Contagion Theories and Learning in Emergent Networks: Evidence from the UK Construction Industry

ABSTRACT

How is information effectively disseminated among actors in networks and how do emergent networks learn? Drawing on the disease metaphor underpinning contagion theories, this study examines network members' exposure to information in emergent networks – "shadow networks", or the way "things actually get done" through informal links between actors. The data collected for this study consists of 45 in-depth semi-structured interviews and two focus group conducted with managers undertaking two UK construction projects over a period of twenty four months. Due to the temporary organizational forms that constitute the construction projects studied actors operate within a network that is evolving, and are thus compelled to negotiate their roles and navigate the most effective means of completing tasks. What we recognize in the construction projects studied is in the presence of ambiguity and novelty actors adopt co-ordination mechanisms that rely on informal communication practices negotiated in situ. *We explore the implications of these findings for network learning opportunities.*

Key words: Contagion Theories; Emergent Networks; Network Learning; Temporary Organizations.

CONTAGION THEORY – AN INTRODUCTION AND APPLICATION

Between the years 541-542 AD, a pandemic (which would again later contribute to the Black Death of the 14th century) swept across the Eastern Roman (Byzantine) Empire. It is estimated that 40% of the citizens of Constantinople were killed by the disease, which is thought to have been spread by rats and fleas hidden inside the grain distribution network.

The rapid spread of disease experienced by the citizens of Constantinople owed its virulence to the highly centralized and controlled grain infrastructure which comprised public granaries and grain ships; this ensured that the unfortunate populous were highly exposed to the virus. In contrast, many business-to-business networks are less connected and more fragmented (e.g. loosely coupled) and prone to change (Håkansson and Ford, 2002). This raises the question of how networks ensure the "spread" of knowledge and information, particularly if this involves informal and emergent communication practices? In the present study, we propose that our understanding of network learning can be enhanced by examining the emergent nature of communication networks and practices. To help achieve this we draw on Contagion Theories in order to provide implications for the facilitation of learning opportunities when faced with emergent network forms.

Contagion Theories are premised on a disease metaphor (Monge and Contractor, 2003) and seek to explain network members' knowledge, attitudes and behaviour based on their *exposure* to the attitudes, information and behaviour of others (Rogers and Kincaid, 1981). In the present study we pose the following research question: *how is information effectively disseminated among actors in networks and how do emergent networks learn?* Put another way, we seek to examine how actors can be – as best as possible – "exposed" to knowledge through communication practices in order to learn how to perform tasks efficiently in changing networks. The data collected for this study consists of 45 in-depth semi-structured interviews and two focus groups conducted with managers undertaking two UK construction projects over a period of twenty four months.

Learning processes in construction network relationships are interesting because they can change radically from project to project and thus the ability of members to form cognitive structures

that support learning is problematic (Dubois and Gadde, 2002). Such changes limit the learning processes of trial, feedback and evaluation. They may, however, also support the development of new ideas and innovation because of the variation in network activities and membership (Weick and Roberts, 1993; Chiu, 2009), although this innovation may not be shared or disseminated beyond the project network. The construction industry also displays certain characteristics that render it particularly complex including short-lived site-specific project-based activity and uncertainty due to a lack of complete specification (Dubois and Gadde, 2002), as well as loose couplings in the permanent industry level network. Such loose couplings between network actors for the majority of the time greatly restrict firms' abilities to learn thus inhibiting sustained cognitive structures (Teece, 1998). Further, while much attention has been afforded to the knowledge held by firms and their knowledge dissemination practices, less attention has been directed towards knowledge and learning at the level of the network (Young and Denize, 2000; Veal and Mouzas, 2010). Therefore, understanding the communication processes and practices that industry actors engage in to enhance network learning through contagion given these circumstances would seem a valuable contribution. Further, by drawing comparisons and contrasting the two case studies, we provide a novel insight into communication practices and attempts to derive cognitive consistency in two challenging and complex networks.

We begin with a discussion of network learning and knowledge capture. Next, we provide a brief overview of contagion theories and evaluate their usefulness in understanding learning in a network context. The remainder of the study empirically examines the application of contagion theories to network learning.

NETWORK LEARNING

While much attention has been afforded to the knowledge held by firms and their knowledge dissemination practices, researchers adopting an industrial networks approach note that less attention has been directed towards knowledge and learning at the level of the network (Young and Denize, 2000; Jyrämä, 2002; Bygballe and Harrison, 2003; Bygballe, 2004; Anderson and Lettl, 2009). Interest in organizational learning at the level of the network, however, has been steadily increasing (Easterby-Smith, Crossan and Nicolini, 2000). Driving this is the recognition that "...organizations are collections of overlapping knowledge systems each of which may be embedded within a wider occupational community" (Araujo, 1998: 331). Understanding the formation of knowledge therefore cannot simply focus on the learning of isolated actors, but rather such learning is dependent on the capabilities and competencies of the wider network (Bangens and Araujo, 2002). Simply put, "networking increases learning" (Håkansson et al., 1999: 450) – or at least the opportunity to learn.

Business networks and their constituent actors serve as a key potential source of learning; whether via regular interactions with certain actors (e.g. suppliers or customers) or by learning through collaborations with other firms (e.g. joint ventures) (Ford, Håkansson and Johanson, 1986; Håkansson and Johanson, 2001; Håkansson and Snehota, 1995; Bångens and Araujo, 2002; Håkansson, 1993; Mouzas, Henneberg and Naude, 2004). The coverage of this topic, however, remains embryonic, fragmented, and is often limited to coverage of a single firm or dyadic perspective of learning (e.g. Crespin and Salle, 2003; Machat, Salle and Fenneteau, 2004; Ciabuschi and Perna, 2008). Three key studies, however, have recognized the importance of network learning and knowledge capture. These contributions have observed that firms stand to learn more in networks based on the number of connections they have with other firms, and that exposure to more firms provides greater opportunities to learn (Håkansson et al. 1999), and also that such opportunities allow for joint problem-solving through social interaction, and "co-educating" (Holmen et al. 2003). This is undertaken in the recognition that joint learning opportunities act as the "glue" that binds networks together (Holmen et al. 2003). We should also caution that a difference exists between knowing and learning that is bridged by capabilities (Bångens and Araujo, 2002). Learning is a process that "...grows by increasing specialization" (Bångens and Araujo, 2002: 573) and such specialization may hinder the acquisition of contrary forms of knowledge (Loasby, 1998).

Against this background, there are a number of unanswered questions that would afford a better understanding of network learning, particularly the activities that facilitate the learning opportunities that firms find so valuable. We argue that network learning capabilities can be examined through the application of contagion theories. Contagion theories seek to understand how actors' are exposed to attitudes, behaviour and information and how this diffuses through networks. Further, contagion theories recognize that exposure to information may not always occur through conventional (or formal) network communication channels, but may also arise through emergent and informal networks. It is to the topic of contagion theories and network learning that we now turn.

CONTAGION THEORIES

A number of theories have attempted to explain the communication practices of networks (such as Cognitive Theories, Consistency Theories, Homophily, and Theories of Social Capital), we employ contagion theories as they are arguably the most developed and understood mechanism to examining the emergence of communications networks (Monge and Contractor, 2003). Contagion theories are a family of related theories that examine how exposure to contact may lead to social influence (Social Information Processing), imitation and mimetic behaviour (Social Learning Theory and Institutional Theory), and similarity in positions and roles within the network structure (Structural Theory of Action: Monge and Contractor, 2003). As noted in the introduction, contagion theories draw on a disease metaphor, where actors are exposed to attitudes, behaviour and information (Burt, 1980). The extent of this exposure will determine the alignment between actors' beliefs and attitudes (Carley, 1991), as a *convergence* model of communication (Rogers and Kincaid, 1981). Contagion theories seek to explain "…networks as conduits for "infectious" attitudes and behavior" (Monge and Contractor, 2003:173). In particular, contagion by cohesion (i.e. direct contact with others in the network) and by structural equivalence (where influence is related to the structural patterns of relationships in the network) are two key mechanism examined in contagion theoretical studies. Hence contagion theory provides a useful framework to examine how communication and knowledge is premised on emergent communication networks based on actors' cognitions and relations with other actors.

Emergent networks refer to "a designation that originally differentiated informal, naturally occurring networks from formal, imposed, or mandated networks" (Monge and Contractor 2003: 8). Such networks are not always fixed by any legal agreements, and could also be viewed as "shadow networks", or the way "things actually get done" through informal links between actors (Kadushin and Brimm 1990). Traditional formal networks were representations of organizations depicting the means by which information was communicated upwards and orders were communicated downwards (Weber 1947). Organizational theorists, however, recognized that these formal organizational structures did not accurately capture informal communications channels and "the grapevine", where information is diffused through organizations other than adhering to formal organizational structures and hierarchies (Follett 1924; Barnard 1938; Davis 1953). Contagion theories recognise that communication is emergent and dependent on network linkages which mitigate the convergence of attitudes and understanding.

Convergence of attitudes and understanding is important as it gives rise to cognitive consistency. This would seem of importance to network learning as divergence creates boundaries between actors that may be difficult to breach (Carlile, 2004). Reflecting the two main mechanisms found in contagion theory (contagion by cohesion, and contagion by structural equivalence: Monge and Contractor, 2003) we focus on two areas of contagion theories that can be used to help explain network learning, namely: behaviour and attitudes through contagion, and barriers to contagion mechanisms.

BEHAVIOUR AND ATTITUDES THROUGH CONTAGION

Contagion theories have been employed to explain actors' behaviours, including absenteeism, job-seeking, and voluntary turnover. For example, Krackhardt and Porter (1986) found that employees who were regularly absent were more likely to be connected through friendship ties. In a comparative study, Feeley and Barnett (1996) studied staff turnover at a supermarket, finding that structural equivalence and social influence networks were an effective predictor of staff turnover. In a study of students' decisions to apply for employment at particular organizations, Kilduff (1992) found that such practices were influenced by their friendship networks.

Contagion theories (particularly those underpinned by social information processing theory) contend that contagion processes over time should lead to a convergence in (or homogenization of) attitudes or actions, and to some form of network knowledge equilibrium where similarities in attitudes are achieved through interaction. Krackhardt and Brass (1994) questioned this assumption, arguing that the influence actors have over one another is contingent on actors' exposure to information and other actors. Two further studies have illuminated social influence in networks. In the first, Krassa (1988) argued that social influence is dependent on the number of people an actor comes into contact with and is influenced by before adopting an attitude or behaviour. Put another way, an actor has a threshold level of contact with other actors before they will adopt a particular attitude or behaviour (Granovetter, 1978). Rice (1993) argued that network contagion theories of social influence should also take into account the level of ambiguity or novelty of a situation or task, proposing that actors are more likely to succumb to social influence when faced with an ambiguous task.

Contagion theories have also been brought to bear on actor's relationships and subsequent attitudes. In this regard structural equivalence refers to actors having similar network relations to other actors in the network and their influence on workplace attitudes (Monge and Contractor, 2003). Studies across various organizational contexts demonstrate that actors in the same social circles were more likely to perceive agreement with others (Friedkin, 1984), employees who were structurally equivalent reported similar attitudes concerning product development (Walker, 1985), and employees who regularly communicated with one another shared comparable interpretations of corporate events (Rentsch, 1990). In contrast to structural equivalence, where two individuals share the same network links and relationships, actors with *regular equivalence* have broadly similar (although not identical) network relationships (White and Reitz, 1989). Pattison (1994) contends that actors who can be characterised as regularly equivalent were more likely to share social cognitions.

BARRIERS TO CONTAGION

Contagion theories are not without their critics. One criticism of contagion theories is that they represent the so-called "hypodermic needle model" of network communication practices. That is, the notion that exposure to information "injects" values and attitudes into actors who will unquestionably adopt an idea or behaviour (Monge and Contractor, 2003). Actors may also be isolated from "message infection" through network isolation; that is the isolation of actors from the highly infectious parts of a network leading to the obstruction of powerful message content. Thirdly, applications of contagion theories have not always taken into account the possibility that an individual may display resistance or inertia towards contagious influences (Monge and Contractor, 2003). For example, the extent to which an actor adopts a particular attitude or behaviour is contingent on the actor's knowledge and confidence in assessing a situation.

Against this background, McGuire (1966) offered an explanation as to how actors may be resistant to contagion. Just as individuals may be inoculated against susceptibility to contracting disease through the exposure of trace amounts of an infecting agent, McGuire (1966) contends that actors may become immune to contagious messages if they are exposed to a weaker form of an argument and/or a counterargument. Hence actors may gain immunity and resistance to certain "accepted" attitudes or behaviours through "inoculation" to contagious network messages. The consequences of this observation suggest that some parts of networks may be immune to the reception

of infecting messages, even if those "immune" actors are linked to other actors in the network (Monge and Contractor, 2003).

CONTAGION THEORIES AND NETWORK LEARNING

Against the foregoing discussion, it is worth assessing the potential value of applying contagion theories to network learning. Although critics of contagion theories have called for greater articulation of the mechanisms that trigger contagion, the practices by which organizations influence other's actions and behaviours, and the content of messages (which may inoculate contagion between actors), the principles expounded by its theories would seem to provide a useful basis to explore informal and emergent network communication – relatively less studied phenomena, but which may more accurately capture the way "things actually get done" in networks (Kadushin and Brimm 1990) and learning may occur. This is in contrast to more formalised collaborations in which learning goals are prescribed (Bygballe, 2004), which has received significant attention (for example, Hamel 1991; Lane and Lubatkin 1998; Powell 1998; Holmquist 1999; Dyer and Nobeoka 2000; Lane, Salk, and Lyles 2001; Zollo, Reuer, and Singh 2002). Bångens and Araujo (2002) highlight three types of learning practices: learning-by-doing (routine and repetitious tasks); learning-by-using (dissimilar capabilities that are embodied in goods and services which actors have access to); and; learning-by-interacting (joint problem-solving between actors). All three of these practices rely on communication and may be understood within a contagion theoretical context. Learning-by-doing over time may lead to a convergence in attitudes or actions, learning-by-using may enhance social influence effects (particularly if the level of ambiguity or novelty of a situation or task is high), and learning-by-interacting may lead to network knowledge equilibrium where similarities in attitudes are achieved through interaction.

A confounding factor to the foregoing is the recognition of the problems firms face, which is "…the utilization of knowledge which is not, and cannot be, known by a single agent" (Tsoukas, 1996: 11), but exists "…as dispersed bits of incomplete and frequently contradictory knowledge which all separate individuals possess" (Hayek, 1945). Thus many knowledgeable actors with considerable expertise may reside outside of the organization, rendering their identification potentially challenging to other actors. This may be exacerbated in project-based settings where temporary forms of organization operate. The phenomenon of "temporary organizations" occurs in typically project-based industries such as advertising, construction, consulting, and high-tech companies. For example, in Bechky's (2006) study of short-term film projects (e.g. music videos, commercials), she found that such short-lived projects – rather than unstable and ephemeral – are often organized around structured (but often negotiated) role systems where autonomy is often exercised *in situ*. Similarly, loose industry coupling presents problems in relation to establishing a learning curve at the individual level, as the interactions of project team members are constantly changing and the opportunity to transfer knowledge to future projects may be limited (Dubois and Gadde, 2002). This is also an issue at the firm and industry levels, as the couplings between activities and learning on different projects may be loose. Hence co-ordination between actors in project-based settings can act as both barrier and catalyst to network learning.

Against this background, the remainder of this study seeks to apply contagion theories to our understanding of informal and emergent communication practices that occur in networks and the capacity for organizational learning opportunities in such contexts through a study two UK construction projects. Specifically, we examine:

i.   Behaviour and attitudes of actors through contagion (contact between individuals, the influence of friendship ties, the influence of social circles and networks, how influence is exerted particularly in ambiguous tasks).

ii. Barriers to contagion (inoculation to network messages and immunity to learning by network members), and the capacity for actors to co-ordinate in project-based settings.

METHODOLOGY
CASE STUDY SELECTION AND CONTEXT

We aim to understand communication practices in emergent networks through the lens of contagion theories in order to help and/or hinder network learning through the exploration of two exemplary case studies. Using a qualitative case study method allowed the researchers to gain an in-depth, and situated, appreciation of complex and inter-related behaviours and attitudes related to how and why network members communicate. Sampling of the two construction projects examined was theoretical (Yin, 1994), and based on the opportunities they provided to observe network learning processes. By collecting data from two different cases, the researchers were able to compare and contrast the data collected from each case.

Case study one (*OfficeProject*: approximately £8.5 million) was a project creating office space and conference and training facilities. The second case (*PowerProject*: approximately £8 million) related to the construction of a combined heat and power plant (CHP) for a large-scale institutional user. In Table 1 we summarise the key features of each case. The management teams (consisting of the client representatives, architect, design team, and contractor representatives) were of approximately equal size on each project, and details are provided in Table 2.

Table 1
Case Summaries

	Case 1: *OfficeProject*	Case 2: *PowerProject*
Value	£8.5 million	£8 million
Purpose	Office accommodation and conference/training facilities	Combined heat and power generation
Supplier	A leading construction, development and services group in the UK. The Group employs 11,400 people worldwide and has annual revenue of £2.1bn.	A leading construction and regeneration group in the UK. The Group employs over 8,500 people and has annual revenue of over £2.5 bn.
Customer	Training and Education Provider	Large-scale site with district heating system to approximately 30 buildings.
Level of Risk	Medium, new variant of energy efficient construction technology previously used by this client in other buildings.	High, if successful this will be the first working CHP plant utilising this form of energy production technology in the UK.
Planning time frame	9 months in planning, this data was collected over the 24 month construction period.	3 years in planning, this data was collected over the 24 month construction period.

Table 2
Respondent Demographics

	Client Team (e.g. Project Director, Project administrator)	Client Team Representatives (e.g. Project Managers and their Quantity Surveyor)	Contractor Team (e.g. Project Managers, and their Quantity Surveyor)	Design Team Specialists (e.g. Architect, Mechanical and Electrical Engineers, Structural Engineers)	Other Specialists (e.g. Clerk of Works, Landscape Specialists, Acoustic Specialists)
OfficeProject	3	3	3	4	5
PowerProject	3	1	4	5	5

* As both projects were in the same geographic region of the UK, some team members were present on both projects.

While the role of the client and other members in the wider network (e.g. sub contractors and other supply chain partners, and external stakeholders such as planning authorities and local council officials) are no doubt important, we chose to focus our data collection and observations on the middle managerial and design team network members. This provided a useful boundary in terms of learning processes as these are the network members who will be meeting on a regular and frequent basis, both formally and informally, and who will be dealing directly with the practical issues and problems that arise in relation to the project design and construction. Due to an anonymity agreement between researchers and informants, we can provide only general information for the nature of each project.

The data collected for this study consists primarily of 45 in-depth semi-structured interviews and two focus group conducted with managers of two UK construction projects over a period of twenty four months. In addition, 14 design team progress meetings were attended (eight for *OfficeProject* and six for *PowerProject*). In each meeting official progress documents were collected and field notes were made. Together with the interview data these meeting observations allowed for a deeper understanding of the data and provided evidence of validity through triangulation. The interviews were conducted at the offices of the respondents and at the construction sites with respondents. The interviews lasted on average 90 minutes and the focus groups lasted two hours or more; all were digitally recorded, resulting in some fifty seven hours' of interview evidence. The theme of the discussions focused on new knowledge recognition and the acquisition, interpretation, dissemination and utilisation of knowledge within the network. This data were transcribed and coded using AtlasTI v6 software, following the coding procedure outlined by Strauss and Corbin (1998).

To ascertain communication behaviours, we drew upon the work of Mohr and Nevin (1990) who characterise frequency, direction (uni or bi-directional) and modality (more formal vs. more informal modes) as important aspects of communication behaviour. We therefore asked each respondent to complete a questionnaire in which they stated who they communicated with (i.e. their ego network; Monge and Contractor 2003), and on a three-point scale (3 = frequent/sustained, 2 = moderate/some, or 1 = infrequent/occasionally) how often they communicated with them. This was collected for both formal (meetings, memos, official documents and sign-offs) and informal communication modes. This data was then analysed using UCINET 6 software. We summarise this analysis in Table 3, which compares aspects of communication behaviours across both projects according to the different roles in the teams, specifically their percentage of ties to and from other actors in the network, and the density of their neighbourhood (the cluster of connections around them). Table 4 looks at the network level data for each project according to communication mode, which includes network density of communications (both in binary present/absent ties format, directional (to/from), and as a value function of their communication strength; i.e. frequency), the network clustering coefficient, and geodesic distance (the distance between two nodes as the number of links in the shortest path between them. In addition, the network transivity (the sense in which a network is characterised by isolation, coupling, structural holes where only 2 of three possible ties are present, and clustering), and its dimensions of hierarchy (Krackhardt's four components) are presented (Hanneman and Riddle, 2005).

Table 3: Role Differences in Communication

	Client Team		Client Team Representatives		Contractor Team		Design Team Specialists		Other Specialists	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Formal Communications % of ties to other actors	**.29**	*.15*	**.35**	*.09*	**.26**	*.06*	**.20**	*.07*	**.21**	*.16*
% of ties from other actors	**.24**	*.19*	**.24**	*.17*	**.22**	*.09*	**.27**	*.14*	**.12**	*.06*
Informal Communications % of ties to other actors	**.28**	*.14*	**.31**	*.04*	**.25**	*.06*	**.19**	*.08*	**.19**	*.13*
% of ties from other actors	**.20**	*.20*	**.24**	*.18*	**.19**	*.11*	**.24**	*.14*	**.10**	*.05*
Formal Communications Cluster Coefficient (densities of the neighbourhoods of each actor)	**.30**	*.11*	**.46**	*.14*	**.48**	*.14*	**.52**	*.09*	**.64**	*.21*
Informal Communications Cluster Coefficient (densities of the neighbourhoods of each actor)	**.28**	*.12*	**.42**	*.13*	**.45**	*.13*	**.50**	*.11*	**.52**	*.21*

Table 4: Network level comparative statistics

	Data type	Office Project Formal Communications	Office Project Informal Communications	Power Project Formal Communications	Power Project Informal Communications
Binary Density (the proportion of all possible dyadic connections that are actually present)	Binary	0.17 (137 ties)	0.16 (132 ties)	0.09 (169 ties)	0.08 (157 ties)
Value Density (the ratio of all tie strength that is actually present to the number of possible ties)	Value	0.30 (std 0.71)	0.30 (std 0.75)	0.14 (std 0.49)	0.15 (std 0.56)
Clustering Coefficient (Weighted Overall graph clustering coefficient)	Binary	0.42	0.40	0.39	0.34
Geodesic Distance (Average distance)	Value	1.46	1.45	1.26	1.33
Distance-based cohesion ("Compactness", range 0 to 1; larger values indicate greater cohesiveness)	Value	0.77	0.78	0.87	0.84
Distance-weighted fragmentation ("Breadth")	Value	0.23	0.23	0.13	0.17
Transitivity (% of triangles with at least 2 legs that have 3 legs)	Binary	24.70%	22.49%	21.56%	18.74%
(% of all triads that are transitive)	Directed	2.37%	2.05%	.76%	.57%
(% of relations that could easily be transitive, actually are)	Directed	56.22%	51.19%	49.01%	43.94%
Krackhardt GTD (connectedness)	Directed	1.00	.87	.64	.87
(hierarchy)	Directed	.63	.54	.68	.74
(efficiency)	Directed	.81	.79	.85	.91
(Least upper bound)	Directed	1.00	1.0	1.0	1.00

FINDINGS

In this section we introduce two cases based on an investigation of network learning in two UK construction projects. Both construction projects demonstrate the challenges to learning inherent in project-based settings that may not be so marked in relatively more stable networks of organizations. We begin our discussion of both cases by providing a general context to each project.

CASE STUDY ONE: *OFFICEPROJECT*

OfficeProject's remit was to create office space and conference and training facilities, having begun on-site construction in July 2008, after a planning stage lasting approximately nine months. The project design team involved nineteen members from nine different organizations. The decisions regarding this build evolved in three main stages. In the first stage, the building was designed for conference and training, with a mixture of small and large group meeting spaces. The planning of this phase of the build occupied the first six months of the timeline. While designing this part of the project, the design team left open the opportunity of an additional (second) floor to the building which could be added at a later stage of the design. While the building shell would be designed to accommodate this, fitting out and occupying the second floor was left as an open option in the early phases of the design process. By the time construction work started in July 2008, the possibility of occupying the second floor was considered a likely outcome, and so design work was conducted on what would need to be altered or added to the current design in order to accommodate this. At this point it was decided to dedicate this second floor space to executive training, and to incorporate innovative and leading edge training and presentation tools (for example, interactive whiteboards). In addition, the space would contain some office accommodation, but would mainly consist of seminar rooms and meeting 'pods'. These pods were designed to be flexible breakout areas for small group meetings and working. Because the possibility of this second floor fit-out was known at the time of initial design, the disruption to the build progress was minimal and the go-ahead for construction was not adversely affected by such a major change in the design.

As the final months leading up to the commencement of the build followed, the client muted the possibility of a second phase to the build. This would be additional office space built next to the phase one building, and connected to it at each level through corridors. Once again, the design team looked at the adjustments that would have to be made to accommodate this. External wall construction

that could later be removed at the points though with the corridors would connect the two phases of the build were discussed, as was the re-sighting of some of the services equipment (for water, heating, and lighting) in order to accommodate a phase two build instruction should it come. Construction commenced in July, with the formal appointment of the contractor and the hand-over of the site from the client to the contractor for construction. By the end of September it was still not clear if phase two would go ahead, and this caused concern for the project supervisors and the contractor. It was now becoming critical that a decision was made, and after much discussion the client team approved the building of the second phase of the project in late January 2009. The start of this second phase of production was to begin in June/July 2009. In the January meeting jokes were made about negotiating with the current contractor to continue with phase two: "*if they delivered phase 1 ok*". In fact, all those involved in the phase one build continued to be employed for the phase two stage of the project, which they all considered as a bonus and in no small part due to the good team working atmosphere and willingness of everyone to accommodate the client in this phased development and approval process. A pictorial representation of the network connections (a sociogram) for *OfficeProject* is seen in Figure 1.

Figure 1: Sociograms for *OfficeProject*

| *OfficeProject* Formal Communications | *OfficeProject* Informal Communication |
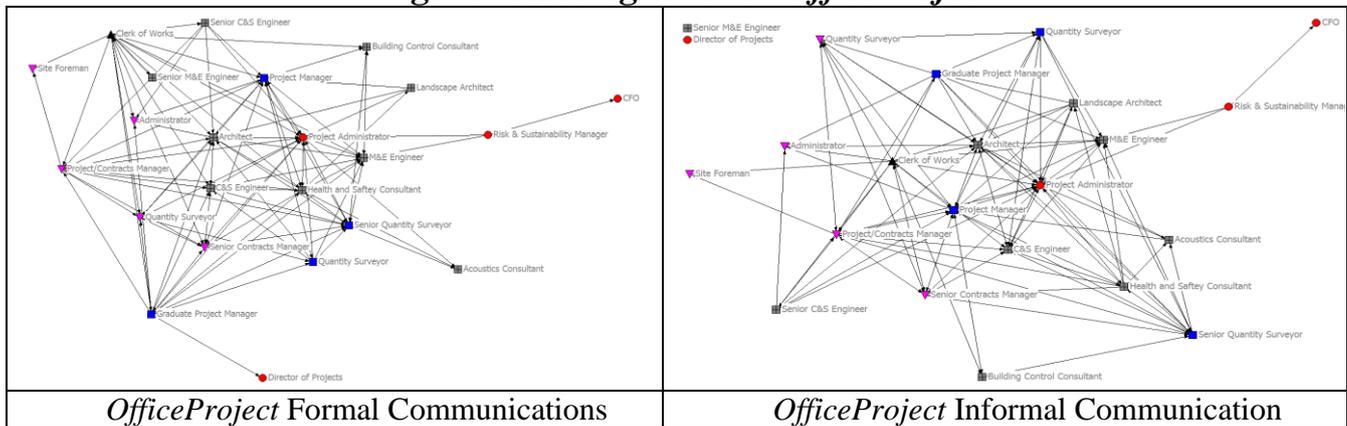
Behaviour and attitudes through contagion

There were five main role groups in the project team membership for both *OfficeProject* and *PowerProject,* as outlined in Table 3. Hierarchically, the Project Administrator would be at the top (answerable to the client board), then the Project manager and the design team, and then the contractor. These levels give us some idea from an organizational perspective of the relative structural properties of some team members as opposed to others. In particular, the density and clustering of relationships given in Table 3. These means tell us the connectedness, size and embeddedness of each actor's neighbourhood (as reflected in the percentage of ties to other actors, and the number of pairs of actors connected in it). For both more formal and more informal communication modes, the Other Specialists have the highest clustering, and the largest difference between formal and informal cluster means (.64 vs. .52). Thus, while formal communications take place within much larger and more embedded neighbourhoods for them, informal communication channels are significantly less structured. They also have by far the lowest percentage mean of formal ties (.12) and informal ties (.10) from the other actor groups, and these figures are both much lower than their means for formal (.21) and informal (.19) ties to other actors. This is reflected in the sociograms in Figure 1, in which these network members often appear more peripherally than other role groups. Their communication density and clustering is characterised by highly clustered neighbourhoods of actors whom they more often communicate to rather than receive communication from. In addition, the less dense clustering of the other role groups may have helped facilitate informal communication situations (such as site

meetings), which often circumvented the more formal structure. For example, the architect may meet with the sub contractors of the main contractor on site to resolve problems.

These informal meetings were essentially problem-solving and issue raising interactions; the engineers, architect, building control, as well as others, will arrange to come on site (not necessarily at the same time) and talk to the contractor and the clerk of works (who manages the interests of the client on the site). Building sites are curious settings, while the site is located at the client's premises, there is a point at the start of the project and at the end when the site is handed over to the contractor, and then handed back. This means that during the build the contractor "owns" the site and is legally responsible for everything that happens on it. Therefore, the client has a clerk of works who represents them on site and communicates with all the sub-contractors and the contractor on a day-to-day basis. It is his job to ensure the project is progressing as expressed by the client. With such responsibilities, it is no wonder that as an Other Specialist the clerk of works may be embedded in a denser and larger network of ties.

The lowest clustering for both communication modes is in the Client Team (.30 and .28), a reflection of their position at the apex of the hierarchy (and centrally in the sociograms in figure 1). In fact, the lowest clustering generally is in the three upper role groups hierarchically (the Client Team, Client Team Representatives, and the Contractor Team) for both communication modes, and there is very little difference between their formal and informal means. The Client Team mean percentage results show a particularly large difference between the informal ties *to* other actors, as opposed to ties *from* other actors (.28 vs. .20), and overall are very similar in pattern to those of the Contractor Team members. The Client Team Representatives have the highest mean percentage of formal (.35) and informal (.31) communications *to* other actors, which reflects their role as the project managers who coordinate the overall build and sit between the client team, and the rest of the construction project members.

The Design Team Specialists group works for the Client Team, advising on specific aspects of the build (primarily engineering and architecture). As the build progresses, many decisions are made "on site", particularly as the implementation of the design is confronted with detailed and specific design requirements which could not have been foreseen (or were too detailed to be designed in advance of the build). In this implementation, some aspects of the intended design are not feasible or practical. There was considerable evidence in both the interviews and the formal progress meetings of "trial and error" and experimentation in dealing with arising issues. One respondent stated that: "*...you can only go so far as a team, but on site, and at a greater level of detail, decisions may be made by individuals.*" However, it is in the nature (and training) of engineers that they enjoy such challenges. The architect, in particular, took pleasure in these situations and was happier in site meetings than in the more formal progress meetings, which other team members found frustrating at times. The architect described how the different mind sets of the contractor (practical) and himself (artistic) could come together in a focused way through such interactions: "*It feels family friendly, like a conductor and an orchestra….You would think we would not get on as he is trying to save money and I am trying to spend it ….But on this project we get on and all work together. It is one of the best working teams I have been on in a long time.*" Throughout *OfficeProject* it was evident the Design team Specialists frequently drew on the expertise from the people at hand and on site from ad hoc meetings, and that these were just as important to them as the more formal lines of reporting. This can be seen in their formal and informal cluster coefficients (.52 and .50), which are higher than the Client Team, Client Team Representatives, and Contractor Teams. Thus they communicate in large and densely connected communication networks, with a greater proportion of their communications coming *from* other network actors (.27 formal and .24 informal) rather than *to* other network actors (.20 formal and .19 informal).

One mechanism that influenced the contagion of attitudes was through friendly social influence. An example of this was in the team dynamics in the meetings held. In the initial meetings between the contractor and the client teams, both groups tended to sit opposite one another in the

room. One of the engineers often joked about this, and in one meeting actually got up and moved across the room and sat with the contractor. As the project progressed the group dynamic changed and seating in meetings was much more informal and random, while actors seemed more integrated and socialised as construction progressed.

Barriers to contagion - immunity to network learning

Several barriers to contagion were evident in *OfficeProject*. At an early phase in the project there were lengthy discussions concerning version control of documents. One engineer expressed his desire to employ an IT system, but this was not ready at the beginning of the project. The contractor had their own system which they were keen to use, but the client was resistant as they recognized that they would have had to learn how to use it, so the traditional methods of email and exchange of documents prevailed. Although this practice worked reasonably well, all actors agreed that an integrated IT system would have worked better; the issue was one of ownership of the system (i.e. the client, the architect, or the contractor) which could not be resolved. Again, at an early phase in the project, several actors were concerned how issues would be dealt with if they were no longer present to help resolve them. An example of this was the structural engineer who was anxious whenever problems were raised (this included issues related to the car parking level and materials being proposed for use in the building).

Postulating that the influence of one node on another declines with the distance between them, the geodesic distance matrix (Table 4) can be used as an index of influence or cohesion (Hanneman and Riddle, 2005). As we have used value data (the frequency of communication) to calculate this, the distance between two actors is defined as the strength of the weakest path between them. For *OfficeProject* the strength of this distance for both formal and informal communication modes shows that on average these were fairly infrequent (1.46 and 1.45), but with compact (.77 and .78) and less fragmented (.23 and .23) communication patterns between network members. In addition, the overall network density (.42 and .40) shows an interesting picture. The proportion of all possible dyadic connections that were actually present was only 17% and 16%, and the value ratio (the ratio of all tie strength that is actually present to the number of possible ties) was only .3 for both communication modes. While these measures look at dyadic relations, small group theorists argue that many of the most interesting and basic questions in network dynamics relate to triadic (rather than simply dyadic) relationships (Hanneman and Riddle, 2005). To explore this we examined the proportion of triads that are transitive (i.e. display a type of balance where if A directs a tie to B, and B directs a tie to C, then A also directs a tie to C). We can see from the results in Table 4 that only 24.7% and 22.49% of dyads are also triads, only 2.37% and 2.05% of all triads display transivity (i.e. they have enough directed ties to display transivity), however 56.22% and 51.19% of the relations that could be transitive actually are. Therefore, we see a pattern of relatively dense communication patterns where ties exist, but a more fragmented picture of ties being established.

As we noted earlier, actors may be resistant to contagion by establishing some immunity to contagious messages if they are exposed to a weaker form of an argument and/or a counterargument, and that some parts of networks may be immune to the reception of infecting messages, even if those "immune" actors are linked to other actors in the network. One test of this may be the hierarchical nature of the network, as in hierarchies contagious messages may become weaker as they are passed down the hierarchy. Krackhardt's GTD measure tells us something about the hierarchical structure of the network. In a pure hierarchical form, every node would have a directed connection and have an in-degree of 1 (one inward directed contact) except the boss (i.e. A to B to C to D …). The four component measures tell us that in terms of connectedness, in the *OfficeProject* network all the actors (1 for formal communications) and almost all (.87 for informal communications) are embedded in a single structure (a condition of hierarchical structures). Only a moderate proportion of all tied pairs have reciprocal ties, and are thus non-hierarchical (.63 and .54). In terms of efficiency – where each actor having communication from a single boss would be the most efficient form, we see that the

network is relatively efficient (.81 and .79), as these are small differences in the deviation from a perfectly hierarchical form (with an in-degree of one for each node, calculated as the difference between the actual number of links minus 1 and the maximum possible links). Finally, the least upper bound (where each actor pair, except those that include the boss, has an actor that directs ties to both actors in the pair – in other words command is unified) shows that all actors have a common boss (1.00). These four measures show *OfficeProject* communication patterns to be fairly strongly hierarchical in structure.

These results point to a network where groups of actors are clustered (compact and less fragmented, but not widely connected across the whole network and where communication patterns are hierarchal). One reason for such clustering may be the fragmentation of expertise on such construction projects. Immunity between actors may be due to the wide variance in professional backgrounds and specialist knowledge, and this might have hampered understanding. To address this, simple artefacts such as the use of drawings, progress charts, reports, and photographs (as well as a sense of humour in actors' interactions with one another) acted as boundary spanning objects between actors and provided ways of sharing new knowledge in the project community. For example, at every meeting actors would examine the progress report, which consisted of a large complex Gantt chart outlining all work flows and time scales, and what factors impinged on the progress of the project. Despite its complexity, this provided meaning for all actors despite their specialisms. In addition, each month the contractor would include pictures of the building in his report, which afforded the client a visual representation of progress.

<div align="center">CASE STUDY TWO POWERPROJECT</div>

PowerProject consisted of a combined heat and power (CHP) plant for a large-scale institutional user which would eventually allow the client to provide up to 90% of its own electricity needs. On-site construction began in July 2008, having previously been in the planning stage for approximately three years. The project design team involved nineteen members from eleven different organizations. Unlike the *OfficeProject* build, the *PowerProject* construction operated as two distinct phases ("the build" and "fit-out" stages). In the first phase, the building (often referred to by the design team as the "shell" or the "shed") was constructed. In the second phase, the power generation equipment was installed (referred to as the "fit-out"). Initial discussions concerning the CHP had been taking place for some time, and a number of different technologies had been considered. However, it was when the Fit-out team project administrator/manager met a CHP specialist who knew a design company that could develop the innovative technology they needed and provide them with the type of power generation they desired, that they then began to consider seriously the instigation of the project. The two-stage approach to the build, as well as uncertainties regarding the innovative technology being employed, provided a number of concerns for the successful completion of *PowerProject*. A pictorial representation of the network connections (a sociogram) for *PowerProject* is seen in Figure 2.

Figure 2: Sociograms for *PowerProject*

| *PowerProject* Formal Communications | *PowerProject* Informal Communication |
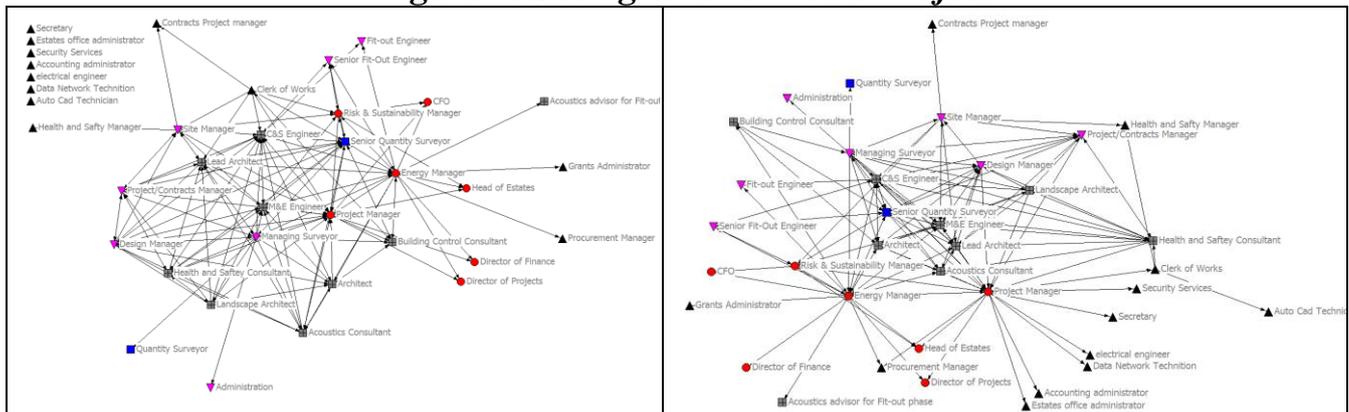
Behaviour and attitudes through contagion

As the results in Table 3 were an aggregate of members from both projects and analysed by role, the observations discussed in relation to *OfficeProject* apply equally to the communication patterns by role on *PowerProject*. The instigation of the project was based on friendship networks and trust between individuals. The client project administrator and his risk and sustainability manager were unsure of adopting the new energy producing technology and felt it would be a high-risk project. It was through their mutual respect of the Fit-out contractor who was a leading innovator in CHP energy generation that they initiated discussions of the project. As a consequence, they were open-minded about the adoption and investigated it further, and commissioned a feasibility report. It was this investigation that triggered their recognition that the project was feasible and that they could learn from pursuing what was a radically innovative technology. In the sociograms in Figure 2, the fit-out team member sit at the periphery of the sociograms, connected mainly thought the project administrator and the risk and sustainability manager, to the rest of the project team.

Consistency in attitudes and knowledge was facilitated in part through the transfer of the original design team to the contractor, which helped with the consistency of the design: "…*had this not been the case the new team would have taken time and made potential changes out of ignorance*" [project administrator]. The client also involved the contractor ahead of the final cost of the contract being agreed. This allowed the contractor to "…*help influence the design while still within the employers fluid design process ahead of the design freeze, it allowed the contractor to prepare suppliers and contractors earlier than would normally be the case, and it helped build a sense of team work with the whole project participants rather than a potential 'contractual' approach often employed in the industry.*"

As was the case with *OfficeProject*, one of the key socialising mechanisms in meetings for *PowerProject* was the use of humour. In every meeting there were lots of jokes, both about key participants on the project and about the process of the build itself. This was often used to defuse tension, form social bonds, and to communicate tacit understanding of the issues. In the second project meeting a joke was made about one of the client's team, whose view of most project delivery one actor viewed as "…"*just-too-late*" *delivery*". A further socialising mechanism employed was a team trip to visit another CHP project. The purpose of this was to observe a similar project being undertaken. This reinforced the team dynamic and afforded group cognitive consistency in the recognition of the problems that the project was having and how they would avoid repeating these mistakes.

Barriers to contagion - immunity to network learning

There were a number of similarities and differences between the network level statistics for the two projects. The average geodesic distance was lower (1.26 and 1.33) meaning that the average distance for both formal and informal communication modes were even more infrequent, however they demonstrated greater compactness (.87 and .84) and less fragmentation (.13 and .17) of communication between network members. The proportion of all possible dyadic connections that were actually present was very low (only 9% and 8%), and the value ratio (the ratio of all tie strength that is actually present to the number of possible ties) was only .14 for formal and .15 for informal communication modes. The overall network density (.39 and .34) was also lower. Only 21.56% and 18.74% (lower than for *OfficeProject*) of dyads are also triads, and most notably, only .76% and .57% of all triads display transivity (i.e. they have enough directed ties to display transivity), with 49.01% and 43.94% (again lower than for *OfficeProject*) of the relations that could be transitive actually are. Therefore, we see the same pattern of relatively dense communication patterns where ties exist, but a more fragmented picture of ties being established however with *PowerProject* these characteristics are even more pronounced.

Arguably the greatest barrier to network learning for *PowerProject* was the variance in views of the project due to the two-stages involved ("build" and "fit-out"), and the innovative technology being employed. This was recognized by the project manager who observed: "*I take a position that the building team - I don't think have totally absorbed - that this project is very much about a lump of engineering that needs a roof on it whereas they are used to providing buildings in their own right that are the total focus of the project. From my perspective the building is a minor focus of the project and so there is a disparity*" and that "*…sometimes this leads to conflict*".

The Krackhardt's GTD results also told a similar story to those of *OfficeProject*, with some more marked results. The four component measures tell us that in terms of connectedness, in the *PowerProject* network fewer actors (.64) for formal communications but the same (.87) for informal communications are embedded in a single structure. Only a moderate proportion (but higher than for *OfficeProject,* particularly for informal communication modes) of all tied pairs have reciprocal ties, and are thus non-hierarchical (.68 and .74). In terms of efficiency the PowerProject network is even more efficient than *OfficeProject* (.85 and .91). Finally, as with *OfficeProject*, the least upper bound shows that all actors have a common boss (1.00). These four measures show communication patterns to be even more strongly hierarchical in structure than for *OfficeProject*.

These results, pointing to even greater disparities and disconnects between members in this network, may well be related to the two-stage nature of the project and the difficulties of co-ordinating the building of the structure and the subsequent fit-out with the CHP technology. One representative for the client observed: "*There is a barrier there, I think because the other team work totally different to the way I do. They are much more formally structured by meetings and notes of meetings and that approach, I believe, which seems to limit communication … I act as a conduit*". In this instance it was recognized that adopting an overly-formalized approach to the project would inhibit flexibility. This was exacerbated by the paucity of evidence of managing the process of the fit-out phase of the project, unlike *OfficeProject*. Actors often had to recall from memory what had been agreed and specified.

Interestingly, in the case of the project leader, immunity to network messages may have been beneficial, particularly as the project manager had to study the regulations independently and was attempting to understand every detail and nuance of the project: "*As project leader my goal is to complete the project successfully…..there is a whole range of regulatory issues and I have to be sure that I comply with what is necessary. In order to be a correctly managed and operated function you have to know all of this and take it on board, the project cannot succeed if that is wrong.*"

Consistent with *OfficeProject*, *PowerProject* employed a number of simple artefacts in order to ensure learning and cognitive consistency in the project network. This included a project time-line, construction designs, and pictures drawn by actors on site as well as in meetings. The underlying commonalities in actors' training (such as using technical drawings) allowed them to bridge understandings, as does prescribed norms driving common behaviours such as Health and Safety procedures and requirements give them a common behavioural culture that dictates how they act and work on site.

CASE ANALYSES AND DISCUSSION

The purpose of this study was to examine network learning through the application of contagion theories. How did contagion manifest in each of the projects studied? Contagion theories help us to recognize the emergent properties of networks and that communication and learning often occur in an ad hoc fashion, *in situ*, and via informal means. Contagion also provides the basis for actors' to "negotiate" their roles and to learn in temporary organizational settings. Temporary organizational forms (Bechky, 2006) are widely used in industries where projects are common such as the performing arts, construction, advertising, consulting, and high-tech industries, among others. The two construction projects examined exhibited common characteristics of temporary organisations: absence of complete design specification, actor role changes, limited access to certain actors at times, task complexity, time pressure, and discontinuous nature of the task.

Due to these characteristics it is impossible to envisage a clear project structure prior to commencement and to foresee the challenges that will be faced in the course of completing a project. As a consequence actors have to operate within a network that is evolving; in other words, to participate in "a game that moves as you play". Exposure to information in such circumstances is most dependent on informal and emergent network communication – relatively less studied phenomena, but which more accurately capture the way "things actually get done" in networks (Kadushin and Brimm 1990), in contrast to more formalised collaborations in which learning goals are prescribed and are relatively well-understood. Hence, contagion theories help explain how actors are "exposed" to information and knowledge in order to learn how to perform tasks efficiently in changing networks.

Similar to Bechky's (2006) study of short-term film projects, which found that such short-lived projects – rather than unstable and ephemeral as portrayed in earlier studies – are often organized around structured (but often negotiated) role systems where autonomy is often exercised *in situ*; our findings also point to temporary organizations that were organized around structured and negotiated role systems where autonomy is almost exclusively exercised in the course of a project. What we recognized in the construction projects studied was in the presence of ambiguity and novelty actors adopt co-ordination mechanisms that rely on informal communication practices negotiated *in situ*. Hence actors "negotiate" the structure of their own emergent network and the form it takes. Formal structures are ever-present but take a secondary role in favour of interpersonal contact performed on an ad hoc basis. Given this circumstance it would seem worthwhile examining the role of co-ordination practices in the two case studies examined. Given each actor's specialisms, natural "cognitive boundaries" are created between actors. These are managed and negotiated in several ways. Role co-ordination is undertaken particularly in tasks which lack permanent structures and strict rules. In the case of both construction projects we observed several mechanisms – that arose through the exposure to attitudes, information and behaviour, or contagion, for each actor in the network – to help enact actor's roles including social influence (such as the use of humour), face-to-face role negotiation, and through the use of simple project artefacts. We examine each in turn.

Good natured humour was used between actors as a socialising mechanism in both projects studied, but it also acted as a valuable means of emphasising role expectations and defusing tensions. Humour at work helps defuse stressful situations as well as to communicate expectations (Hatch, 1997; Roy, 1959), and to help create social structure (Coser, 1959). An example of this was observed in *PowerProject* when a contractor joked about completing projects for the client who would inevitably view these as "…"*just-too-late" delivery*" in a team meeting. All participants in the meeting (including the client) laughed at this remark; however it did serve as a means to gently admonish the client who they felt harboured unrealistic assumptions concerning the completion of projects which often have high degrees of ambiguity and novelty. Another instance of humour was the actions of one team member during a team meeting for *OfficeProject*. In the initial meetings between the contractor and the client teams both groups had occupied adjacent positions opposite one another in the room. In one meeting an engineer remarked on this and made a joke about the situation, he then (rather theatrically) got up and walked across the room and sat with the contractor. Although team members laughed at his observation this also served as a veiled reminder that they would collectively fail or succeed as a group rather than individuals and that the project was ultimately a team endeavour.

Face-to-face role negotiation was also evident in the numerous informal site meetings. During these ad hoc meetings actors (such as engineers, for example) would, often through a process of trial and error, and experimentation, attempt to resolve situations where the design was not feasible or practical. Actors usually took pleasure from these situations, and from drawing on the expertise at hand on the site rather than necessarily through formal lines of reporting. In contrast, the formal meetings were viewed less favourably by participants. Influence was also exerted through friendship networks. For example, *PowerProject* was initiated based on the friendships between actors who began informal discussions concerning the adoption of a perceived high-risk technology.

A series of simple artefacts acted as a useful mechanism to achieve role co-ordination in both projects. This included the use of drawings, progress charts, reports, and photographs, all of which served as boundary spanning objects between actors and their "cognitive boundaries" and provided ways of sharing knowledge on both construction projects. Such artefacts are valuable particularly when a task or project involves "...many actors attempting to coordinate activities in a fixed time period where the goal may be relatively clear but the ways in which it can be achieved are not" (Mason and Easton, 2009: 7). Consequently the artefacts helped actors to breach each other's cognitive boundaries and to help ensure cognitive consistency across tasks. Previous studies have demonstrated that simple artefacts (such as Excel spreadsheets, architectural plans, and digital 3-D representations) act as a means to negotiate interpretations, practices and priorities, and as a way of capturing knowledge across diverse communities of practice (Cacciatori, 2008; Brown and Duguid, 1991).

Finally, what can we infer about network learning given the foregoing? What we have observed in the two construction projects studied is that actors' are exposed to attitudes, behaviour and information in differing and evolving ways that are often via informal means, which is due to (and influenced by) the characteristics of the temporary organizations they are operating within. As a consequence actors were compelled to negotiate and reconcile their role within each project. This role negotiation ultimately influenced the nature and extent to which actors learned. Role negotiation in the emergent network was undertaken to ensure cognitive consistency and achieve consensus in what were complex and ambiguous tasks, to manage and express expectations, as well as to ensure that actors' had similar interpretations of situations and practices in order to complete both projects. Considering the learning types proposed by Bångens and Araujo (2002), face-to-face role negotiation and social influence provided actors with opportunities for learning-by-interacting (learning from other actors) and for learning-by-doing (undertaking often challenging tasks with other actors), while the use of simple artefacts provided opportunities for learning-by-using (breaching cognitive boundaries through shared artefacts). We summarise this in Table 5.

Table 5
Contagion, Role Negotiation, and Learning Opportunities

CONTAGION Exposure to Information	ROLE NEGOTIATION Purpose	LEARNING OPPORTUNITIES Outcome
Face-to-face role negotiation *(informal meetings, in situ, ad hoc,* *interlocking, friendship networks)*	Ensure consistency, Negotiate consensus	Opportunities for learning-by-interacting, Opportunities for learning-by-doing
Social influence *(humour, gentle admonishing,* *socializing)*	Expressing expectations, Managing expectations	Opportunities for learning-by-interacting
Artefacts *(drawings, progress charts, reports,* *photographs)*	Maintaining consistency, interpretation, and practices	Opportunities for learning-by-using

CONCLUSIONS: CONTAGION AND LEARNING

In this study we posed the question: how is information effectively disseminated among actors in networks and how do emergent networks learn? Drawing on the disease metaphor underpinning contagion theories, we examined network members' exposure to knowledge, attitudes and behaviours of other actors. Contagion theories recognize that networks have emergent properties and that actors may learn from one another through both formal and informal means. Due to the temporary organizational forms of the construction projects studied actors operate within a network that is evolving, actors were compelled to negotiate their roles and negotiate the most effective means of completing tasks. We proposed that communication, as enacted through the practices and processes of contagion, offers important learning opportunities (by doing, using, and interacting) for enhancing

social integration and cognitive consistency. By the same token, resistance to contagion may come from pre-existing attitudes and beliefs formed through a weaker form of a contagious network message (i.e. inoculation) or a resistance to change (i.e. immunity). Our results showed marked differences in communication practices by the different role groups, and across the two different projects.

Our contribution recognizes that communication is emergent and dependent on network linkages which mitigate the convergence of attitudes and understanding. These networks could be viewed as "shadow networks", or the way "things actually get done" through informal links between actors. Communication and learning in these networks is "emergent", and does not necessarily follow typical organizational structures, but rather informal "grape vine" type communications. This has important implications for managing in such networks, as information may bypass traditional and more formal routes to help inform actors. In this sense companies learn *with* rather than *from* each other. Against this, actors' roles are continuously "...being learned and elaborated" (Bechky, 2006: 14).

Instances of behaviour and attitude change through contagion were evidenced and offer insights into managerial practice in such networks. In particular, the use of artefacts (i.e. drawings, progress charts, reports, and photographs in particular) may offer important opportunities to bring together fragmented expertise and enhance the clustering of project communication behaviour in strongly hierarchical project structures. In addition, face-to-face role negotiation, influenced by personal relationships such as friendship ties, offer opportunities to ensure consistency and consensus. Finally, socialisation mechanisms such as the use of humour in more formal communication settings and the instigation of a team expedition to a similar project to benchmark progress and help problem-solve common issues, provided important contagion opportunities to learn.

Project structure also provided an insight into possible barriers to contagion. In particular, on *PowerProject* the two-stage nature of the project (the building structure followed by the equipment fit-out) let to difficulties of co-ordination and immunity to learning by members of the network. Therefore, project structure needs to be considered as an important feature of network learning. Considerations of network structure to enhance the effectiveness or efficiency of network operations needs to be balanced with the impact on communication behaviours and contagion in the network.

The limitations of our study reside primarily in its reliance on inductive methodology, and therefore its limited ability to statistically generalise to other construction industry relationships and to other industries. However, as a contributor to theory building our findings do recognise key aspects of contagion in organisational networks. Further evidence from alternative cases in other industries or contexts would further extend this work in relation to the how and why of contagion in networks, as would alternative methodologies which could seek to statistically generalise the what, where, how, and who of contagion in networks.

The implications of this study highlight the importance in recognizing how learning occurs in temporary organizations and how learning takes place through informal means within emergent networks. There would seem to be significant merit in future research that considers learning in "shadow networks" and also in temporary organizational forms.

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