a longer decision and action delay does *not* necessarily lead to more divergence, or disconnects.

To make a more complete analysis of the model, we ran a Monte Carlo simulation of the model for (n=100) different random seeds for different values of decision and action delay in SPO and KTR (20 values) and for different levels of communication clarity (3 values) – a total of 6,000 simulation runs. To be able to compare the deviation in different runs, we define Average Divergence Index (ADI) as following:

$$ADI = 1/n \sum_{i=1}^{n} \sum_{t=1}^{m} (|\text{ SPO's baseline on } D_{(i,t)} - \text{KTR's baseline on } D_{(i,t)}|)$$

where i and t indices represent random seeds and time respectively, and m is the time horizon, i.e. 36 months. So, if there is a larger ADI, we have more divergence among players' baselines, and less shared understanding.

Figure 4 summarizes the results. In Figure 4 the x-axis is the KTR's and SPO's decision and action delay and the Y-axis is the ADI, indicating cumulative divergence over time. Three different lines in the graph show different levels of communication clarity.

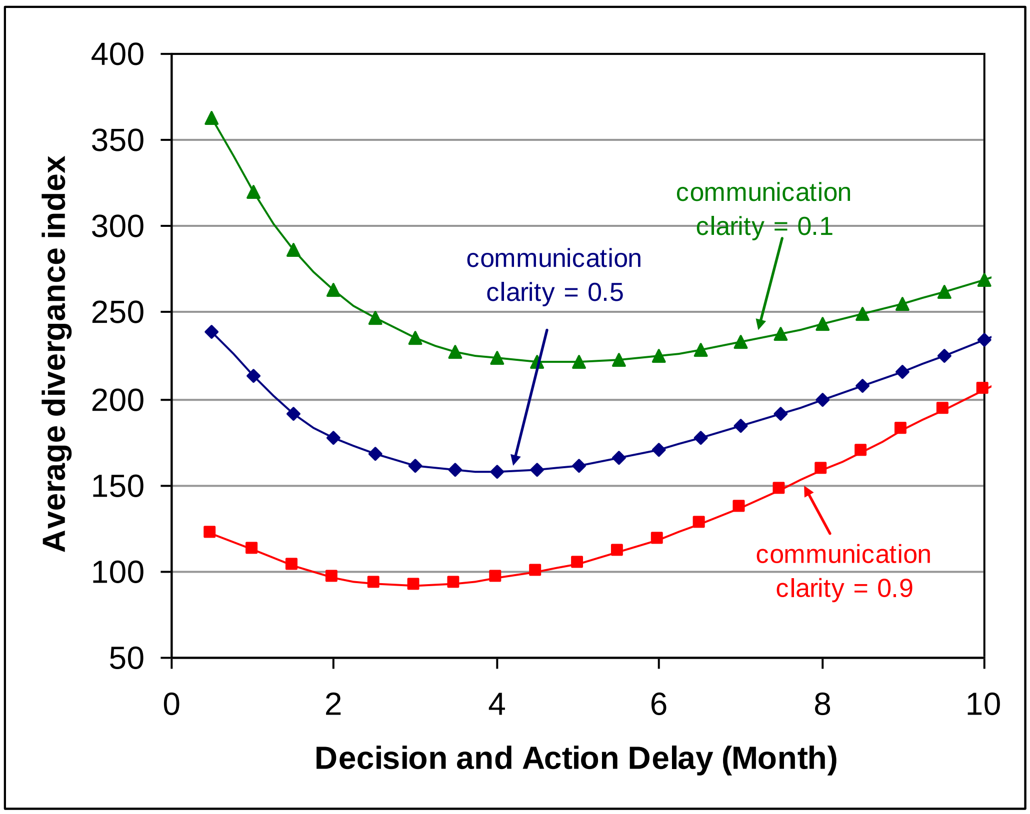


Figure 4: Average divergence index for different levels of decision and action delay and different values of communication clarity between KTR and SPO.

Note: Each data point represents results from a Monte Carlo simulation for 100 different random seeds, and the figure reports results from total of 6,000 simulation runs in a 36-month complex project.

Three major points emerge from Figure 4. First, comparing three levels of communication clarity, as we intuitively expected, we see that given a constant decision and action delay, higher communication clarity results in a lower divergence index. When communication clarity increases, that is, when players send clearer messages, players' understandings of the baseline converge much faster. Further, when players have increased ability to receive and understand the messages sent, they are able to perceive the other players' understanding and align with them. These points intensify the importance of using proper tools and techniques to increase communication clarity and expertise level. Robust boundary objects — concrete objects used to communicate and transform meanings across different boundaries of expertise, norms, and time frames (Carlile, 2002; Greer, Black, & Adams, 2006) — play a crucial rule in this respect.

Second, focusing on one of the three graphs in Figure 4, we see that, in contrast to expectation, faster response (shorter delay) does not necessary result in more convergence across the organizations. In the scenario that communication clarity is mediocre (equal to 0.5), very long *and very short* delays both result in high ADI. As we see, there is an optimal time of decision and action delay, which in the "medium communication clarity" scenario is about 4 months.

Third, the optimal delay value for decision and action is different in the three different levels of communication clarity. In the scenario in which communication clarity is equal to 0.9, the ADI reaches its minimum (and shared understanding its maximum) when decision and action delay equals about 3 months, but in the scenario that communication clarity is very low, equal to 0.1, the ADI obtains its minimum when the decision and action delay equals about 5 months.

In other words, these graphs illustrate an interactive effect between communication clarity and decision and action delay. This suggests that we cannot independently discuss whether a reduction in an organization's decision and action delay will decrease disconnects and increase communication convergence unless we also know more about the level of communication clarity for each organization.

The complex effect of decision and action delay on understanding divergence can be decomposed and explained as the result of two different phenomena which work in opposite directions. On the one hand, longer delays increase oscillation, which results in a larger gap between the players. When players respond with a long delay to what they have perceived, they may create larger gaps between their baselines. Simply put, when the KTR responds slowly to the SPO's observed baseline, the SPO might change requirements again before seeing the effects of KTR's actions. This is in keeping with the interviewees' hypothesis, that slower responses to one's partner's message are expected to impede convergence (see interviewees' explanation 5 in Study 1, and quotes from interviewees such as "the change is changed," "always in reaction mode," and "By the time it gets to the [authorizing board], the contractor has done most of the work").

On the other hand, delay helps to damp noise. Information delays play a smoothing role, and when there is noise in the system, delaying decisions and actions helps us distinguish the "real" signal from the noise. Practically, if individuals are uncertain about the importance of a particular topic, they often wait to see if it comes up again, with the assumption that an important signal will persist or be repeated. When the KTR's decision and action delay is long enough, the KTR is able to smooth the noisy signals that have come from the SPO, and understand better what the SPO is communicating, rather than changing its baseline multiple times based on unclear and ambiguous pieces of information. So, these two aspects of delays play opposite roles, creating a trade-off for acting quickly on ambiguous information. While being responsive to the other players is important and can help project progress, when less clarity exists in the communications—and there is evidence of this in interviewees' hypotheses that poor writing, inadequate documentation, and convoluted change processes cause disconnects—a fast response can be based on a wrong interpretation, resulting in more divergence and subsequently higher costs. These phenomena warn us about believing that "faster is always better" in uncertain environments and suggest more careful actions, especially when communication clarity or orientation expertise level is low.

Further, one can argue that communication clarity – in contrast to the model's assumption – is not necessarily constant through a project, but people may get to know others' languages and processes (and formats) as they continue to work together. This can lead to the idea that "decision and action" related delays can have more beneficial effects in the first stages of a project because they lead to more understanding prior to action, but as the project continues, responding faster to the other partners may offer a more effective strategy for shared understanding. In short, the "optimal" value of decision and action delay may vary dynamically as a project progresses.

DISCUSSION

We conducted two complementary studies to study failure in governmental complex projects and specifically to investigate challenges for creating shared understanding across government and contractor organizations. In Study 1, we examined the process of building shared understanding in governmental complex projects in a specific case in the aerospace industry. A qualitative analysis of the data from 30 semi-structured interviews revealed that lack of shared understanding across the government and contractor is common in complex projects. The analyses of the informants' attributed causes of lack of shared understanding centered on 5 common themes: (1) difficulties of communication across professional and organizational boundaries, (2) frequent changes in requirements, (3) lack of expertise in the government System Program Office, (4) slowness of both the System Program Office and the contractor in making sense of proposed changes, and (5) slowness in decision and action, especially in the System Program Office. Each of these causal explanations were further analyzed and divided into sub-categories to explore *why* each of them happen.

In Study 2, in order to move toward a normative analysis, we presented a simulation model of inter-organizational collaboration in complex governmental projects based on the causal themes extracted in the first study. Our normative analysis was more directed toward understanding effects of delays in the system, especially decision and action delays, due to concerns raised during interviews. The simulation results suggest approaches to increase government performance in complex projects. First, these results corroborate that communication clarity can significantly influence complex project performance. When communication clarity increases, that is, when players send clearer messages, players' understandings of the project baseline converge much faster. Further, when players have increased expertise to receive and understand the communications sent, they are able to perceive the other's understanding and align with it. These points intensify the importance of using appropriate tools and techniques to increase communication clarity and expertise level. As stated, design and use of boundary objects (Carlile, 2002; Black and Andersen, 2012) play a crucial rule in this respect. Complex projects can benefit from requiring multiple boundary objects and using communication techniques that help reveal the shared mental model of a group of cross-organizational experts (Kim, 2009).

Second, Monte Carlo analysis showed that decision and action delay have a complex effect on communication performance and, ultimately, on project performance. Our analysis revealed that decision and action delay has interactive effects with communication clarity on players' shared understanding. The results suggest that faster decision and action processes, on one hand, result in more convergence among players' understanding by synchronizing two parties' actions and decreasing oscillations (and therefore rework) across the organizations. On the other hand, as the level of communication clarity decreases, decision and action delay helps each player have a better understanding of the other party's messages by waiting for clarifications before taking actions that might not be desired and impose further rework. Further, the analysis showed that under different levels of communication clarity, there is a relatively optimal decision and action delay in which organizations approach the most shared understanding possible in a complex innovative undertaking.

This paper contributes to discussions about how to improve government performance in complex projects by examining the role of shared understanding in complex projects. Building on recent literature of complex products, we looked beyond profit-seeking behaviors across organization and studied *what else* can contribute to project failure in complex contexts. We argue that some portion of failures may be attributed to challenges in creating shared understanding, as influenced by effects of communication clarity, expertise level, and decision and action delay. In other words, the dyadic, feedback-based communications in complex projects that is inherently part of innovative projects can cause disconnects and result in failure. While current literature discusses improving the contracting performance and inter-organizational collaborations (Van Slyke, 2009), inter-changeable effects of trust and relational contracts (Gibbons & Henderson, 2012), finding common grounds for communication (Bertelli & Smith, 2010), traversing (Boland and Tenkasi, 1995) versus transcending knowledge differences (Majchrzak et al. 2012), cost under-estimation in complex products (Melese et al., 2007), complexities of performance measurement (Young, 2007), and possibilities of gaming to satisfy performance indicators without doing the actual job required by government contracts (Courty & Marschke, 2004), our study is unique in that it demonstrates that, even if all parties want to engage in a win-win collaboration, still there will be barriers for performance rooted in the feedback-based and delayed nature of communication processes within the projects. The implications of this study are that efforts to achieve successful outcomes from complex contracting can be insufficient unless attention is also paid to creating incentives, processes, and skills to increase shared understanding through the dimensions outlined here, throughout complex projects.

APPENDIX

We follow Rahmandad and Sterman's (2012) guideline for reporting simulation-based research in social sciences, depicted in the following.

I: Equations for a simple project

Equations 1 represents KTR's baseline based on their perception. Adjustment speed is 1/KTR decision and action delay. Initial value of base line for KTR is set to 50. SPO's baseline on D1 is constant (equation 2).

$$\frac{d}{dt}\text{KTR's baseline on D1} = \frac{\text{KTR perception of D1} - \text{KTR's baseline on D1}}{\text{KTR decision and action delay}}$$

(equation 1)

SPO's baseline on D1 = 100 (equation 2)

Equation 3 represents KTR's perception based on the SPO's baseline, error and observation and orientation delay. The smooth function is a common representation of information delay in differential equation modeling (Sterman, 2000). In other words, in equation 3, KTR perception of D1 is the lagged variable of "SPO's baseline on D1+SPO KTR joint communication error" with the delay of "KTR observation and orientation delay" and the initial value of "SPO's baseline on D1."

KTR perception of D1= Smooth3i(SPO's baseline on D1+SPO KTR joint communication error, KTR observation and orientation delay, SPO's baseline on D1) (equation 3)

Equation 4 is the classic pink noise generator. For more information see Sterman (2000, pp. 913-924).

SPO KTR joint communication error= (1-Clarity of SPO) (1-KTR orientation expertise level) Normal communication error (24 KTR observation and orientation delay/ Time Step) $^{0.5}$ random uniform (-0.5, 0.5, seed) (equation 4)

II: Equations for a complex project

Equations 5 and 6 represent an organization's baseline based on its perception. Adjustment speed is organization's decision and action delay. Initial value of base line for KTR is set to 50 and SPO is set to 100.

$$\frac{d}{dt}\text{KTR's baseline on D1} = \frac{\text{KTR perception of D1} - \text{KTR's baseline on D1}}{\text{KTR decision and action delay}} \qquad \text{(equation 5)}$$

$$\frac{d}{dt}\text{SPO's baseline on D1} = \frac{\text{SPO perception of D1} - \text{SPO's baseline on D1}}{\text{SPO decision and action delay}} \qquad \text{(equation 6)}$$

Equations 7 and 8 calculate one's perception based on the other party's baseline, error, and observation and orientation delay. The smooth function is a common representation of information delay in differential equation modeling (Sterman, 2000). For example in equation 3, KTR perception of D1 is the lagged variable of "SPO's baseline on D1+SPO KTR joint communication error" with the delay of "KTR observation and orientation delay" and the initial value of "SPO's baseline on D1."

KTR perception of D1= Smooth3i(SPO's baseline on D1+SPO KTR joint communication error, KTR observation and orientation delay, SPO's baseline on D1) (equation 7)

SPO perception of D1= Smooth3i(KTR's baseline on D1+KTR SPO joint communication error, SPO observation and orientation delay, KTR's baseline on D1) (equation 8)

Equations 9 and 10 are classic pink noise creators. For more information see Sterman (2000, pp. 913-924).

KTR SPO joint communication error= (1-Clarity of KTR) (1-SPO orientation expertise level) Normal communication error (24 SPO observation and orientation delay/ Time Step) $^{0.5}$ random uniform(-0.5, 0.5, seed) (equation 9)

SPO KTR joint communication error= (1-Clarity of SPO) (1-KTR orientation expertise level) Normal communication error (24 KTR observation and orientation delay/ Time Step) $^{0.5}$ random uniform (-0.5, 0.5, seed) (equation 10)

III: Parameters

The following sets of parameter values are used to create figures 3a—3d (Table A1). The values are either extracted from the interviews (specifically, delays) or are adjusted to qualitatively reproduce baseline change through a 36-month length project in aerospace.

	Figure 3a	**Figure 3b**	**Figure 3c**	**Figure 3d**
Clarity of KTR	-	0.7	0.35	0.35
Clarity of SPO	0.7	0.7	0.35	0.35
KTR orientation expertise level	0.7	0.7	0.35	0.35
SPO orientation expertise level	-	0.7	0.35	0.35
Normal communication error	50	50	50	50
KTR decision and action delay (months)	3	3	3	6
SPO decision and action delay (months)	-	3	3	1
KTR observation and orientation delay (months)	3	3	3	3
SPO observation and orientation delay (months)	-	3	3	3

Table A1: Parameter values for different base runs

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