

THE DYNAMICS OF BOUNDARY OBJECTS, SOCIAL INFRASTRUCTURES AND SOCIAL IDENTITIES

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Abstract

This paper takes a dynamic approach to understanding the nature and role of boundary objects by examining them in relation to the social infrastructures within which they are embedded and to the social identities of the groups that share them. We present a case study that describes the introduction of 3D modelling technologies into the AEC industry and the changes that consequently occurred. Based on the case study we suggest that boundary objects are used not only as a translation device, but also as a resource to form and express social identities. We further suggest the occurrence of a dynamic process whereby changes in boundary objects enable changes in social infrastructures and social identities in one group. These changes, in turn, create the conditions for change in bordering groups through shared boundary objects and boundary practices.

Keywords: Boundary Objects, Social Infrastructures, Social Identities, Organisational Change.

1 INTRODUCTION

Information technology is increasingly being used to support knowledge work and collaboration among individuals from different communities of practices, and the notion of boundary objects has emerged as a useful conceptual device to study its role. Issues such as representing knowledge and bridging conceptual differences among various social contexts have been central concerns in that regard (Boland & Tenkasi, 1995). Boundary objects are abstract or physical artefacts which reside in the interfaces between organisations and have the capacity to bridge perceptual and practical differences among diverse communities in order to reach common understandings and effective cooperation (Henderson, 1991; Karsten et. al., 2001). Thus, boundary objects have been conceptualised as a basic condition for the emergence of a mutual semantic foundation on which meaningful communication can take place among different social entities such as organisational functions or groups of professionals (Star & Griesemer, 1989; Bowker & Star, 1999; Carlile, 2002).

Past work on boundary objects has focused on their role as *translation devices* that mediate two or more social communities. According to Star and Griesemer (1989), certain artefacts are flexible enough to accommodate different interpretations emanating from the various social groups, yet robust enough to maintain a common identity across all social contexts, thus allowing translation to take place across the boundary. This theme is evident in the work of various authors all demonstrating the occurrence of translation in different contexts (e.g.: Carlile, 2002; Henderson, 1991; Ackerman & Alverson, 1999; Yakura, 2002).

However, for the most part, past research on boundary objects has not examined the internal dynamics of interacting social communities and has implicitly assumed that social communities and the boundary objects they employ do not change over time. In part, this is because the emergence and use of boundary objects have mostly been examined in a context of relatively stable settings and/or for short periods of time.

In this paper, we propose to take a more dynamic approach to understanding boundary objects by examining their relationships with the *social infrastructures* within which they are embedded and with the *social identities* of the groups that share them. Doing so helps situate boundary objects in a rich, practical context, thereby contributing to a better understanding of their nature and dynamics.

In this study, we focus on the role of IT artefacts as boundary objects. Due to their inherent ability to embed complex computational and modelling capabilities and their interpretive flexibility (Bijker, 1995), IT artefacts prove to be particularly interesting boundary objects to study. Communities imbed technology into their working practices and into their group and professional projects (McLaughlin et. al., 1999). These incorporations of technology take many forms and involve diverse evaluations and attributions of meaning. Although it has been acknowledged that technological artefacts can be used as vehicles to communicate among diverse groups (Carlile, 2002), past studies on IT artefacts, as boundary objects, have not examined their role in the dynamic changes of social identities and social infrastructures among interacting organisations.

The limited research that has looked at boundary objects over time and has taken into account the nature and dynamics of the groups that share them led us to an inductive case study that aimed to explore the relationships among boundary objects and the social identities and infrastructures of the groups that share them, during a process of inter-organisational change. The research setting was the Architecture, Engineering and Construction (AEC) industry. During our study (2002-present), the AEC industry has been undergoing significant technological changes (the introduction of three dimensional (3D) modelling software) and changes in some of its actors' IT

boundary objects, which are interrelated with changes in their social infrastructures and social identities.

We found that boundary objects are used not only as a translation device that enables communication among diverse groups but also as a resource by groups to symbolically form and express their social identities in a predominantly relational process that takes place in the *interface* - an area where social infrastructures overlap. The enactment and negotiation of social identities is a process that unfolds through the engagements of social groups in mutual *boundary practices*. Conceptually, these practices take place in the interface, which is populated by boundary objects that both support and are supported by boundary practices. We further found that boundary objects are part of an ongoing process whereby changes in boundary objects enable changes in social infrastructures and identities in one group which, in turn, create the conditions of possibility for change in bordering groups when engaging shared boundary objects and practices.

In what follows, we first review the literature on boundary objects. Second, we explain the theoretical constructs we use in the paper. Third, we introduce a case study from the AEC industry. Fourth, we put forth a model based on the case study. Fifth, we present a discussion and finally we identify contributions, suggestions for future research, and limitations.

2 BACKGROUND: BOUNDARY OBJECTS IN THE LITERATURE

The notion of boundary objects was first introduced by Star and Griesemer (1989), who described the attributes of boundary objects that enable them to serve as translation devices: they inhabit several intersecting social worlds and satisfy the informational requirements of each; they are weakly structured in common use and become strongly structured in individual-site use; and they have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable and function as a means of translation. They conclude that the creation and management of boundary objects is a key process in developing and maintaining coherence across intersecting communities (Bowker & Star, 1999).

The concept of boundary objects has been subsequently applied in various contexts such as design teams (Henderson, 1991; Henderson 1998; Subrahmanian et. al., 2003), new product development (Carlile, 2002), accounting systems (Briers & Chua, 2001), production and manufacturing systems (Garrety & Badham, 2000; Karsten et. al., 2001) and implementation of information systems (Yakura, 2002). These studies have expanded the original conceptualisation of boundary objects by adding a variety of distinctions. For example, Garrety and Badham (2000) distinguished between primary and secondary boundary objects in socio-technical projects, the former being the technology itself – the material artefact around which activity is organized, and the latter being other physical or abstract entities that enable communication across social communities (e.g. contracts). Brier and Chua (2001), on the other hand, distinguished between ideal and visionary boundary objects. Visionary boundary objects are conceptual in nature and therefore cannot be argued against (e.g. institutionalised organisational “best practices”). Finally, Carlile (2002) distinguished among different types of boundaries – syntactic, semantic, and pragmatic - that require different types of boundary objects. He argued that as novelty of the situation increases, organisations will face more pragmatic boundaries and they will need boundary objects that allow them to see the consequences of social interactions with other social groups. Thus, Carlile anticipates that boundary objects may be dynamic, but does not elaborate on the change process.

Different artefacts in different contexts have been studied as boundary objects. For example, Yakura (2002) looked at timelines (i.e. a graphical representation of a set of temporal units in the lifetime of a project) as boundary objects, and demonstrated their ability to reconcile diverse socially constructed temporal arrangements. Henderson (1991) emphasized the role of visual representations as boundary objects in the world of design engineers. Karsten et. al. (2001) studied the role of boundary objects in the process of perspective taking (Boland & Tenkasi, 1995). Wenger suggested that boundary objects can be used as a means to bridge across boundaries between communities of practice in order to enhance inter-organisational learning activities (Wenger, 2000). Finally, Subrahmanian et. al. (2003) discussed changes in design and manufacturing teams and the consequent affects they have on boundary objects. They claimed that changes disrupt common grounds among organisations and therefore open a debate on the role of existing boundary objects, but fall short of exploring the dynamic process by which boundary objects relate to social infrastructures and identities.

Although the types and use of boundary objects have been examined in a variety of organisational and social settings, most research on boundary objects has examined them in a context of relatively stable settings and/or for short periods of time. A few exceptions hint at the potential for dynamic change in boundary objects, but do not explore that dynamic process. In addition, research on boundary objects has not explored the social dynamics within interacting groups, or the changing social identities and infrastructures that are associated with dynamic boundary objects. In short, the relationship between social infrastructures, social identities and the creation and maintenance of boundary objects has remained largely unexplored.

Building on these gaps in the literature, we conducted an inductive case study which indicated that boundary objects not only serve as translation devices, but that they are also used as a resource to form social identities in a primarily relational process that takes place in the interface between groups. The study also demonstrated that boundary objects are an immanent part of a dynamic process in which changes in social infrastructures and identities in one group cascade into bordering groups.

3 THEORETICAL CONSTRUCTS

3.1 Social infrastructures

Social infrastructure refers to a contextual background for practice and thought (Star, 2000). A well functioning infrastructure is in the background in the sense that it remains invisible and undisputed as long as breakdowns do not occur. It is contextual because it serves as an infrastructure only in relation to organized systems of practices and meanings, so that what seems natural and taken for granted for members of one community may acquire different meanings and possibly seem artificial and foreign to members of another.

Social infrastructures embody social institutions that have their own trajectory, and meaning systems that are attached to them. That social institutions have their own trajectory implies that when activities are repeated frequently they tend to be cast into a pattern and performed recurrently in the future as part of a routine and taken for granted way of doing things. Thus, as institutions gain ontological independence they chart courses of action and indicate particular actors that are expected to perform them. As actors are inducted into a social infrastructure and its constituting institutions, they go through a process of socialisation which entails the internalisation of role-specific knowledge and language, values and semantic fields that facilitate routine sense-making and interpretations and enable knowledgeable conduct within an institutional field.

Social infrastructures entail a stream of ongoing practices and concepts which hold particular meanings to members of a community. Over time the association of specific practices or concepts with specific intents, or the recognition of certain practices and concepts as expressing certain meanings, becomes taken for granted and is no longer reflected upon, at which point it recedes into the background and becomes part of the infrastructure. Then it serves as a basis on which new meanings and practices are constructed.

3.2 Boundary objects

Boundary objects are part of the social infrastructure. They are represented in tangible occurrences in the world. By that we do not mean that they necessarily have a material manifestation but rather that they constitute a phenomenon to which people refer and in relation to which they construct meanings. However, boundary objects are unique because they spread across two or more social infrastructures. They are an infrastructural phenomenon that is shared by members of more than one community in the course of their interaction. Therefore, they are located at the interface of two or more social infrastructures, a region where one infrastructure starts and another ends¹.

Boundary objects have one objective manifestation. That is, they are embodied in a specific artefact (physical or conceptual) which is recognizable as such to members of more than one community. However, the meanings that are constructed in relation to boundary objects differ across communities (this illuminates the contextual nature of the infrastructure). This is because boundary objects are supported by and interpreted in light of different infrastructures that get produced over time by the interacting communities.

3.3 Social identities

In this paper we adopt a relational approach to understanding social identity. This approach suggests that a group derives its meaning and identity from the changing positions and roles that it plays within a social interaction. The latter, seen as an ongoing, dynamic process, then becomes the focus of analysis (Emirbayer, 1997). Identities are not assumed as independent existences present a priori to any relation. Instead, identities are formed within the relations that are predicated of them (Cassirer, 1953).

Thus, we accept that identities are not unified but rather fragmented and multifaceted; never singular but multiply constructed across different, often intersecting, practices, and discourses; and are constantly in the process of change and transformation (Hall, 1996). As Margaret Somers and Gloria Gibson point out, “While a... categorical approach presumes internally stable concepts...the [relational] approach embeds the actor within relationships...that shift over time and space...The classification of an actor divorced from analytic relationality is neither ontologically intelligible nor meaningful” (1994, p.65, 69).

Accordingly, we maintain that social identities are representations of the group-in-context, and are defined not only based on similarities among group members and on shared experiences, but also in relation to and through differentiation from those without. Therefore, as the nature of the ‘other’ constituting the comparative frame of reference changes, so too must the meaning of the relevant groups.

¹ An interface is a dynamic conceptual construct rather than a stable concrete one. Examples are: communication between a customer and a company through a website, the work of a translator, or crossing time zones. In all these examples boundary objects will be used. E.g., a website in the first example, a dictionary in the second one, and a watch in the third.

Finally, the approach we take posits that social identity is best understood as a verb rather than a noun. Social identities are an ongoing enactment that takes place in the interaction between groups. This interaction is dynamically constituted by the engagement of groups in mutual practices and discourses.

4 EMPIRICAL LENS: VIGNETTES OF BOUNDARY OBJECTS SOCIAL INFRASTRUCTURES AND IDENTITIES IN THE AEC INDUSTRY

To explore the relationships of boundary objects, social identities and social infrastructures we conducted a case study in the AEC industry. The latter is an appropriate setting for this study because of its distributed and dynamic nature which requires cooperation among diverse actors for the successful completion of construction projects, and therefore necessitates the use of boundary objects. Further, each project witnesses a new configuration of actors and resources and thus represents a new composition of perspectives, practices, languages and expertise.

Effective collaboration in large-scale construction projects requires efficient management of information flow and skilful coordination of group activities. This is particularly important in the Architecture, Engineering and Construction (AEC) industry, where the parties involved in the design and construction process are necessarily multidisciplinary and represent diverse design, contracting and supply firms. Participants in a construction project typically work independently while making decisions that inevitably affect the other participants in the construction process. Hence coordination and communication are a central component of all major AEC endeavours.

The observations that follow are based on over fifty interviews which were conducted over the course of the last three years. We interviewed numerous stakeholders in the AEC industry in the United States in an effort to examine the dynamics of organisational change and innovative activities that occurred as digitised, three dimensional (3D) modelling technologies were introduced into the industry by architect Frank Gehry (Boland et. al., Forthcoming).

In this paper, we focus on one general contracting company, Hoffman Construction Company, and examine how their social infrastructure, social identity and boundary objects have changed in a dynamic process of reciprocal adjustments. Our first meeting with Hoffman Construction Company was in December 2003, when two of us visited their offices in Seattle, Washington. To date, we conducted eight interviews with two Hoffman employees: two interviews with Doug Wynn, a VP at the company, and six interviews with Dale Stenning, a senior project manager. Two of the six interviews with Dale Stenning were conducted during two additional trips that one of us made to Hoffman's offices. All other interviews were conducted over the phone.

Normally, the responsibility to oversee the effective coordination and cooperation among the various stakeholders in a project lies on the shoulders of the general contractor. The general contractor receives the contract documents from the architects and manages the communication and coordination process on behalf of the owner of the building. The contractor is in charge of managing communication channels among the different subcontractors and of mediating communications between the subcontractors and the architectural team. The contractor is also responsible to manage the process of translating the architect's contract documents into detailed drawings for subcontractors and eventually the shop drawings for the material fabricators.

The three vignettes below illustrate the changing dynamics of interactions among the various actors in Hoffman's projects in three different points in time. They depict the changing nature of Hoffman's social identity and social infrastructure when they change their use of boundary objects as the AEC industry moves from a 2D paper-based practice to a digitised 3D-based practice.

The first vignette describes Hoffman's social identity and infrastructural practices prior to using 3D modelling technologies. The second vignette demonstrates how organisational changes instigated by one organisation (Gehry Partners, LLC), cascade to interacting organisations through mutual boundary objects (3D digitised representations), and how social identities and infrastructures change as a result. The third vignette shows how Hoffman Company's social identity and infrastructure continue to evolve when it partakes in a project where different kinds of interactions among the stakeholders reshape the use of boundary objects.

4.1 The Process Manager: Hoffman Company prior to using 3D

Before using 3D modelling technologies, Hoffman Company has traditionally used 2D computer-aided design (CAD) tools in its construction projects. In the design and construction world, a substantial amount of communication takes place via 2D, CAD-produced visual representations and 2D paper-based representations, which serve as primary boundary objects (Henderson, 1991). In a 2D environment, Hoffman managed the project in a sequential manner. 2D paper-based contract documents are delivered to Hoffman Company from the architect. The documents specify performance and quality requirements of the building and physical properties of the architects' design intent. Many of the systems that must be included - mechanical, electrical and structural - are shown schematically, but not in elaborate detail. Hoffman distributes these documents to the different subcontractors that are involved in the project. The subcontractors submit back to Hoffman the information associated with their proposed product, which entails specific work plans and shop drawings. The latter are detailed depictions of the manufactured items that go in the building and the systems that tie into them. These shop drawings, and not the contract documents, become the blue prints used for building. Hoffman Company then has to make sure the shop drawings are in compliance with the contract requirements and then forwards them to the architect for approval. When the drawings are approved by the architect, they are sent back to the subcontractors that can begin their work. The coordinated shop drawings process then begins. Since the contract documents are very schematic and do not specify the construction process, it remains unclear which components of the building need to get built first. In principle, each subcontractor wants to be the first to lay its equipment and product so that they serve as a standard for other subcontractors. In reality it is a 'wild west' situation. For example, who ever provides Hoffman with their shop drawings first, has a chance to set the standard. However, Hoffman Company tries to structure this procedure by setting up meetings in an effort to regulate the process.

In a 2D-based project Hoffman Company is situated at a central node in the system composed of the architect, the subcontractors and itself. Much like a poker dealer, it sits at a table as each party lays out their cards for the construction process. Each player keeps their proprietary information to themselves and tries to negotiate the sequence of construction and the location of their components for their own benefit.

4.2 The dispersed collaborator: Using 3D modelling technologies with Gehry's Company

In the late 1990's, Hoffman Company was involved in the construction of the Experience Music Project (EMP) in Seattle, which was designed by Frank Gehry. Gehry is famous for his exceptional designs such as the Guggenheim Museum in Bilbao Spain and the Disney Concert Hall in Los Angeles. These unique buildings are designed using 3D modelling software, CATIA. Gehry's first project using CATIA was a large fish sculpture for the Barcelona Olympic Games in 1992. The EMP project was one of the first Gehry projects to use 3D representations as contract documents, and to insist that the main subcontractors adopt CATIA.

Hoffman Construction was the construction manager for EMP, and Dale Stenning was the Senior project engineer. He described the work on EMP as a top-down process. The architect imposed CATIA 3D representations on Hoffman and on the construction team. Structural and mechanical engineers, prime subcontractors, and Hoffman, all had to learn how to use CATIA in one way or another. They were all influenced by it and had to absorb it. As a result, Hoffman Company's typical role as a general contractor markedly changed. Instead of being a 'poker dealer' and managing a highly linear and structured communication process, Hoffman's presence and role in the project became highly dispersed.

The use of 3D models created a much more tightly coupled and interdependent system composed of architects, contractors, clients and constructors. In this system the architects play a more central and involved role than in a 2D representation-based process. The 3D models are created by the design team and serve as the central component around which construction efforts revolve (instead of the shop drawings that are produced by the subcontractors, in a 2D-based process). However, since most of the subcontractors are not familiar with the CATIA system, CATIA workstations and operators were embedded in them, and paid for by Hoffman. This is a very unusual situation where the general contractor has de-facto employees in the subcontractors. Usually the two parties maintain a clear separating line between them. But on the EMP there was no clear division.

Although the 3D models were produced by Gehry Partners, their development was a collaborative effort in which both Hoffman and the subcontractors took part. Usually, due to liability issues, the general contractor prefers not to 'touch' the contract documents and rather just shuffle the cards, deal them out and manage the sequence. But on EMP, Hoffman and the subcontractors added information to the 3D models to take them from schematics to construction documents. In that sense, Hoffman Company and the subcontractors were more involved in the process that they normally would be.

4.3 The Knowledge Broker: Hoffman after the 'Gehry experience'

After the EMP project, Hoffman Company was involved in the construction of the Seattle Library which was completed in 2003. Here, again, Hoffman faced a new situation. The building was geometrically complex, and the architect was another international "star", Rem Koolhaas, who had also used 3D modelling technologies in designing the structure. However, due to liability issues, the architects refused to share the 3D models with Hoffman or the subcontractors. They were only willing to release a limited number of models and even then it was done on a "use at your own risk" basis. Therefore, all official communication between the architects and the other participants in the project was 2D and paper based. However, because of the complex nature of the building and the fact that the work environment was predominantly 3D in nature, Hoffman Company had to step in and create its own 3D models to enable construction.

Dale Stenning was again the Hoffman senior project engineer, and he commented a number of times that Hoffman took some lessons learned from the EMP project and implemented them with their subcontractors on the Seattle Library project. That is, Hoffman was much more proactive in its efforts to create a tightly coupled system to enhance collaboration among the subcontractors. However, it was done more efficiently than on the EMP, since here nothing was imposed on the subcontractors. In fact, unlike the EMP, Hoffman made a strategic choice to recruit key subcontractors (Glazing, Steel, Plumbing, Heating and Cooling) who had prior experience with using 3D modelling technologies in their own practice.

Another indication of Hoffman's proactive conduct was the 3D AutoCAD environment that they set up with which all the subcontractors' proprietary technologies could interface. Thus, the AutoCAD platform served as a central translation device which mediated all computerised

communication. The use of 3D models enabled Hoffman to create a collaborative project management context among subcontractors whose interests are often conflicting with each other. It was primarily because in a 3D environment, subcontractors are able to ‘see’ potential consequences of actions prior to taking them. This can potentially lower risk and cost for the subcontractors because the ‘unknowns’ are less looming.

Further, to enhance communication with and among the subcontractors, Hoffman did extensive surveying work on the project. Usually, the general contractor does some surveying work to provide all the subcontractors with a basic x, y, z, grid that they can measure off of. But on complex projects like the Seattle Library, there is so much more detail to the layout process that it is not enough just to give line and grid information. So Hoffman did a lot of detailed surveying work and distributed out the information to the different subcontractors, helping them to set the layout to their installed components.

Playing such a proactive role in the construction process was an opportunity for Hoffman Company to create a vision that was consonant with the architect’s and motivated the subcontractors to collaborate with them and with each other. In that role, Hoffman brought more knowledge to play and as Dale Stenning put it, was able to act more like a knowledge broker than a poker dealer, resulting in different social dynamics among the project team members.

5 A MODEL OF DYNAMIC RELATIONSHIPS AMONG BOUNDARY OBJECTS, BOUNDARY PRACTICES, SOCIAL INFRASTRUCTURES AND SOCIAL IDENTITIES

Based on the three vignettes we propose a model that describes the dynamic interplay among social infrastructures, boundary objects, boundary practices, and social identities of interacting social groups (See figure 1). The black arrows in the figure connote that the constructs in the model are related to each other in a reciprocal manner rather than a causal one. Below, we explain the relationships among the key constructs in detail.

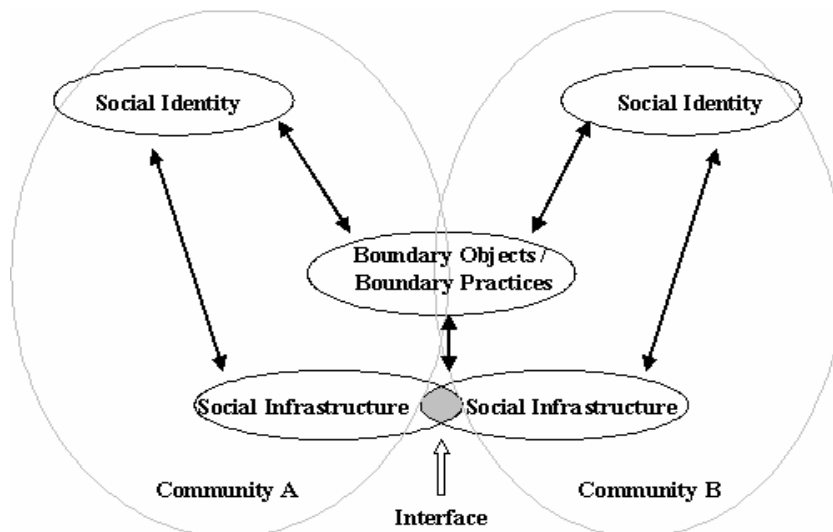


Figure 1. The dynamic relationships of boundary objects, boundary practices, social identities and social infrastructures

conceptual area where at least two infrastructures meet), and therefore always involves at least

Boundary objects, boundary practices and social identities -

Communities establish and express their social identities by using boundary objects that support and are supported by mutual boundary practices.

The ongoing enactment of boundary practices provides the context for the construction of relational social identities.

This process takes place in the interface (a

two communities. However, communities also use boundary objects and engage in boundary practices in ways that are consonant with existing social identities. Therefore, the relationships among boundary objects, boundary practices and social identities are reciprocal.

Social identities and social infrastructures - Social identities are also shaped through participation in the social infrastructure and the creation of a mutually constitutive set of institutions and related meanings that are attached to them. At the same time, social infrastructures are continually formed by recurring activities which are a manifestation of social identities. Therefore the two constructs are tied together in a reciprocal relationship.

Boundary objects, boundary practices and interfaces - Boundary objects are embedded in the interface. They are represented in practices and artefacts that make up the social infrastructures of different communities and are rendered meaningful when the communities engage in boundary practices (conducted in reference to one another). In that sense boundary objects are enabled via ongoing boundary practices. However, boundary objects also enable boundary practices. Their inherent vagueness is what makes possible the maintenance of ongoing collaborative relationships among communities even in the absence of an agreed upon set of shared meanings.

The constructs that make up our theoretical model are woven together in such a way that a change in one will result in changes in the others in a dynamic process that crosses organisational boundaries. For example, let's say that a new information system is introduced into organisation A, to replace an old system that supported key processes in that organisation's daily functioning, thereby changing its social infrastructure. As a result, organisational practices and work routines change as well. This might change the manner in which organisation A engages with organisation B, and therefore, changes the interface between them. In other words, the new information system could alter boundary practices and/or boundary objects that are shared by the two organisations. The changing patterns of interactions between organisation A and organisation B then change the conditions for the ongoing enactment of their social identities, enabling new patterns of identities to emerge. These new patterns of social identities that were enabled by mutual boundary objects and boundary practices then cascade into organisation B's social infrastructure (institutional practices). This, in turn, could change the way in which organisation B interacts with organisation C, thereby enabling further changes in social identities.

Our theoretical model reflects two important implications that arise from our case study. First, boundary objects are used not only as a translation device to bridge informational and practical gaps between communities but also as a resource to form and inform social identities. This process involves changing patterns of boundary practices and interfaces. Second, boundary objects are part of a dynamic system whose elements are bound up together in reciprocal relationships. When change occurs in one of the elements it will carry over to the others. These changes cannot be accommodated within a single organisation. Transformations in one organisation will cascade to neighbouring organisations through joint boundary objects.

6 APPLYING THE MODEL IN THE AEC INDUSTRY

The three vignettes above demonstrate the reciprocal dynamic relationships among the key constructs shown in figure 1. Prior to working with Frank Gehry, Hoffman's social identity reflected a traditional construction management company, defined in part by its use of 2D drawings as boundary objects and its ability to draw on infrastructural standard industry practices. The use of 2D boundary objects in conjunction with boundary practices such as sequentially managing communication channels between subcontractors and architects, constituted the interface between them which served as the backdrop for the ongoing enactment of Hoffman's social identity as the process manager.

However, this social identity began changing as Hoffman began interacting with Gehry Partners. As mentioned, Gehry Partners itself went through major organisational changes when it incorporated 3D tools into its own practice. When these tools were used as boundary objects on the EMP, the changes within Gehry Partners cascaded to other organisations that shared the boundary objects with them. As we saw, the use of 3D tools as boundary objects by Gehry Partners changed the pattern of boundary practices that constituted the interface between them and Hoffman. This, in turn, disrupted Hoffman's ongoing and taken-for-granted infrastructural knowledge and practices, and changed the conditions for the enactment of their social identity. In other words, Hoffman was no longer able to draw on 2D boundary object to form its relationships (i.e., its boundary practices) with the architect and subcontractors in a way that would reaffirm its 'process manager' identity. The new 3D boundary objects fundamentally changed the interaction patterns that constituted the interface that was shared by all the involved actors. The previously prevalent linear-sequential process was reshaped to a much tighter, collaborative system. In this system, traditional organisational distinctions collapsed, organisational boundaries blurred and, consequently, existing social identities were transformed. Rather than having a distinct, and somewhat removed, position in the construction process (as was the case in a 2D-based process), Hoffman now played a much more involved role, manifested by having its own CATIA operators embedded in the subcontractors, and by taking a hands-on approach with the 3D models that were produced by Gehry.

Whereas changes in boundary objects were the main initial instigator of change, further transformations were enabled because of changing social infrastructures and boundary practices. Similar to EMP, 3D tools were also used on the Seattle Library project, however, in a very different manner. Unlike Gehry Partners, Rem Koolhaas was not willing to distribute his 3D models to Hoffman and the subcontractors. As a result, boundary practices common to the architects, Hoffman and the subcontractors changed, and so did the conditions for the enactment of Hoffman's social identity. Under the new conditions, 3D tools were no longer used as boundary objects between the architect and the rest of the actors. Paper documents were used instead. However, due to the complexity of the building, Hoffman and the subcontractors still had to use 3D tools as they are able to accommodate and transfer multiple layers of complex information. Thus, 3D tools were used as a boundary object between Hoffman and the subcontractors and among the subcontractors. But whereas on EMP 3D models were generated by the architects and used by them to communicate with other actors in a top-down manner, here the use of boundary objects was done in a bottom-up process. Namely, 3D models were generated by Hoffman and the subcontractors and were used by them to create a shared platform that enhanced collaboration among them. In that process, which constituted the boundary practices, Hoffman's social identity was reshaped. They played a much more proactive role which was expressed both in them providing surveying information to the subcontractors and in orchestrating and managing the shared platform. As organisational boundaries and the use of boundary objects were re-charted, so were social identities. Rather than being dispersed across various organisations, Hoffman's role positioned it as a central coordinator and supplier of knowledge.

7 CONTRIBUTIONS, FUTURE RESEARCH AND LIMITATIONS

Our theory and vignettes provide some important insights for future research and practice. First, for boundary objects literature, our study suggests that future research should pay closer attention to the changing dynamics of boundary objects and boundary practices. The meaning of boundary objects changes as the context of their use change. Yet, the social context itself is constructed by the use and interpretations of boundary objects. Therefore we need to examine boundary objects

as part of a larger, dynamic social ecology that is composed of social infrastructures and social identities.

Second, within this ecology, it is important to examine the role of IT as boundary objects. To date, research on the topic has been scarce. Our paper provides an initial insight by suggesting that IT should be understood not only as objects that can enter an organisation and change it in any number of ways, but also as an artefact that is used by diverse actors and groups who attach different meanings to it and construct different identities in relation to it.

Third, our study also suggests that organisational change can be better understood in the context of reciprocal dynamic relationships constituted through the use of boundary objects, social identities and social infrastructures. Some organisational change literature has examined factors that facilitate organisational change or that influence resistance to it (Labianca et. al., 2000). Other more process-oriented studies have examined the actual process of organisational change (Van De Ven & Poole, 1995). IS researchers have been examining the impact of IT on organisational change (Robey & Boudreau, 1999). What is striking in the extant literature is the scant attention paid to the fact that organisations are situated in dynamic and reciprocal social systems that are mediated and supported by boundary objects and practices. Understanding organisational change in such social context is particularly important given that organisations increasingly communicate with one another through various forms of IT that serve as boundary objects. Our theoretical perspective complements traditional theories on organisational change by explicitly incorporating such dynamic and reciprocal inter-organisational social contexts. Our model suggests that IT-enabled organisational change is likely to be unsuccessful if it is internally focused. As shown in the vignettes, any attempt to initiate such change will instigate further changes in neighbouring organisations through mutual boundary objects which could have real, and often unexpected, consequences.

Finally, due to the scope of this paper, we were only able to describe a small fraction of the change process. A more methodical application of our theoretical model necessitates an examination of a wider set of players over a longer period of time. Future researchers would be wise to follow suit.

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