4-1-2008

Supporting Knowledge Creation through Interorganizational Information Systems: Pragmatic Collaboration between Object Worlds

Nicholas Berente
Case Western Reserve University, nxb41@case.edu

Ryan Baxter
Case Western Reserve University, baxter@cwru.edu

芽|Sprouts Working Papers on Information Systems ISSN 1535-6078

Supporting Knowledge Creation through Interorganizational Information Systems: Pragmatic Collaboration between Object Worlds

Nicholas Berente
Case Western Reserve University, USA

Ryan Baxter
Case Western Reserve University, USA

Abstract
In pursuit of radical innovation, firms are increasingly turning to joint knowledge creating design activity between firms. The bulk of research on interorganizational systems, however, addresses the way transactional activity supports explicitly defined sequential or pooled processes. Design activity by nature requires cross-functional reciprocal processes that cannot be entirely defined in advance. We draw the notion of an â object worldâ from design theory to distinguish between collaborators on a basis other than functional groups, as cross-functional collaboration can generally be assumed in such design activity. We also draw the principles of information pooling and group interaction from the economic theory of pragmatic collaboration to address potential for inter-firm opportunism. By studying multiple episodes of collaboration in one of Frank Gehryâ s innovative construction projects, our data indicates that higher object world congruence between actors generally requires lower degrees of group interaction, but a greater amount of information pooling. Less object world congruence appears associated with more frequent interaction and lower, or more strategic, levels of information pooling.

Keywords: Interorganizational Systems, Knowledge Creation, Object Worlds, Pragmatic Collaboration

Permanent URL: http://sprouts.aisnet.org/6-4

Reference: Berente, N., Baxter, R. (2006). "Supporting Knowledge Creation through Interorganizational Information Systems: Pragmatic Collaboration between Object Worlds," Case Western Reserve University, USA . *Sprouts: Working Papers on Information Systems*, 6(4). http://sprouts.aisnet.org/6-4

Introduction

In recent interviews with 750 of the world's leading CEOs, IBM found that innovation topped their list of challenges, and 76% of those CEOS found interorganizational collaboration with partners and customers to be a key driver in innovation (IBM 2006). Academic researchers have also increasingly focused on the notion that locus of innovation is often found in the space between firms (von Hippel 1988; Powell, Koput, Smith-Doer 1996; Dyer & Singh 1998; Inkpen & Dinur 1998; Helper, MacDuffie, Sabel 2000; Van de Ven 2005). With few exceptions, however, information systems literature does not specifically address the ways in which information systems can support the joint generation of knowledge required for innovation at the boundaries of two or more firms.

In this paper we adopt a lens of pragmatic collaboration (Helper et al 2000) and the idea of "object worlds" (Bucciarelli 1992) to understand how information systems support the joint knowledge creation evident in the collaborative relationships in a context of projects that involve multiple and heterogeneous collaborating partners. We examine how Gehry Partners LLP, one of the most renowned architecture firms in the world engages in highly innovative architectural practices with its partnering firms by using advanced CAD/CAM environments. In particular we examine how variations in the objects worlds across different partners in construction projects and the principles of pragmatic collaboration (information pooling, interpersonal interaction) are addressed by using 3D modeling tools (CATIA™) and networking solutions.

The remainder of the paper is organized as follows. First we will briefly review the literature on interorganizational systems and knowledge creation, and then introduce the concepts of pragmatic collaboration and object worlds. Using data from our multi-year study of Gehry Partners, we will present three narratives representing episodes from one of their projects. From these narratives we will draw out the relationship between forms of information pooling, group interaction, and the various object worlds among the collaborators. We will conclude with implications for interorganizational systems research and infer some lessons for the design of interorganizational systems.

Interorganizational Systems & Joint Knowledge Creation

The bulk of research on interorganizational information systems has focused on transactional applications (Malhotra et al 2005), such as electronic data interchange (EDI, e.g. Cash & Konsynski 1985; Clark & Stoddard 1996; Bensaou 1997; Choudhury 1997; Mukhopadhyay & Kekre 2002; Subramani 2004). When interorganizational systems research discusses the topic of innovation, it is often in terms of diffusion of the interorganizational system (Lyytinen & Damsgaard 2001) or process innovations around transaction-oriented systems (Clark & Stoddard 1996). Interorganizational systems that support the joint knowledge creation required for technological breakthroughs, complex product development, or radical design innovations, have not been addressed at length in information system literature (with few exceptions, see e.g. Kumar & van Dissel 1996; Majchrzak et al 2000; Malhotra et al 2001; Argyres 1999).

Knowledge creation in interorganizational systems research can be associated with reducing uncertainties through better information processing in a value chain. Different forms of uncertainty can be reduced by increased interorganizational cooperation (Bensaou 1997), and by generating various interorganizational structures: pooled, sequential, and reciprocal (Kumar & van Dissel 1996). Technologies supporting pooled and sequential structures have a transactional focus, because such structures are "embedded in standard and well-specified protocols" (Malhotra et al 2005, p.150). Reciprocal structures, in contrast, support emergent knowledge processes necessary for innovation at the interorganizational level. Emergent knowledge processes are those without explicit, well-defined process structures, users, or information requirements (Markus et al 2002). "Reciprocal" interorganizational structures utilize networked technology and are theoretically feasible, but "these transactions are usually formed dynamically and often will not have a history of stable structures […] the sheer variety of reciprocal relationships would require the use of human agents and mechanisms such as trust to identify, assess, and manage the dynamically occurring risks in this situation" (Kumar & van Dissel 1996, p.294). Therefore, in reciprocal "interchanges," networked technologies can support the interorganizational exchanges, but problems occur with the management of activities surrounding these systems: monitoring, negotiation, and trust.

In contrast to this image of interorganizational human interaction being supported peripherally through technology, researchers have recently studied interorganizational knowledge-creating collaboration that is entirely mediated through technology in virtual teams that create radical and complex innovations such as rockets (Malhotra et al 2001; Majchrzak et al 2000), or stealth bombers (Argyres 1999). In such tasks, information systems act not only as a critical mediator or communication tool for virtual teams (Malhotra et al 2001; Majchrzak et al 2000), but also as means for central information processing that support individual knowledge creation around design objects, to be later shared (Argyres 1999). While communication outside of the system is deemed inevitable, especially for complicated design issues (Malhotra et al 2001), it is only through generating specific technical grammars enforced by the interorganizational system that inter-personal interactions can be minimized and design behaviors monitored and assessed through information systems (Argyres 1999). Although these systems may be intended to support sharing of many forms of knowledge, these technical features are not fully adopted and many forms of knowledge are not shared (Malhotra et al 2001; Majchrzak et al 2000), or organizations avoid the risk of opportunism by "withholding valuable information" (Argyres 1999, p.173).

Thus, it is apparent that information systems can become important for successful interorganizational knowledge creation efforts - both as a means to reduce interpersonal interactions, as well as a means to share critical product or task information. However, the amount of information shared and the level of interorganizational communication vary across applications studied thus far. Yet, the reason for this variance is not known. To address this gap in knowledge, we will new draw upon the notions of "pragmatic collaboration" and "object worlds" to identify conditions that affect the level of knowledge sharing and communication.

Pragmatic Collaboration

Research on transaction-focused interorganizational information systems has largely drawn upon the transaction-cost theory of organizations (Williamson 1985). Transaction-cost theory predicts that when explicit contracting and routinization of activity is possible, then firms will work together through the market. If however, this is not the case – when joint knowledge creation is critical to success – then firms will vertically integrate. This sort of activity requires a high degree of coordination and "unstructured technical dialog" and is one of the reasons firms exist (Argyres 1999). Yet, we find interorganizational relationships that share these characteristics to be more and more commonplace. Therefore a "non-standard" theory of the firm has been proposed to explain interorganizational "pragmatic collaboration," whereby firms engage in joint knowledge creation while at the same time seeking to control opportunism (Helper, MacDuffie, Sabel 2000). Pragmatic collaboration involves a number of practices, or mechanisms, that depend on two activities: information pooling and "face to face" group interaction.

Information pooling has the goal to both share information, and "to allow the collaborators to monitor one another's activities closely enough to detect performance failures and deception before they lead to disastrous consequences" (Helper et al 2000, p.466). The second practice, group interaction, involves frequent, synchronous group discussions, which are necessary to efficiently to create, sustain, and leverage the multidimensional knowledge capacity within the interorganizational groups.

We know that sharing information between heterogeneous interorganizational groups is rife with problems (Boland & Tenkasi 1995). These groups are not only diverse along their functional specialties, but they also vary greatly in the "object worlds" they inhabit. As a result different communities have different ways of interpreting and communicating situations. In circumstances where highly diverse groups are put together to create knowledge, they must engage in extensive sense-making to work effectively and offer means to calibrate and project their "object worlds."

Object Worlds

An individual engaged knowledge creating activity is typically some type of designer. For example, Malhotra et al (2001), Majchrzak et al (2000), and Argyres (1999) the study subjects were engineers of diverse technical specialties. In fact, in the case of joint-knowledge creating activity, a diversity of disciplines must be assumed, as this forms a fundamental reason for engaging in the joint activity. Yet, disciplines are not the only criteria by which designers differ – even designers with similar specialties can inhabit vastly different "object worlds" (Bucciarelli 1992).

An "object world" describes the unique, personal context within which a designer does design work. The object world is made up of physical artifacts, tools and instruments, as well as abstract formalisms, design principles, and methods. Object worlds are fixed in the sense that they permeate and support design activity, but while a designer learns, object worlds "are given new expression and show a different nuance from one design task to another" (Bucciarelli 1992, p.81). Incongruity of object worlds between designers creates problems with communication - even among designers of the same discipline.

When the object world perspective is applied to previous studies (i.e. Malhotra et al 2001; Majchrzak et al 2000, Argyres 1999) the engineers associated with them do not appear so diverse. Granted, they are multi-disciplinary in training, yet they are all engineers with an experience on aerospace projects. They work for large organizations, and are used to spending time in meetings and projecting their perspectives to other specialties. One might imagine their work areas even look similar – with large screen workstations running powerful computer-aided design and analysis applications, while they call over cubicle walls to ask each other occasional questions. Although they differ significantly in technical specialty, and maybe even in social background, hobbies, and any number of other areas, from an object world perspective they can conceivably be regarded fairly homogenous.

Therefore we look to Gehry Parners and their suppliers to answer whether, when the diversity of specialties is increased, the growing disparity between object worlds impacts the way interorganizational actors use information systems and associated practices to improve their knowledge sharing. In particular we ask: *how is the variance in object worlds related to the level and scope of information pooling and the frequency and intensity of interpersonal interaction in interorganizational joint knowledge creating activity?*

To begin answering this question, we present our analysis of the Gehry Partners design practices and how they used principles of pragmatic collaboration in the context of 3D use for effective knowledge creation.

Research Methodology

This study is part of a four-year, ongoing longitudinal project undertaken to study the practices of Gehry Partners from an information systems perspective. Gehry Partners represents a unique, extreme case (Yin 2003) of an organization continually engaged in new projects resulting in radical innovations. These projects continually take place through different configurations of interorganizational firms, at different locations, and across time. As presented elsewhere, Gehry's practices offer insight into the cascading nature of innovation (Boland et al 2005), high reliability organization (Carlo et al. 2004), and the relationship of boundary objects to identities and infrastructures (Gal et al. 2004). In each study we have used the practices of Gehry Partners and multiple collaborators to gain insights for IT based innovation and use of advanced tools to manage complex construction projects. As revelation is our primary goal one extreme case is deemed sufficient for sampling (Yin 2003). From this single case study we draw upon multiple episodes of collaboration that took place over the life of the project.

Over the course of the study, we have conducted 103 interviews over 20 different organizations involved with Gehry Partner projects as well as other projects in the architecture, engineering, and construction (AEC) industry. We have meticulously examined detailed practices from a number of Gehry's projects, including the Guggenheim Museum in Bilbao, Spain, the Experience Music Project in Seattle, the Millenium Bandshell in Chicago, the Bard College Center for the Performing Arts, the MIT Stata Center, and the Princeton Science Library. Our research group has engaged in weekly meetings to collectively make sense of the various data sources over the course of the last four years.

For this study, we chose to focus on Gehry's work on the Peter B. Lewis Building at Case Western Reserve University (see Figure 1). Interviews were analyzed thematically using ATLAS.ti™, a qualitative data analysis software package, and data used to construct the following narratives was collected and discussed by the authors. Narratives were jointly created by the authors to represent the totality of the data from this project, and were subject to scrutiny and feedback from other project team members to assure faithful representation.

Figure 1: Peter B. Lewis Building at Case Western Reserve University

Gehry Partners Overview

Frank Gehry designs radically new types of buildings and has been highly successful at orchestrating the creation of new knowledge in the architecture, engineering, and construction industry necessary to get them built. Gehry's designs challenge the conventional building styles undermining the material and practice assumptions associated with implementing these designs. Stated more precisely, certain aspects of Gehry's designs do not draw upon the conventional practices of builders, but rather upon the wider possibilities following the laws of physics. While architects have always been an impetus for innovative changes, Gehry's innovative changes are large enough in scale and scope to pose a risk of being infeasible for the construction given the need for cost and timing estimates, in advance. Thus, a key challenge for Gehry is how to develop new knowledge to execute his designs within the constraints of predictable cost and timing estimates. Recognizing that cost and timing estimates are built upon the assumptions about conventional materials, labor, and construction processes, designs that do not follow the conventional must not only generate new knowledge to complete the design but also generate this knowledge earlier in the design process to persuade contractors and sponsors to be willing to build the building..

In developing new knowledge to address the challenges associated with his designs Gehry must deal with a diverse and fragmented industry with a strong culture and history of coordinating their activities in risk aversive ways. Furthermore, the industry is regulated by local and regional governmental bodies that approve the building projects. This presents collaborators with not only the need for solutions to novel design challenges, but to do so within the existing AEC contextual framework and monitoring practices.

The context of this study is the design and construction of the Peter B. Lewis Building, where a mix of both local and out-of-town contractors were assembled for the project. While some of these organizations have worked with Gehry Partners in the past, many were working with the firm for the first time. We will focus on three key aspects of the building involving interorganizational relationships with subcontractors: (1) Framing and Drywall; (2)Sheet metal fabrication of the roof; and (3) Concrete from the view point of how both information pooling and group interactions took place.

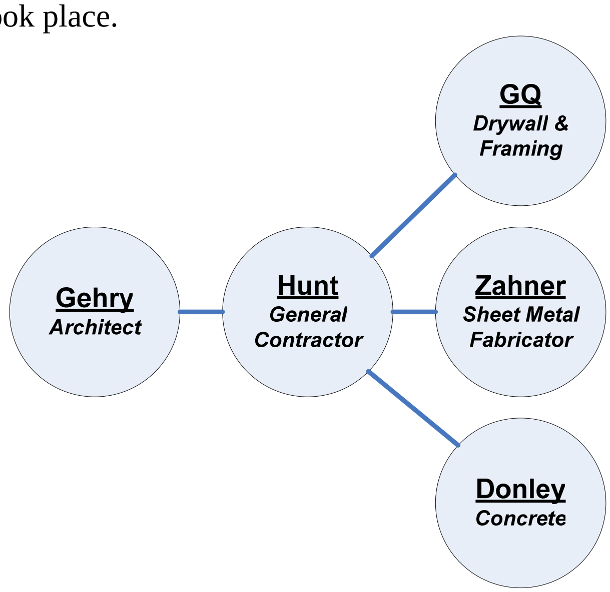

Figure 2: Gehry's interorganizational structure

Architects typically work through a general contractor to manage and coordinate the activities of the subcontractors, and Gehry Partners is no different. For this project the general contractor was Hunt Construction, an out-of-state firm that had worked with Gehry Partners in the past quite successfully. Figure 2 illustrates a simplified version of the interorganizational structure for the purposes.

Typically, construction projects are sequential in task structure. In the "preconstruction" phase, the architect completes the design, takes care of contractual arrangements with contractors and subcontractors, and prepares to construct the building. This is followed by a bidding process where subcontractors analyze piles of two-dimensional drawings and price the job based on that stack of drawings. Changes to the drawings often affect contractor costs and allow contractors to change their pricing. In the "construction" phase, the architect is more far removed, occasionally answering questions or clarifying items that were not specified, but any significant design activity is long complete. Interorganizational communication is typically done through highly standardized documents, such as literally hundreds of two-dimensional paper drawings. Often this communication can take the form of digitized computer-aided design (CAD) drawings (AutoCAD™ is the de facto standard package).

While different projects reflect this simple phase structure in varying degrees, Gehry Partners never adheres to such a linear sequence. Quite the contrary, Gehry Partners engages in what they refer to as "design assist," where subcontractors give input in the pre-construction phase. Throughout the design process, Gehry continues to collaborate with construction firms to change designs – sometime as construction is taking place. To support this continuous, multi-dimensional joint knowledge creation, Gehry requires that many contractors purchase and become trained on an advanced three-dimensional CAD system, CATIA™, and use the system as the master "document" to which they refer in construction. Use of two-dimensional drawings is highly limited, as changes are continually taking place and updating and distributing so many documents would be virtually impossible. Rather, all organizations share the same database, and the evolving digital model takes the place of standard contractual drawings. Next we will present three case summaries that illustrate mechanisms and strategies employed to foster knowledge creation in a Frank Gehry designed building both in terms of information pooling and group interactions.

Results

Following are three narratives describing the interorganizational activities associated with specific subcontractors. Each narrative is followed by a short interpretation.

Design Assist to Develop New Concepts of Internal Framing

During the pre-construction phases Gehry instituted a process involving the trades and engineers called *design assist*. While it is not unusual for engineers and building trades to consult with architects during pre-construction, Gehry's design assist process was aimed at actually evolving their current designs to reflect how they should be built, assembled, and with what materials. A major purpose of this was to improve the cost and timing predictability for the project.

GQ, the internal framing and dry-wall contractor was first brought on in the design development phase and asked to bid on and cost the framing and drywall for the building. To come up with an accurate bid they had to develop a construction technique for the type of material and how they would assemble it in according to the design.

GQ was introduced to the project by looking at 2D drawings and the 3D physical model. They recognized very early that the task was highly complex compared to the traditional methods of framing and drywall assembly and finishing. It was a type of building and work that had not been previously accomplished by them, or by others known to them.

According to Gehry Partners, withholding more sophisticated 3D representations was a strategic move recognizing that not all trades were ready to handle 3D representations of buildings. In the words of a partner of Frank Gehry's:

> …normally wouldn't want to show any computer data to somebody who does drywall because they'll just double their price. And the logic will be, well if you need all of that, this must really be hard. So there's a cultural barrier depending on where you are in the trade.
>
> (Interview with a partner from Gehry Partners)

This didn't mean that GQ did not use 3D, rather it was a carefully strategic process by Gehry to prepare them for acceptance of the technology by making it more useful.

> Any of the trades that don't have to have engineering, you have to be very careful how you present the information because the first reaction could be, this isn't gonna help me. This building must be really difficult. And there's a situation in which we don't even introduce the information 'cause we get in trouble. And we used to do that a lot in the early days. And we realized if we show it to 'em now, they're gonna see it as a problem. If we let them get, they think they're okay with that, let them get in trouble and then we'll get them out of trouble with it and they'll adopt it and that, you'll see that change during the course of a project.
>
> (Interview with a partner from Gehry Partners)

According to the GQ project manager, later they were given access to the 3D CAD model:

> …which totally changed in our mind-- everything. Because what we were trying to figure out on drawings [2D drawings] all of a sudden became more of a reality. We were shown the physical models so we could see that it was a very difficult project. But we were [initially] relying on the information in the documents to give us enough to build the job. What we did realize when we were shown the [3D CAD], we were shown how we were going to build the job. Because once you get the reality of the 3D which brings reality to the drawings, it definitely changed our perception of what we were doing and what path we were going to take to build.
>
> (Interview with Project Manager of GQ)

Based on this comment, one might be led to believe that the introduction of the 3D model provided the detail of how to assemble the internal framing system. However, the 3D model provided by Gehry did not contain all of the detail of how to assemble the framing members. On this issue a manager from the General Contractor noted:

> I mean, literally, Frank Gehry on the drywall gives the film of paint on surface, that's all he gives. He didn't give us the framing conventions. We had to go back that system up with a frame in. He told us that it had to be a 6" stud, but he didn't tell us where to put that 6" stud, and it's our responsibility to locate that stud, and to create the methods to actually physically do it in the field. And that's where a lot of our innovation, and our creation, and that was done to more than using one of these things. That was 90% of our inventive process, it was, especially in the drywall, is get the drywall form and get Ed Sellers in.
>
> (Manager at General Contractor, Hunt Construction)

The 3D model was not a full digital prototype as might be found in product development, aerospace, or automotive industries. However, 3D visualization was essential for them to design, test, and eventually decide on a framing method. It contained the necessary connections to other system components to evaluate the impact of proposing different framing methods. Initially, Gehry did provide a *framing concept* in which they suggest a way to develop the internal framing system. This framing concept, however, was not robust enough to be used in the more complex and undulating surfaces. The architectural design had suggested that the studs be bent for the curves (see Figure 3); however, according to GQ this would not be possible in the way Gehry had suggested.

Figure 3: Drywall of the Peter B. Lewis Building

Working with the general contractor and the architect, in the architect's office, they jointly came up with an approach that GQ would use for the project. The collaborative process involved working significantly in 3D CAD to understand the shapes and apply the new framing concepts being developed. Over the course of 8 months the collaboration evolved various concepts by modeling them in 3D and then doing mock-ups and tests in the field. A key aspect of this development was involving those who would eventually frame-up the building. GQ's project manager states how this process worked:

> All the binders and binders of paper went out to the field because you got to bring it back to what they're used to. And that's 2D. So I had to bring it back to them in that form. It was really something, as I would go to California, I'd spend 4 or 5 days, I'd come back and I'd have this whole group of guys on the job just starving for information, and just dragging me over to the computer. We'd email the CATIA work I did back to the job so that they could see what I did. And then they'd tell me what I did wrong, then what I did right. And then they would try to take the AutoCAD work and relate it back to what was in CATIA. It was really difficult. Very difficult. Near the end, we had a system down that was quick and efficient.

The degree of intensity devoted by Ed Sellars and his organization was unusual during this phase of the designing process. He states that:

> I have never, ever spent more than an hour in an architect's office prior to this job. And I spent 22 trips, 4 and 5 days at a time in their office. And I mean I've spent some days in there where I was in there at 8:00 in the morning and I didn't get out of there until 10 or 11 at night, working on this frame.

Ultimately, the process involved extracting data from 3D CAD to 2D CAD and then sending this information to computer numerically controlled (CNC) equipment to cut the appropriate sizes and shapes.

Interpretation of Framing and Drywall Episode

The above narrative illustrates the involvement of GQ, a sub-contractor with no previous experience in 3D CAD or on such complex projects, into Gehry's design assist process. As GQ's project manager indicates, his team is used to working with 2D drawings. They are on unfamiliar ground assisting in the design, and certainly have never used a powerful tool like CATIA™ in prior jobs. Their object world is quite different from Gehry's, and it appears that with limited, strategic information pooling, and highly frequent collocated interaction, suitable communication was achieved for a successful co-design.

What is striking about this example is the frequency of collaboration required to come up with the new framing solutions, and the strategic way in which Gehry Partners doled out access to the pooled information. This example points to a possible insight that where new interorganizational partners engage without the initial capability for information pooling, that pooling of perspectives and plans (Helper et al. 2000) is an important preliminary step. It also shows the necessity of frequent interactions physically at site as CQ did in Gehry's office.

Pooling Multiple Perspectives for Undulating Roofs: High Tolerance with 3D CAD with Smooth and Flowing Architecture

The design and installation of the undulating stainless steel roof on the Peter B. Lewis building involved the collaboration between Gehry, the architectural metal designer, Zahner corporation, and the metal envelope contractor Crown Corr, Inc. While Zahner had significant experience with Gehry, this was only the second Gehry project for Crown Corr.

Zahner, the metal fabricator of the roof for the Peter B. Lewis building has worked on over 20 projects with Frank Gehry since 1987. During this time Zahner's design and fabrication process has evolved significantly in their use of sophisticated 3D software and technology. Over the years Zahner and Gehry have benefited from one another. As Zahner has expanded his capability by striving to fulfill complex aspects of Gehry's designs, Gehry has later incorporated Zahner's capabilities in subsequent designs.

Zahner has clearly bought into the idea of having a single 3D master model of the building design. This puts Zahner and Gehry clearly on the same mental page, so to speak, in many ways.

> It's in the building industry to me, and I've stated it several times, that it's a real potential to bring the designer back in as the master builder. If he does a parametric model, then he's brought all the pieces together. And I saw how it worked on EMP, if there was ever any question, "Well how does this work?" The general contractor might say, "Well how does this interface here?" We'd immediately go to the model and see. And put layers in that either the sheet rock here interfaced with the sheet metal interfaced with the wood, and you could see it. You could see how the interface occurs.
>
> (William Zahner, Interview)

3D parametric models are inter-connected digital prototypes of the building enabling the interference checking and simulation of design changes. A single master model means that all related parties can draw upon a single source of information to input into their processes. The parametric nature of the model enables changes, hypothetical or real, to be modeled and understood more comprehensively.

While Zahner made good use of the CATIA™ 3D model to design the patterns and approach to the roof, they also had to consider that they would be handing off the installation aspect. This meant that reducing variability to make the installation easier would be a plus.

> We mainly made pieces at the end that were long that had been the cut and formed, cause we made that final transition. We simplified it. If Zahner was doing it, we would have made that a little cleaner because, but we knew that somebody else was installing it, so we made it okay, how do we make this simple and make it still look good for Frank Gehry, cause that's where your eye's gonna fall. Your eye is gonna follow those edges. So we simplified it so the cut, we just bend them in the field and then we had a curved section that we placed over the top of it splined. That's the way it was done in the field. Can't see it up close, it still looks fine.
>
> (William Zahner, Interview)

Despite the efforts for simplicity, the task was still difficult. Crown Corr manager, Greg Husarik commented on working together to figure out how to install the metal roof:

> Whenever we ran into a problem, we worked together to figure to find the solution. That was the only way to do it. It wasn't like some jobs where the architect designs it and you have to duplicate it exactly as drawn. This job was just so complicated and unlike everything else, that we had to make some things work. All in all, the architect on site was happy with what we came up with. It turned into a big love fest, partly because we've got some really good guys doing the work."
>
> (Bas 2001, Direct Quote of Greg Husarik of Crown Corr)

> Occasionally there was a dramatic "Oh my God!" when materials or sight lines didn't line up. There was little in the way of printed blueprints or documents to consult. Instead, it was back to the computer screen, back to CATIA - which was fortunately always right, never wrong, and eventually allowed for any quirks to be worked out. The alternatives could have been disastrous.
>
> (Bas 2001)

Crown Corr, was informed early by the general contractor that they would need to be familiar with CATIA™ and how to use it. Crown Corr's use of CATIA™ was required according to Hunt. Compared to traditional AutoCAD™, CATIA™ allows for very tight tolerances. Hunt further emphasized the need to be within these tight tolerances on the roof. This resulted in significant difficulty, initially, at installing the roof shingles:

> We drove tolerance so hard and had it so ingrained that when it came to the shingle installation, these guys [Crown Corr] were getting so precise about the layout of the shingle on installing it, in fact we had this two-person crew one day that got a total of four shingles put up cause they were just, and they didn't work for very long out there, but for some reason everybody just got hung up on this, you know, this method of putting the shingles on and what it realized, and what we realized is through getting a relationship with Gerhard [Gehry and Associates, Project Architect] out there, is that it was, it basically boiled down to smooth and flowing and just as long as you knew that the shingle pattern wasn't gonna unfold on you, when you got to the top and get your drainage pattern screwed up, Frank Gehry didn't care just as long as the surface laid down, it was flat and had a good trim at the edge. …What we realized is that once we got through some trial and error, put some shingles up, had to take 'em off, there was a way of being able to put shingles on the building in a very fast method.
>
> (Hunt Construction Manager)

The above excerpts illustrate the close collaboration, pooling of perspectives, to retain the balance of tight tolerances with the ideas of *smooth and flowing*. They also illustrate how the tight tolerances represented both in the 3D model and reinforced by Hunt led to some difficulties early on when the perspectives were not pooled. Another important aspect is how the Peter B. Lewis building differed from the previous project that Zahner and Crown Corr had worked on together, Gehry's *Experience Music Project* in Seattle, WA. There, by request of Gehry, all of the roof shingles were specifically designed to be different. It may have been that the precision required to interconnect the unique pieces at EMP actually increased reliance on CATIA and high tolerances moving away from the more qualitative ideas of smooth and flowing required when more of the pieces were standardized.

Interpretation of Undulating Roof Episode

The above vignette illustrates complex information pooling in several ways. First, Zahner relies significantly on the master model (CATIA™) approach to designing architecture. This allows them to understand complex interrelationships in the building components as a result of design changes or further development. Zahner and Gehry have formed an interesting interorganizational joint knowledge creation process that is more evident over the course of their relationship as opposed to one single project. Thus, as Zahner's capabilities advance, Gehry is able to both take advantage of these and push Zahner in different ways.

Similar to the GQ vignette, this example highlights the challenges with new knowledge application and refinement between the design and implementation worlds. New design knowledge developed by two organizations that have evolved together over a long time period still have to face the how to get their ideas implemented into practice where not only representational technologies are related, but perspectives and plans are based in different professional cultures and historical trajectories, resulting in challenges to information pooling leading to miscommunication and delays.

Additionally, Zahner's application of Gehry's 3D master model demonstrates further knowledge creation by Zahner that is still dependent upon the collaboration between Gehry and those that will implement the designs—Crown Corr. The master model allows for Zahner to develop ideas by simulating and understanding complex interrelationships without as much frequent interaction with Gehry. Due to their experience with Gehry's practices, and their long-standing adoption of CATIA™, one can assume that the object worlds of designers from the two firms are fairly aligned – certainly with respect to the primary design tool--CATIA™. It is therefore noteworthy to point out the very high degree of information pooling with lower collocated interpersonal interaction.

New Cross Functional Terminology for Reshaping Concrete

Donley, Inc., an engineering and construction firm specializing in concrete work was invited to the project by the general contractor, Hunt Construction. In contrast to GQ, Donley was a larger organization with significant experience engaging in pre-construction design processes in previous projects. Another significant difference between the Donley and GQ is their different functional role in the project. GQ's work with framing is likely a more flexible process that is built upon the concrete. In this project the concrete work was not only an obvious structural element, but also drove much of the undulating and unique geometric shapes. Thus, the precision and accuracy of the concrete work was critical. At the same time, the development of precision concrete required in a complex project like this was extremely difficult. As the concrete portion of the project was critical there was necessarily greater consideration of it during the early phases of a project when the design was still fluidly explored. The complexity of the project proved very difficult as the designs evolved and changed. The challenge arose from the difficulty in modeling changes and implications of structural design changes to the process of forming up and pouring concrete. A key assumption for concrete work is that concrete formwork is standardized and is intended to be reused on multiple jobs resulting in significant cost savings. The standardized formwork also uses standard and repetitive methods for set up and configurations in traditional rectilinear shapes. The complex and unusual 3D freeform shapes challenged these conventions, dismissing many of them and necessitating many customized shapes and concrete forms. Changes in a conventional rectilinear design shape can easily be accounted for without affecting the concrete form work method and processes—it becomes a simple add or subtract based on the same principle logic. However, changes in complex and unusual shapes can result in the significant rework of already unique concrete form shapes.

> The unique thing here isn't, you know, a lot of the other preconstruction we do, you're working with the 2D information. …Now when you get into an evolving design, yeah, this can evolve, but it's much easier to switch gears because it's flat, okay. Now when you're getting something that wall's evolving where they go into the model and they tweak a few things here and there, it makes a difference in what you did with formwork process and your design, cause you have to go through many different screens of grabbing information to develop your formwork, whereas with a two-dimensional project like a parking garage, yeah, so they cut this much off. We'll cut that much square area off, you know, our formwork is still pretty much the same as far as your themes and your flat table. But if you've gone to the point where you've developed this curve this way, now you change it a little bit this way or this way, you've got to go back through all the processes of extraction the points in order to do that formwork design again.

Donley did not have to alter the core concept of how concrete is shaped. Rather, their critical challenge was how to accommodate the three dimensional complexity and then translate that into a process for those working in the field (see Figure 4).

Figure 4. Concrete Geometry of the Peter B. Lewis Building

Donley was involved, like GQ and Zahner in the Gehry design assist process, but had a different interpretation of that process. They did not see their early involvement as designing, but rather as trying to solve constructability issues and determine the possibilities of concrete application given certain design considerations. This is the standard perspective that Donley and most sub-contractors carry onto their pre-construction design activity.

> The way it was set up initially, that was different, you know, it was more of a design assist, I guess that's how they termed it. But we weren't really doing any design per se, but we were kind of

> looking at some of the constructability issues that were surrounding the evolving design as it was coming out, say yeah, "we can't do that, I know we can't do this. Can we do this," you know, try to simplify some of the processes…
>
> …we were looking at the model, we were looking at 3D AutoCAD extractions during the pre-construction process, but until the model was complete and we got the actual 3D extraction through supplemental PRs and information from Hunt through Gehry that we were able to do our formwork design at that point.
>
> (Interview with Manager at Donley)

Through the pre-construction engagement Donley became aware of the complexity of the project, that the project was still evolving and that 3D representations would become essential for the concrete work—something that they earlier thought they might avoid.

> Yeah, initially we hadn't planned on using that much 3D, but as the pre-construction evolved, it became pretty clear that 3D AutoCAD and 3D AutoCAD extractions out of CATIA were gonna be needed in order to build the structure.
>
> And it was the only way to build it … not to build the entire structure, but to build all your ruled and curved surfaces. Now the straight walls and that, I mean, that 2D is fine, but building any of the ruled surfaces and curving surfaces, we definitely needed the 3D AutoCAD, and that came to light as the preconstruction process evolved.

Donley was told by both Gehry and Hunt that they did not need to adopt the same 3D software, CATIA™ that Gehry was using, but that extractions from CATIA imported into 3D AutoCAD would be sufficient. However, this decision would prove to be a significant challenge in pooling information. Using the 3D data, the engineers designed the uniquely shaped forms and methods for shimming the forms to create the appropriate curve. The placement of shims to achieve the appropriate curve was done in 3D and at points extracted into 2D printouts of the final location for the field carpenters to put the shims in place. The concrete forms are represented in detailed shop drawings which specify where the forms are place and how to make them so that they will provide the proper shape. The formwork engineer used 2D and 3D drawings with written descriptions in the formwork shop drawings. The set of shop drawings are instructions with 3D visual information as well as precise calculations.

Additionally, the formwork engineer and builders had to collaborate more frequently to clarify what was in the shop drawings. This resulted in the formwork engineer learning from those assembling the forms so that he could better design knowing the constraints in the field. As he put it those in the field would say: *"'Hey, you know you can't bend a three-quarter inch sheet of plywood that way, you can only bend it this way and this way and so forth.' And you don't know that in AutoCAD or anything when you are drawing it you just hope for the best"* (Formwork engineer interview). Field carpenters also learned to interpret and understand the 3D drawings and associated terminology so that they could share any problems with the formwork engineer when following the shop drawings. *"They learned from the drawings and they learned the lingo and the communication on it. So they could call up and say, 'hey, you know you're so many degrees off here from your coordinate.' For awhile there we actually developed a new terminology or a new communication process on the job where we educated them, and they educated us"* (Formwork engineer interview).

The shift to a 3D coordinate system from the standard 2D system was supported by new visual representations to help the field workers reestablish their processes. Insightfully, the formwork engineer recognizes that this shift was not just increasing the information flow or frequency but was actually a whole new vocabulary to convey the ideas from the design to the field. The process of working out the correct way to coordinate changes between how engineers were designing the complex shapes and how the field carpenters would utilize this information took considerable time for Donley.

> Yeah, I mean I think most of the construction industry uses 2D flat paper drawings and this was something that was by far different than anything we'd ever done before, so, we start giving a carpenter, foreman, or even your engineers on site, all these drawings with all these splines and you know there's cuts every 8 inches, on every wall and you start flipping things around and showing different views, you gotta be able to explain to these guys, we have to build it, what they're looking at, and it just took some time to be able to realize, how do I put this on a 2D piece of paper, and show 'em what they're looking at and what they need to do to build the forms.

Occasionally, the difficulty in communicating between the field carpenters and the designers resulted in the need to use CATIA™ as a visual aid for resolving misunderstandings.

> There was maybe one or two, there was a couple instances where there was something that I couldn't even describe. I couldn't put it on paper and I didn't have enough paper to explain it. So I would grab the guy, you know, I'd say, hey, I'll be back in a minutes. I'm sitting in Hunt's trailer, we're looking at the screen, and there's this little sliver of concrete that needed to grow on the edge of one of the curved walls and it was so when the brick came around the building and butted into it, and it all had to match just right for some waterproofing stuff. Anyway, there was some reason it had to be there, and there was no way for me to explain it to this guy. So I went up on top deck and grabbed Don, our carpenter foreman. I said,"man, you gotta look at this. There's no way I can explain it to you. You're just gonna have to see it for yourself." So he walked in the trailer… he's looking at this things and he's like, "do we have to do this? [laughter] Is that absolutely necessary?" And of course it was. It had to be there. Very rarely did they get into the trailer and see CATIA, but sometimes when you could not explain what was going on you had to zoom out and say, "okay Don, here's your wall, you see that little line." Then you zoom in on it and this is what it needs to do.

A major challenge faced by Donley was having accurate and up to date data via extracts from the CATIA™ model. Donley noted that many times issues that they saw in AutoCAD™, where certain details were not accurate later turned out to be because they did not have the most recent data or due to information transfer problems between CATIA™ and AutoCAD™. This led to discussions with Hunt trying to resolve the discrepancy noted by Donley with other subs and ultimately with Gehry.

> Right, if I told, you know, their [Hunt Construction] guys on site or whatever, and say, "hey, there's a problem with something not working out." We would all go in their trailer and get on the computer and pull the CATIA model up and spin it around and try and figure out what the issues was and see who was right, who's wrong.

Another apparent source of the disconnection between current and outdated model data seemed to be the ongoing design of other elements (e.g., structural steel) while Donley was working out the details for concrete. These changes had effects to the concrete or the attachments that were to be embedded within the concrete. These changes were difficult to cope with as they might result in significant redesign because of the lack of a robust concrete forming process in light of the complex structure.

Through the process Donley also discussed that the nature of communication between those in their own firm and with the general contractor was different than in other jobs.

> I don't think Donley's ever put a project engineer on site with 3D AutoCAD and every column that they pour, they need to plot, you know, in a computer and then slice it at different elevation and then talk back and forth with the engineers, you know, almost once or twice an hour

depending on where they were on the job and get them information. You're constantly radioing information back and forth.
Typically, I don't think I would have been on site… pulling information off of a computer, and turning around 3D AutoCAD extractions and printing out little sketches to give to engineers. I've got a binder of sketches three inches thick…

Interpretation of Concrete Episode

Making sense of the Donley activity is less straightforward than the other two examples. The object worlds, were quite different as in the GQ example, as were the mindsets about the collaboration. Although Donley was, in effect, engaged in a joint knowledge creating activity, they were apparently not aware of this. They were attempting to treat this project like any other, and the effect was a dramatic increase in complexity.

For example, Donley was not able to take facile advantage of information pooling with Hunt and Gehry. Rather, they relied on a cumbersome routine to translate the designs to a format that was comfortable. Even in this case, however, new practices such as the AutoCAD™ person on location were in evidence.

Another interesting point is that Donley seems to have spent far less time engaging with the architect, or at least at the architect's office. In the interview a manager at Donley mentions that, "*Most of the communication went through Hunt. We wouldn't hardly ever call the architect and get information. I mean, it had to go through Hunt so they knew what was going on.*" This last case appears to be somewhat confounding, as information pooling did not take place beyond sending translated documents back and forth, and there was no significant collocated human interaction. Whereas GQ seemed to make up for the lack of experience in pooling information in 3D CAD via pooling of perspectives and plans (i.e., frequent group interactions), Donley did not achieve such success.

Discussion

These episodes illustrate the impact of sophisticated 3D technology in a complex and innovative setting where multiple diverse professionals collaborate to create and employ new knowledge. In this study, we looked to develop a nuanced perspective of the effects of diverse object worlds (Bucciarelli 1992) in an interorganizational setting involving a high degree of complexity and dependence upon sophisticated information technologies. The object world perspective is particularly salient because it involves the act of design in relation to a context rife with artifacts – many of which are technological artifacts. In these episodes, the challenge of development and implementation of new interorganizational knowledge are apparent and met through various strategies. Using the notion of pragmatic collaboration we focus on the role of information technologies as they relate to information pooling and frequent group discussions among distinctive object worlds.

Object worlds can be incongruent, and therefore make collaboration challenging. Our findings indicate that if object worlds are highly similar, or congruent, joint knowledge creating activity is more likely to take advantage of greater and more formal knowledge pooling while requiring less collocated human interaction. This is a beneficial insight for practice, as interorganizational systems should be implemented, and associated practices prescribed, in accordance with the congruency of object worlds of the collaborators. Also, perhaps functional diversity should not be the only criteria by which interorganizational teams are assembled, as object world congruence can be another criterion.

The physical aspect of the object world is also particularly important to studies involving information technologies. Too often the IT artifact itself is treated shallowly (Orlikowski &

Iacono 2001), and similar types of systems are treated as one. The object world perspective inspires researchers to consider key differences in the way individuals interact with their systems. For example, the idea of 3D CAD can be black-boxed. However, by looking at object worlds involved in using 3D CATIA™ versus 3D AUTOCAD™ in the Donley example, we see that there can be significant differences. This focus on technology associated with designing activity is reminiscent of Bijker's (1995) technological frames, as both include artifacts as well as interpretations. The difference is in emphasis. Object worlds are personal, but can have many shared elements across a community, whereas technological frames are entirely social.

To aid in understanding the importance of object worlds in interorganizational design efforts, we leveraged key principles from the theory of pragmatic collaboration, which is an economic model that specifically addresses interorganizational innovation. While looking to optimize cross-functional knowledge-creating teams, it is important to keep in mind that the team is interorganizational, and therefore, subject to governance issues that do not apply to organizational teams. Between companies there is always threat of some sort of opportunism (Williamson 1985). In such arrangements, governance cannot be exhaustively, explicitly contracted at the outset of collaboration, and such issues must be somehow addressed during collaboration. Therefore we draw on the theory of pragmatic collaboration to guide our view of proper interorganizational arrangements both generate knowledge and control opportunism (Helper et al 2000). This is enabled through mechanisms of selective information pooling and ongoing interpersonal interaction. This does not mean that knowledge creation cannot occur without these enablers; just that opportunism is not necessarily being controlled. This may explain our Donley example. In that case, neither frequent interaction nor proper information pooling took place, and object worlds were not congruent, yet enough knowledge creation appeared to take place after some pain to satisfy the project requirements. Not only did it appear inefficient, but there was likely room for opportunism on the part of either party. While this opportunism may not have occurred, it is important to consider such possibilities when implementing interorganizational systems.

Overall, we find that by coupling the notion of object world congruence with the information pooling and group interaction principles of pragmatic collaboration, we can establish a novel view of how interorganizational knowledge creation activity can be effectively supported by information systems. Because of the radical nature of some types of innovation, firms engaged in collaboration may suffer and opportunism may creep in when information pooling is not effectively addressed. In these examples we find that information technology was used to explore and validate new knowledge possibilities, not only enable communications, store information, or coordinate and control. This highlights a more creative aspect of the role of information systems. Our findings also suggest that in professionally diverse collaborations the pooling of information via information technology cannot solely depend on a new technical grammar for design or collaboration (Argyres 1999). The construction of a collaborative grammar for communication among diverse specialties is fragmented, partial, and incomplete.

Conclusion

In this research we used Gehry Partners' interorganizational practices to gain insight into the role of information technology in joint knowledge creation between firms. We found that groups with congruent object worlds will likely require less frequent interaction during the collaboration process, but will require a great deal of standardized information pooling. For groups with incongruent frames our data indicates that interpersonal interaction will be much more significant, assuming proper control of opportunism, while information pooling must be executed in more of a strategic manner.

The study of "design" is important to management of interorganizational innovation processes, because joint knowledge creation necessarily involves design. This is quite clear in cases such as Gehry's radical architectural constructions, or on cutting-edge aerospace projects where engineers collaboratively design stealth bombers (Argyris 1999) or rockets (Malhotra et al 2001), but it can also apply to other contexts across functional disciplines. For example, effective, knowledge-creating management practices have been likened to "designing" (Boland & Collopy 2004). Therefore, we drew from theoretical work in the philosophy of design, and have introduced the idea of an "object world" to explain the personal space by which designers actively engage in designing. Congruence of object worlds is thus posited to have a significant impact on the nature of interorganizational knowledge-creating collaboration.

Also, since the topic necessarily involves activity outside of the boundaries of the firm, it is important to address governance issues when conducting information systems research. While others have discussed some governance issues (Argyres 1999; Malhotra et al 2001), we introduce the notion of pragmatic collaboration and leverage two key principles: information pooling and frequent group interaction, to describe necessary conditions for micro-level opportunism control during collaboration.

References

Argyres, N. S. "The impact of information technology on coordination: Evidence from the B-2 "Stealth" bomber." *Organization Science* 10(2): 1999,162-180.

Bensaou, M. "Interorganizational cooperation: The role of information technology - an empirical comparison of US and Japanese supplier relations." *Information Systems Research* 8(2): (1997), pp. 107-124.

Bijker,W. *Of bicycles, bakelites, and bulbs: Towards a theory of sociotechnical change*. MIT Press, 1995.

Boland, R.J. & Collopy, F. *Managing as Designing*, Stanford University Press, 2004.

Boland, R.J., Lyytinen, K. & Yoo, Y. "Path Creation with Digital 3D Representation: Networks of Innovation in Architectural Design and Construction," *Sprouts: Working Papers on Information Environments, Systems and Organizations,* (3:1), 2004, pp 1-28.

Boland, R. J. and R. V. Tenkasi "Perspective Making and Perspective-Taking in Communities of Knowing." *Organization Science* 6(4): 1995, pp.350-372.

Bucciarelli, L.L. *Designing Engineers*, MIT Press, 1992.

Carlo, J. L., Lyytinen, K. and Boland, R. J. "Systemic Risk, IT Artifacts, and High Reliability Organizations: A Case of Constructing a Radical Architecture" *Sprouts: Working Papers on Information Environments, Systems and Organizations*, (4:2), 2004, pp 57-73.

Cash, J.I. & Konsynski, B.R. "IS redraws competitive boundaries." *Harvard Business Review*, (63:2), 1985, pp. 134.

Choudhury, V. "Strategic choices in the development of interorganizational information systems." *Information Systems Research* 8(1): 1997, pp.1-24.

Theodore H. Clark, Donna B. Stoddard, "Interorganizational Business Process Redesign: Merging Technological and Process Innovation," *29th Hawaii International Conference on System Sciences (HICSS) Volume 4: Organizational Systems and Technology*, p.349, 1996.

Damsgaard, J. and K. Lyytinen "Contours of diffusion of Electronic Data Interchange in Finland overcoming technological barriers and collaborating to make it happen." *Journal of Strategic Information Systems* 7(4): 1998, 275-297.

Dyer, J. H. and H. Singh "The relational view: Cooperative strategy and sources of interorganizational competitive advantage." *Academy of Management Review* 23(4): 1998, pp.660-679.

Gal, U., Yoo, Y., and Boland, R. "The dynamics of boundary objects, social infrastructures and social identities", In *Proceedings of the Thirteenth European Conference on Information Systems*, 2005.

Helper, S., J.P. MacDuffie, et al. "Pragmatic collaborations: advancing knowledge while controlling opportunism." *Industrial and Corporate Change*, (9:3), 2000, p. 443.

IBM (2006), "The IBM Global CEO Study"
http://www-03.ibm.com/press/us/en/pressrelease/19289.wss

Inkpen, A. C. and A. Dinur "Knowledge management processes and international joint ventures." *Organization Science* 9(4): 1998, pp.454-468.

Kumar, K. and H. G. vanDissel "Sustainable collaboration: Managing conflict and cooperation in interorganizational systems." *MISQ* 20(3): 1996, pp.279-300.

Majchrzak, A., R. E. Rice, et al. "Technology adaptation: The case of a computer-supported interorganizational virtual team." *MISQ* 24(4): 2000, pp.569-600.

Malhotra, A., A. Majchrzak, et al. "Radical innovation without collocation: A case study at Boeing-Rocketdyne." *MISQ* 25(2): 2001, pp.229-249.

Malhotra, A., S. Gosain, et al. "Absorptive capacity configurations in supply chains: Gearing for partner-enabled market knowledge creation." *MISQ* 29(1): 2005, p.145-187.

Markus, M. L., A. Majchrzak, et al. "A design theory for systems that support emergent knowledge processes." *MISQ* 26(3): 2002, pp.179-212.

Mukhopadhyay, T., S. Kekre, et al. "Business Value of Information Technology - a Study of Electronic Data Interchange." *MISQ* 19(2): 1995, pp.137-156.

Orlikowski, W. J. and C. S. Iacono "Research commentary: Desperately seeking the "IT" in IT research - A call to theorizing the IT artifact." *Information Systems Research* 12(2): 2001, pp.121-134.

Powell, W. W., K. W. Koput, et al. "Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology." *Administrative Science Quarterly* 41(1): 1996, 116-145.

Subramani, M. "How do suppliers benefit from information technology use in supply chain relationships?" *MISQ* 28(1): 2004, pp. 45-73.

Van de Ven, A. H. "Running in packs to develop knowledge-intensive technologies." *MISQ* 29(2): 2005, pp.365-377.

von Hippel, E. *The Sources of Innovation*, Oxford University Press, 1988.

Williamson, O.E. *The Economic Institutions of Capitalism*, The Free Press, 1985.

Yin, R.K., Case Study Research Design and Methods, Sage Publications 2003.

芽|Sprouts
Working Papers on Information Systems | ISSN 1535-6078

Office:
Sprouts
University of Amsterdam
Roetersstraat 11, Room E 2.74
1018 WB Amsterdam, Netherlands
Email: admin@sprouts.aisnet.org

芽|Sprouts