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**Influences of Social Capital on Knowledge Creation: an exploration in the
UK Built Environment Sector**

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Abstract

The UK Built Environment Sector faces a number of important challenges such as reducing carbon emissions and cost. New knowledge should be created to develop new practices, competences and capabilities to overcome these challenges. Studies that characterise knowledge creation as a transformation process through the networks of social relationships and intra-organisational teams are needed to understand, and thus improve such processes in project environments. Structural, relational and cognitive dimensions of Social Capital influence the utilisation of knowledge creation opportunities inherent in project networks. Hence, Social Capital provides the essential infrastructure for knowledge creation. A fresh approach to operationalising the concept of SC through social network analysis and content analysis is thus required. This paper develops and explores the conceptual relationships between knowledge creation and social capital in the context of two live building projects. There are two main conclusions. First, structural network indices are indicators of knowledge creation opportunities but they should be considered in conjunction with the relational and cognitive dimensions to determine whether and how opportunities are being utilised. Second, project communication strategies should be designed to enable actors in structurally advantageous positions for knowledge creation to utilise these opportunities.

Keywords: social capital, knowledge creation, social network analysis, absorptive capacity.

1. Introduction

The built environment sectors across the globe and in the UK are under immense pressure to improve design and building practices to substantially reduce buildings' energy use (WBS, 2009) and to respond to increasing demand in unconventional activity, e.g. upgrading existing stock. Companies that can create new knowledge, will be able to respond to such big challenges (Stern,2006). Despite this important role and the recognition that an organisation's capability to continuously source, combine, develop and apply knowledge is its main source of competitive advantage (Cross, Parker, Prusak and Borgatti, 2001), our understanding of how knowledge is created in project environments is still very limited. This is due to limited research on the determinants of and precedents for the type of social processes, patterns and practices associated with effective management of knowledge in project environments (Brookes, Morton, Dainty and Burns, 2006). Also, little effort has been put into systematic ways of working with knowledge that is embedded in networks (Cross et al., 2001).

The main proposition of this paper is that Social Capital, i.e. the aggregate of resources that network members accrue as a result of their relationships, provides the essential infrastructure for knowledge creation opportunities to be utilised. If this is achieved; new knowledge, new practices, competences and capabilities can be created (Ciborra and Andreu, 2001). Unlike resources, these outputs are unique to each organisation, unit or team; and so are the sources of competitive advantage (Grant, 2000). As a result, units have a better chance of adapting to changing business environments by changing their practices, sustaining their competitive advantage, and continuing to meet

their customers' requirements (Wagner and Hansen, 2005). Those that are capable of utilising these opportunities are better placed to respond to the challenges that they face.

Project environments within the built environment sector provide an appropriate context for knowledge creation as networks of professionals who integrate their specialist knowledge for the delivery of an asset to meet the client's brief. These specialists already subconsciously create extensive new knowledge. The challenge is to find ways of understanding this process so that practitioners become aware of their competence, enabling them and their teams to rise to the grand challenges that the industry faces.

This can be achieved by understanding how Social Capital influences the creation of new knowledge in project networks. The collective influence of sources resources of social capital on the knowledge creation process have remained largely unexplored (Borgatti and Cross, 2003). A fresh approach to exploring these influences is thus required. This paper aims to develop one by operationalising the concept of social capital through social network analysis and content analysis. The key research questions are:

- 1) Do actors use the knowledge creation opportunities their structural positions offer? If so, how?
- 2) How do structural, relational and cognitive dimensions of social capital collectively create and influence the conditions for knowledge creation?
- 3) How do practitioners utilise resources of social capital for knowledge exchange and combination?

In order to answer the above questions, this paper first briefly introduces the concept of Social Capital. Then its conceptual relationship with knowledge creation is established. Section 4 explains the methodological approach. Data analysis and the emergent results are discussed in Section 5. Conclusions are drawn and recommendations for further research are made in the final section.

2. Social Capital: definition & discourse

Social Capital is the whole of the actual or potential resources that individuals can access through their relationships (aka ties) with other people (Bourdieu, 1986). It constitutes individuals making the demands (“the possessors”), those agreeing to the demands (“the sources”) and the resources at their disposal. The configuration of individuals and their ties with others determine the structural dimension. The personal relationships that individuals may develop by utilising the opportunities they accrue as a result of their structural positioning is the relational dimension. Those resources providing shared representations, interpretations, and systems of meaning, e.g. shared common language in a particular sector, make up the cognitive dimension (Nahapiet and Ghoshal, 1998). Many studies that consider the relationship between social capital and knowledge creation focus on the structural features of networks. They explore the potential the structure inherits for timely access to knowledge resources and for knowledge transfer (see for example Willem and Scarborough, 2006; and Chiu, Hsu and Wang, 2006). Others follow Lin (2001) by taking the view that network locations are only precursors to knowledge creation opportunities within the networks and therefore tie contents should be analysed to identify whether and how these opportunities are utilised. Studies in both camps tend to oversee either the tie contents or the possessors’ network locations. Thus, the relationship between Social Capital and its

influence on knowledge creation remains largely unexplored (Borgatti and Cross, 2003). This important gap must be closed to provide new insights into how new knowledge is created.

Tsai and Ghoshal (1998) should be credited for leading the way. They draw upon social network theory to explore the structural dimension and its influence on relational and cognitive dimensions in terms of their potential to stimulate trust and perceived trustworthiness; and to shape a common set of goals and values between individuals that belong to a particular network. They focus on Granovetter's (1973) views on the strength of ties forming dyadic relationshipsⁱⁱ and on the centrality of a business unit. As a result, other structural stimulators of knowledge creation are overseen even in this novel study.

Beyond this exception, many authors refer to Cohen and Levinthal's (1990) seminal work on absorptive capacity in their discussions of how new knowledge is created (for example Tsai, 2001 and Jashapara, 2007). Most follow their approach to use R&D activity as a measure of absorptive capacity, which some argue is not the best indicator (Schmidt, 2005; and Miozzo and Dewick, 2002). Hence, a new approach to exploring the knowledge creation process outside the domain of R&D intensity is necessary. It should focus on understanding how resources of social capital are utilised during the two generic knowledge processes, i.e. exchange and combination, and how they influence and create the conditions for knowledge creation to occur.

3. Knowledge Creation and Social Capital

The approaches to developing a theory of knowledge creation can be divided into two strands. The first one is dominated by Nonaka's (1994) Socialisation, Externalisation, Combination and Internalisation (SECI) model. It characterises

knowledge creation as a process of conversion from tacit to explicit to tacit knowledge. The second strand focuses on exchange and combination of knowledge through social interaction (McFadyen and Cannella Jr, 2004). A detailed discussion of the first strand is out of the scope of this paper, which focuses on the social aspects of KC rather than the conversion of one type of knowledge to another. Therefore, a brief literature review of the second strand follows.

Social interaction plays an important role in creating new knowledge by exchanging and combining diverse knowledge from different sources in novel ways (Kogut and Zander, 1992; Grant, 1996; and Nahapiet and Ghoshal, 1998). Application of this new knowledge to commercial ends ahead of their competitors gives organisations competitive advantage (Grant, 1996). These complex social processes are enacted through coactivity and relationships between possessors of knowledge (Nahapiet and Ghoshal, 1998).

Moran and Goshal (1996) identify three conditions for knowledge creation: opportunities for exchange and combination, individuals who can recognise the value of external knowledge; and their motivation to enter into transactions that do not follow common market norms. The networks of social relationships of people, and of intra-organisational teams provide opportunities by making communication channels available (Zander and Kogut, 1995). They also facilitate search for knowledge (Baldwin and Hanel, 2003), provide the potential for knowledge acquisition to networkⁱⁱⁱ (Inkpen and Tsang, 2005; and Cross et al.,2001). Moreover, they enable the integration of specialist knowledge (Caloghirou, Kastelli and Tsakanikas, 2004; Un and Cuervo-Cazurra, 2004; Huang and Newell, 2003).

Timely access to resources and referrals is another advantage these networks offer by facilitating faster access to knowledge that resides in it.. This may well increase the value of knowledge given that an organisation's ability to create new knowledge faster than its competitors is of the essence. Actors are also likely to be made aware of knowledge creation opportunities through referrals from other network members, potentially increasing the diversity of the knowledge to which network members have access.

As such, possessors, sources and the resources within a network create opportunities for knowledge creation. These are the building blocks of Social Capital which provides a robust framework to study how these opportunities emerge and how individuals utilise them. As stated above, studies in this domain focus on the structural features of networks, and offer two opposing views on how network structures facilitate access to (external) knowledge, and thus create knowledge creation opportunities.

Both strands accept that tie strengths and network density have different influences depending on the type of knowledge that is being transferred. The first standpoint is that 'weak ties' (Granovetter, 1973) and 'structural holes' Burt (2001) provide better access to external knowledge. 'Weak ties' are considered effective for the transfer of non-complex, easy to codify knowledge. They are also more likely to become bridges for new information distributed in different regions of a network (Granovetter, 1973). Structural holes are the weaker connections between sub-networks separating non-redundant sources, i.e. nodes that connect different nodes (Burt, 2001). They provide access to external knowledge sources through brokers who bridge clusters of networks and/or the unit and the external environment. Dyadic redundancy indicates how many of the other sources in the neighbourhood of a possessor are also

tied to each other. The larger the proportion of others in the neighbourhood who are tied to a given source, the more "redundant" the possessor's direct tie becomes (Hanneman and Riddle, 2005). Dyadic redundancy is used as a measure of structural holes in a network. High levels indicate that there are few structural holes (Hanneman and Riddle, 2005). A node's potential to become a 'broker' or 'gatekeeper' is measured by 'betweenness centrality' which reflects whether a node has a high potential to control and filter information flow between others (Loosemore, 1998). It is calculated by counting the shortest paths between all pairs of nodes in a network. If nodes are located on many shortest paths, then they have higher betweenness centrality scores.

The second strand focuses on the density of a network and its 'strong ties'. Density represents the number of existing connections as a percentage of all theoretically possible connections. A density figure of 50% denotes that only 50% of all possible connections actually exist. Dense networks are considered to possess higher levels of Social Capital. Their members have access to more resources, but they are more likely to be constrained by the network's norms and values, reducing the likelihood of pursuing new ideas and initiatives.

Efficiency of communication in a dense network hangs on a delicate balance. On the one hand, there is the potential to transfer information and knowledge to all parts without exception. A significant advantage is that tacit, complex knowledge, which is more likely to yield new practices than explicit knowledge, can be transferred effectively through strong ties which characterise dense networks (Hansen, 1999). These ties also indicate social cohesion which in turn increases a node's willingness and motivation to invest time and effort in knowledge transactions (Reagans and McEvily, 2003). As such, dense networks support the relational and cognitive dimensions of Social Capital. On

the other hand, there is the risk of communication and/or information overload in networks with densities above 0.50 (or 50%) (Krebs and Holley, no date) due to higher number of redundant ties. Nodes in dense networks with high degree centralities could be at higher risk of communication overload than those with lower scores. This is mainly because the former are more closely connected to their immediate environments, and thus have higher communication activity (Freeman, 1979).

The above literature provides a robust starting point to sketch knowledge creation opportunities that structural aspects of networks offer by illustrating their varied and potentially contrasting influences. It has three main weaknesses however. First, it deals with a limited number of structural network characteristics at any one time, leaving aside the cumulative effect of a given structure. Second, structural positioning on its own does not reflect whether nodes make effective use of such opportunities. This should be established through empirical research, bearing in mind that relational and cognitive dimensions may explain differences in the knowledge-creating behaviour of nodes. These differences mainly emanate from the fact that the possessors and the sources do not follow the principles of transaction economics when they are utilising opportunities for knowledge creation (Grant, 1996; and Portes, 1998). Actors are deemed to consider sources of social capital such as reciprocity of exchanges, in deciding whether to take part in a knowledge transaction. Third, the remaining conditions for creating new knowledge, i.e. actors' ability to recognise the value of external knowledge and motivation, are by definition overseen because they are largely influenced by cognitive and relational dimensions (Nahapiet and Ghoshal, 1998). This paper aims to make

a contribution to overcoming such weaknesses by exploring the collective influences of the three dimensions.

Knowledge creation opportunities are only utilised if actors recognise the value of existing knowledge in terms of its potential to be utilised in commercial markets. Cohen and Levinthal's (1990) absorptive capacity concept underpins the explanations as to how individuals perceive this value (see for example Tsai, 2001 and Jashapara, 2007). It also represents '[an organisation's ability to] identify sources for effective acquisition of new, external information; assimilate and apply it to commercial needs' (Cohen and Levinthal, 1990). Nahapiet and Ghoshal (1998) collectively term these capabilities as 'combination capability'. They argue that it is largely dependent on the cognitive dimension, which provides people with a common language and understanding, in other words some prior related knowledge. The level of prior related knowledge is dependent on both an organisation's interface with the external environment and the transfer of knowledge within and across its subunits (Cohen and Levinthal, 1990). Hence, structurally, individuals who stand at the interface of either the firm and the external environment or between subunits within the firm play an important role in the recognition of value (Cohen and Levinthal, 1990).

Shared language has a number of additional influences. First, it increases the number of opportunities to create new knowledge because actors have (or develop) an appreciation of the ways in which action may be co-ordinated as a result of being aware of each other's knowledge and expertise (Nahapiet and Ghoshal, 1998). Second, it facilitates an actor's ability to gain access to resources. Third, it increases the exchange performance of distributed knowledge systems (Borgatti and Cross, 2003) by enhancing the efficiency

with which knowledge can be transferred- i.e. “capacity for aggregation” (Grant, 1996).

A number of structural indices have also been shown to be precursors of absorptive capacity. These include: structural holes representing a unit's interface with the external environment (Cohen and Levinthal, 1990; and Burt, 2005, quoted in Borgatti and Li, 2009) and network reach (Burt, 1997, Friedkin, 1983 and Hansen, 2002). How structural holes facilitate access to new external knowledge has been described above. Network reach is a measure of the length of information paths between nodes. It is calculated by counting the number of paths of different lengths, e.g. Path Length 1, and then representing this number as a percentage of all paths of different lengths. The key paths in networks are one and two steps, and on rare occasions three steps (Burt, 1997). Such “short-path lengths enable the team to know precisely about opportunities to create new knowledge and to discard irrelevant opportunities” (Hansen, 2002). Thus, short path lengths in a network have a positive influence on its absorptive capacity by enabling nodes who span them assess the value of external knowledge.

Motivation is another condition for knowledge creation . Individuals need to feel that their engagement in the knowledge activities would be worthwhile, despite the uncertainties associated with them, e.g. uncertainty of what is being exchanged, its value and whether a return will at all be received. Sources are more likely to be motivated, if they are confident of receiving a return equal to the value created by the resource that they provide (Grant, 1996; and Moran and Goshal,1996). Such confidence exists in environments where trust is abundant; and norms, values, obligations and expectations dictate reciprocating favours.

The relational dimension is instrumental in establishing such an environment, where actors are obliged to behave in certain ways that fit in with the norms of that particular 'society'. For example, members are more likely to be motivated to engage in knowledge transactions in a network where sharing knowledge to improve project performance, is the norm. A source's level of motivation to take part in such transactions is also determined by how much bounded solidarity he developed with the other members. The emergent trust gives sources the confidence that exchanges will be reciprocal, even if payback is in a different currency such as the granting of approval or allegiance; and comes collectively from the network in the form of status, honour or approval, rather than only the recipient. Such guarantees are accepted by the sources because these transactions are embedded in the social structure of the network and are governed by enforceable trust which is nurtured by the relational dimension. Thus, this dimension counter-balances the opaqueness and uncertainty associated with knowledge transactions, and could deal with issues around reluctance to share knowledge and provide motivation to sources in the network.

This section established social capital as a useful concept to explain how knowledge is developed and shared within social contexts including project environments. It illustrated how its different dimensions help the conditions for knowledge creation to occur. It identified tie strengths, network density, structural holes, network reach; and degree and betweenness centralities as structural indices which potentially make knowledge creation opportunities available to network members. Moreover, it discussed how the relational and cognitive dimensions could influence the utilisation of these opportunities. The

next section explains the methodological approach devised to explore these relationships in an empirical context.

4. Methodology

A methodological approach that can deal with the three dimensions of Social Capital is instrumental for achieving this paper's aim. Thus, the concept should be operationalised in terms of its structural and qualitative aspects (Van Deth, 2003 and Adler and Kwon, 2002). The analytical approach should facilitate both the exploration of structural aspects, through network analysis, and of relational and cognitive dimensions, through qualitative analysis of the tie contents. This approach reduces the risk of unduly focussing on the network structure by using network locations as measures of social capital. Instead, network locations are considered its precursors and "embedded resources [to be] valid measures for [it]" (Lin 2001).

Existing knowledge in this study area is limited. Thus, this research is exploratory, dictating a qualitative approach in a case study context. Case studies are appropriate because of the inextricable relationships between the different dimensions of social capital and the tie contents, making this system a complex one to study. The methods chosen, the length of the research programme, and the industrial partners' eagerness to receive at least the initial results within a short-time scale called for a small sample of two case studies. They were selected, in collaboration with senior staff affiliated with industrial partners. The chosen projects had to be procured using 'collaborative' contracts, require knowledge creation, unique to the industrial partners, type of projects partners were likely to undertake in the future; and in the pre-construction phase. These criteria were used to ensure that knowledge

creation could be studied in its context. Two intra-organisational project teams which were undertaking projects over £3m value in South-East England were selected. Projects were chosen as the units of analysis mainly because they have long been regarded as the settings of complex processes of new value creation and innovation (Sayles and Chandler, 1971;Winch, 1998).

Project One was the construction of an office block in the City of London by one of the UK's largest development companies to become the headquarters of an insurance company. It was delivered through a joint-venture between a construction management company and the development company. It made use of a pioneering twin wall technology and concrete made of china clay stent as well as fly ash. These innovative solutions required discussions between the parties involved to commence well in advance of construction to allow time to obtain test data, develop mix designs and perform trials. At the time of data collection, the project was in construction phase with much of the structural framework complete.

Project Two was the refurbishment of a laboratory/office facility for two multinational pharmaceutical companies that merged three years before the project commenced. The £5m project was undertaken in order to co-locate two research groups of the merged companies so that process efficiencies could be achieved. At the time of this research project, Project 2 was in early design phase which involved internal clients and external consultants. Thus, it was necessary to manage and meet expectations of many internal clients which had different views on safety assessments, procurement, etc. The client and the main delivery partner had established working relationships for more than a decade.

Semi-structured interviews were used for data collection. The interviewees were identified in collaboration with Project Directors (or their equivalent) in each case so that team members that were most likely to play an important role in creating knowledge were included and that the sample was representative. Thus, the members' importance for knowledge creation defined the boundaries of the networks to be studied. This was a "reputational approach" to boundary identification (Scott, 2000). It was necessary to gain the teams' trust and full support, despite the inherent potential bias. As such anticipated levels of co-operation gained prominence over the global representativeness of the deliberately small sample. Following this sampling approach, eighteen interviews were conducted for each case study. All but one were recorded.

The interviewees were asked to focus their minds on a recent incident where they needed to come up with a new idea to solve a problem and answer the questions bearing this event in mind. As such, the data reflects the attributions of the respondents to the knowledge that they created. This is one of the main limitations of this research.

The respondents stated how often (i.e. daily (4), weekly, monthly, rarely (1)) they contacted other people within the team to source knowledge. Structural matrices, which were imported to InFlow 3.1 and UCINET 6 for Social Network Analysis (SNA), were then generated. Table 1 shows the header row and the first row in a structural matrix. The first column identifies the interviewee, the second one his sources of knowledge and the third the frequency of contact. InFlow3.1 and UCINET6 calculated the network indices discussed in Section 2. Two packages had to be used to produce good visual network representations as well as calculating all the necessary indices. Structural indices were used to

identify areas of focus for qualitative analysis which determined whether and how knowledge creation opportunities inherent in the networks were being utilised.

Data on relational and cognitive dimensions was collected through a series of open-ended questions (see Table 2 for selected examples). This rich, qualitative data was tabulated in an Excel matrix for each case study. The interviewees formed the rows of these matrices, while the open-ended questions became the columns. Tabulation eased the management of and access to the rich, contextual data. Also, Excel's filter feature facilitated the viewing of data chunks when the relationships between the structural and the relational and cognitive dimensions were being explored.

5. Analysis & Results

Network maps for Project 1 and Project 2 are respectively illustrated in Figure 1 and Figure 2. The project managers' central positioning and the lack of structural holes are evident in both maps. High dyadic redundancy results, (highlighted in Table 3 and Table 4), corroborate the lack of structural holes.

In Project 1, key actors such as the client's project directors (or managers), who are arguably better placed to recognise the value of external information because of their grasp of the overall picture, are located in neighbourhoods with very few structural holes (Figure 1 and Table 3). Moreover, all but one are affiliated with the construction management company and are connected to each other mainly with strong ties (**Error! Reference source not found.** Table 3). Their positioning and the strength of their ties limit their exposure to external sources of knowledge, and thus their absorptive capacity. Qualitative data shows that actors' network positions do not correlate with the level of their

external knowledge use, which is variable. Their first choices of external knowledge sources are websites, company knowledge repositories on the intranet and other sources of explicit knowledge. Hence, these actors do not use their Social Capital in accessing external knowledge.

Actors with high dyadic redundancies in Project 2 however are affiliated with different companies and are linked to each other with strong and weak ties (Figure 2 and Table 4). The majority of the weak ties connect actors affiliated with the Client organisation and their consultants, providing structural opportunities for absorbing knowledge external to the different organisations. Actors in these positions make use of external knowledge at different levels but just over half choose colleagues in their organisations or in their supply-chain as their first port of call for external knowledge. This finding contrasts with Project 1 and suggests a heavier reliance on social capital to source external knowledge.

Table 5 illustrates that actors with high dyadic redundancies also have the highest betweenness centrality scores, providing the opportunity either to play brokerage roles or to control information flow. Contrary to the common perception and appearing at the top of the betweenness centrality rankings with markedly higher scores, the project managers do not hold the knowledge networks together however. Figure 3 and Figure 4 show the relevant maps excluding the PMs and their ties. Both networks remain intact with slightly lower densities (Project 1 32% and 27% respectively, Project 2 46% and 44% respectively), suggesting that PMs have redundant links that are not critical for knowledge transfer within the network. Therefore, they have the capacity to replace their redundant links with external links that would enhance their absorptive capacity.

This area of improvement is evident in the qualitative data regarding PMs use of external knowledge. Both PMs have unique advantages in accessing external knowledge resources given that they have the highest degree centrality results (Table 6). These positions also mean that they are well-connected to their teams, have high levels of direct communication with other nodes. But, these structural advantages are not exploited. Neither PM has extensively used external knowledge to find new ways of doing things in their projects. PM1 says his level of external knowledge use, which is sourced from web-sites, journals and personal contacts, is low. PM2 makes average use of external knowledge, which is sourced from colleagues in his office and web-sites. Both PMs could spread the net wider than they currently do in terms of accessing external knowledge rather than acting as knowledge banks to their team members.

The actors who used external knowledge to a high extent in Project 1 (n=7), also made limited use of their Social Capital in sourcing external knowledge. The majority of them (n=6) invariably sourced explicit information from web-sites, journals or exhibitions. This is also reflected in the fact that only one of these seven people puts a lot of effort into maintaining his external contacts. Findings on the use of external knowledge in Project 2 are very similar to Project 1. Hence, actors in both networks could improve their practices in terms of making use of their social capital to source external knowledge, rather than mostly sourcing external explicit knowledge.

However, Social Capital is more influential in sourcing knowledge within the team, as shown by the network density results and analysis of the relevant qualitative data. Project 2 has a high density (0.46) (see Table 7), providing nodes with fewer non-redundant resources than a sparse network, whilst

facilitating the sharing, maintenance and preservation of its resources (Borgatti and Li, 2009). Actors in this network rely on their dense network to create new knowledge. Just over half of the respondents (n=10) acknowledge 'informal chats' as the first knowledge creation opportunity (Table 8). This is followed by 'individual meetings with relevant members of the team' and 'formal meetings'. These actors also spend some of their free time with the sources that they would first consult, and put 'a lot' of effort into maintaining these contacts, nurturing social capital (Table 8). This is in stark contrast to the actors who consider that in the main 'formal team meetings' provide opportunities to create new knowledge. They invariably state that they put 'average' or 'very little' effort into maintaining their contacts. Clearly, there is a relationship between the amount of effort actors put into maintaining their social capital and whether or not they consider it to provide knowledge creation opportunities.

Further exploration of Network 2 (see Figure 5) shows that the advantages offered by social capital and strong ties to transfer complex knowledge across the network are mainly within the project management company, and that the PM is critical. The strongest ties (4) are only between employees of the project management company. Ties of strength 3 connect them to the consultants and the client through the PM. When the PM is hidden from the map two clusters, i.e. project delivery team and client organisation, emerge.

It is also evident that 'the chain of command' could limit the utilisation of the opportunities that SC provides in Project 2. The client imposed a hierarchical decision-making procedure which requires extensive stakeholder consultation upon the delivery team. 15 out of 18 respondents consult the team providing PM services to source knowledge and information (Table 9). 'Chain of command' determines the first point of contact for about half of these

respondents (n=7), including those who first state 'informal chats' as a knowledge creation opportunity (Table 8). The rest, who are invariably high-up in the 'chain of command', make this choice based on the source's perceived technical or managerial specialist knowledge. The three respondents, who do not consult the PM team in the first instance, are affiliated with the client and their first port of call is end-users or client's FM team. Hence, the 'chain of command' determines the first port of call for knowledge sourcing rather than relational aspects of Social Capital even for actors who consider it to provide knowledge creation opportunities and who put effort into maintaining it. As a result, actors are constrained in terms of contacting the 'right' person with the relevant knowledge first. PM2 thus becomes the main knowledge/information controller rather than a broker.

Project 1 has a lower density at 0.32 (Table 7) and the results indicate that social capital does not play a very important role in creating new knowledge. Actors use their perception of each other's roles and responsibilities, and thus expertise, to identify the sources of relevant information and/or advice for solving problems. All interviewees who explained how they do this (n=12) stated that "[who I contact first] depends on the problem. I would go to the person best placed to answer the query." Interestingly, 'informal meetings' are identified as the first knowledge creation opportunity by one of the actors only, whilst 14 actors out of the 18 interviewees state 'meetings' to provide such opportunities. Moreover, the majority (n=15) do not spend any free time together, reducing any chances for Social Capital to develop. Perhaps it is not surprising then that knowledge is sourced through longer, i.e. three or four step, paths (Table 10). This suggests that actors' perceptions of each other's work are not accurate due to the lower level of common knowledge inherent in

the network, resulting in referrals to the 'right' person (Friedkin, 1983 and Burt, 1997). Another reason behind the lack of common knowledge could be that half the interviewees (n=9) do not consider sharing a similar language to be important in communicating new ideas.

It is clear from the above discussion that neither network offers structural advantages for absorptive capacity due to lack of structural holes, and that the absorptive capacity of Project 1 is low. Moreover, knowledge activities of actors who are in positions to control information flow within the network because of their high degree centralities (Table 6) and high dyadic redundancies are isolated from the other companies involved in the project. This reduces the levels of common knowledge within the intra-organisational team, indicating low levels of absorptive capacity.

Similar isolation problems are also evident in Project 2. The following quotes from two of the actors with high dyadic redundancies reveal that knowledge is shared inter-organisationally, despite their location in an intra-organisational exchange hub:

"..I would interface with people I have worked with previously within [this company] that I know have some knowledge in the area or might be able to point me in the right direction." The PM

"Yes, I share what I have learnt within our own management structure, and through these teams that we have, headed by my boss and that goes down even to the juniors." Client Representative 1

The above isolation issues are related to how actors view the importance of having prior related knowledge of new technology or practice that emerges

through knowledge creation and of sharing a similar language with others in the team to enhance their absorptive capacities. Only a minority of people (n=3) were familiar with the new technology or practice that was used in Project 1. Even they said that it was *not* important to share a similar language or norms with the people that they collaborated with to solve problems or to source information. In Project 2 where Social Capital capital is important for knowledge creation, the majority of people (n=13) were either familiar or very familiar with the new practice or technology. Only one of them stated that sharing a common language was *not* important. All but one of those who said common language was important cited 'informal chats' as the first opportunity to combine & exchange knowledge, suggesting a close link between social capital and absorptive capacity.

However, such a clear link between social capital and motivation to create new knowledge could not be identified. Reagans and McEvily (2003) argue that the strength of ties indicate social cohesion which in turn increases motivation. Only two of the eighteen interviewees in Project 1 said they were not motivated to come up with new ideas and to share them. Both these interviewees were connected with relatively strong ties and were affiliated with the construction management company. They stated the lack of recognition from management and lack of adequate human resources on site as the reasons behind their demotivation. Similar findings emerged in Project 2. Only one interviewee said he was not motivated, whilst another one said he was only prepared to share knowledge with his team within the client organisation. The first interviewee stated that the post-project review procedure enabled sharing within the client organisation and considered people were encouraged to share their knowledge with others. The second interviewee suggested that strategic

agreement at the early stages of the project and changes to the project management process would motivate people to share new ideas. Unlike the demotivated actors in the first network, both these interviewees are connected with relatively weak ties. Hence, our data is not conclusive in terms of the relationship between the strength of an actor's ties and his/her motivation to share knowledge, whilst it provides further evidence that there is a relationship between motivation and; availability of resources and recognition from senior management.

6. Conclusions

The literature review revealed the concept of Social Capital, operationalised through Social Network Analysis and content analysis, to be an alternative approach to understanding knowledge creation within project environments. This paper developed such an approach and applied it in an empirical context within the built environment sector for the first time. It thus contributed to existing knowledge by providing a framework for other researchers to follow and elaborate on. In addition, the paper drew together a number of structural indices that indicate knowledge creation opportunities inherent in networks and put forward arguments as to how they might be related to the relational and cognitive dimensions of social capital. As such, the research framework has the potential to be developed into a diagnostic tool for practitioners to assess how knowledge creation opportunities are utilised in project networks.

The emergent results point to four key findings. First, they demonstrate that structural indices are indicators of knowledge creation opportunities but they should be considered in conjunction with relational and cognitive dimensions to determine whether and how opportunities are being utilised. This integrated

approach helps identify the possible reasons as to why opportunities may not be utilised. Hence, this study corroborates Lin's (2001) argument that network locations facilitate but do not necessarily determine access to resources. Issues such as an actor's perception of whether senior management recognises their efforts determine whether the opportunities are utilised.

Second, it has been shown that contrary to Borgatti and Cross' (2003) claim that knowing and valuing what other nodes know have a strong influence on determining the first port of call for knowledge sourcing, other factors, such as the project communication strategy, could take precedence in this choice. The results illustrated that inaccurate perceptions of others' knowledge and the project set-up could reduce the efficiency of knowledge transfer by increasing the path lengths. Communication mechanisms should be designed such that actors with high potential to assess the value of external knowledge use their time for such assessments rather than becoming knowledge controllers as was the case for PM2. This would also increase the chances of utilising the knowledge creation opportunities that actors acknowledge Social Capital provides.

Third, key figures in both projects are identified to be in advantageous locations either for brokering external knowledge or for controlling the knowledge flow through the network. However, qualitative aspects, such as the affiliations of the actors in particular clusters show that these opportunities are not fully utilised as the PMs function as information controllers rather than knowledge brokers. The discussion also shows that dense intra-organisational networks with limited structural holes do not always limit knowledge creation opportunities provided that they do not suffer from the 'not-invented-here' syndrome. As such structural positions are only precursors of such

opportunities. The challenge in terms of designing a network conducive to knowledge creation is to identify the density range and the level of structural holes at which there is enough access to new, external sources and “a sufficient level of knowledge overlap to ensure effective communication, interactions across individuals [with specialist knowledge]” (Cohen and Levinthal, 1990).

Fourth, data on the relationship between levels of motivation and the strengths of an actor’s ties is inconclusive but there is a relationship between motivation and availability of resources and recognition from senior management. Hence, in this dataset the relational dimension has a higher influence on motivation than the structural dimension.

The main limitation of this research is that the findings cannot be generalised due to the deliberately small sample and that they rely on attributions made by the respondents. A large scale longitudinal study is required to verify the initial findings, to collect enough data for generalisations to be made and to explore the potential to develop a diagnostic approach for practitioners based on the research framework presented. This approach would help practitioners identify which knowledge creation opportunities the structural, relational and cognitive dimensions of their networks avail and to what extent they are utilised. As such, it would enable practitioners design networks that can make better use of such opportunities.

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From_name	To_name	Strength
Project Director	Commercial Manager	4

Table 1. Header row & the first row in a structural matrix (Esra Kurul)

Social Capital Dimension	Examples of open-ended questions
Relational	<ol style="list-style-type: none"> 1. Who do you contact first when you have a problem and why that person? In what capacity do you know him (or her)? 2. Who do you contact first when you want to find out something or need some information? and why that person? In what capacity do you know him (or her)? 3. Do you also spend some of your free time with the above people? 4. Do you feel motivated to come up with new ideas and apply them to this project?
Cognitive	<ol style="list-style-type: none"> 1. How familiar were you with the new technology or practice that was developed (or used) in the context of this project? 2. How easy is it to explain to others what you have learned in this project? 3. Have you picked up anything that could be applied for this project when you were doing something else (e.g. reading a newspaper, watching TV etc)? 4. How important is the fact that you share a similar language (technical terms, daily jargon) or norms in communicating with the people from whom you source information?

Table 2. Examples of open-ended questions (Esra Kurul)

Figure 1. Project 1 Network Map (Esra Kurul)

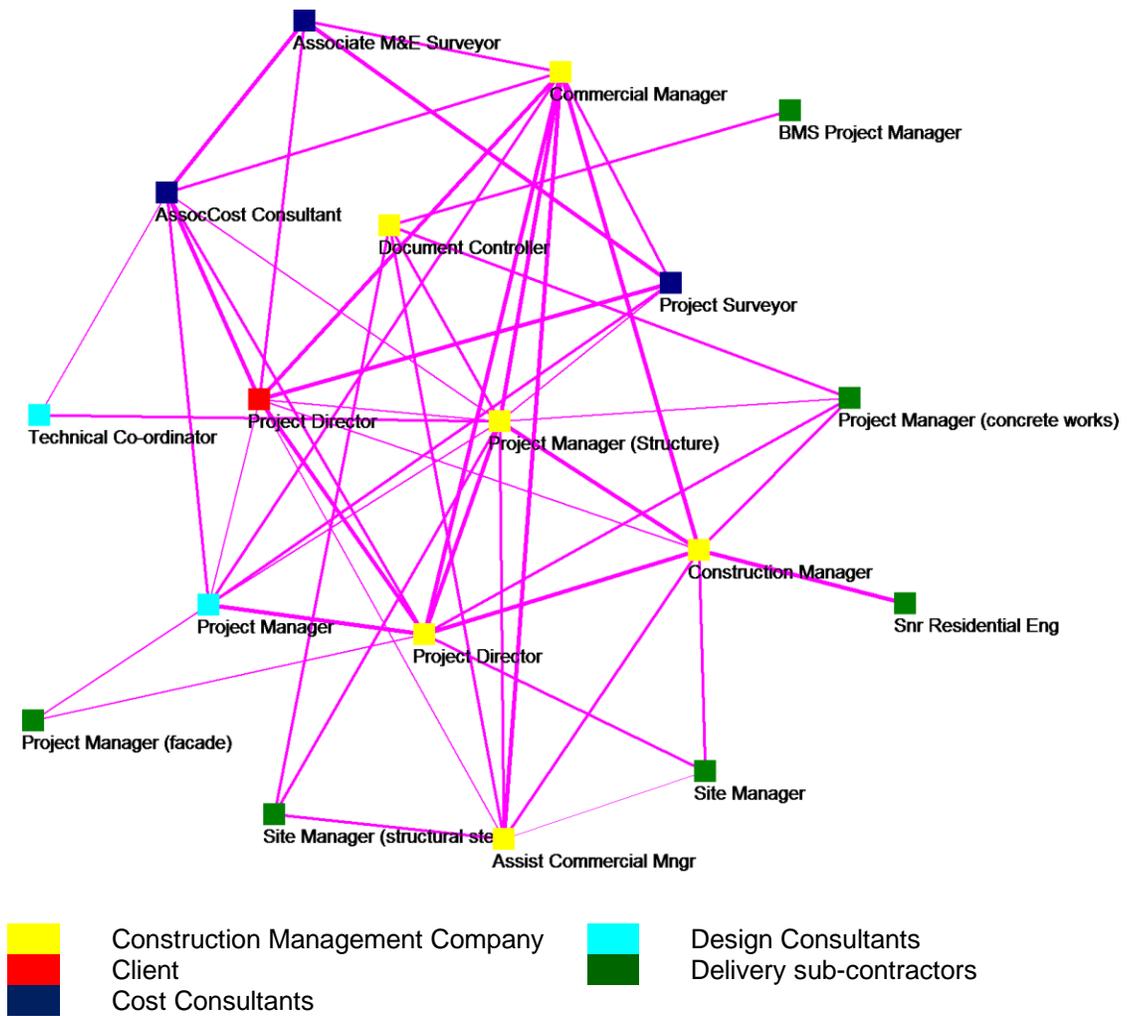
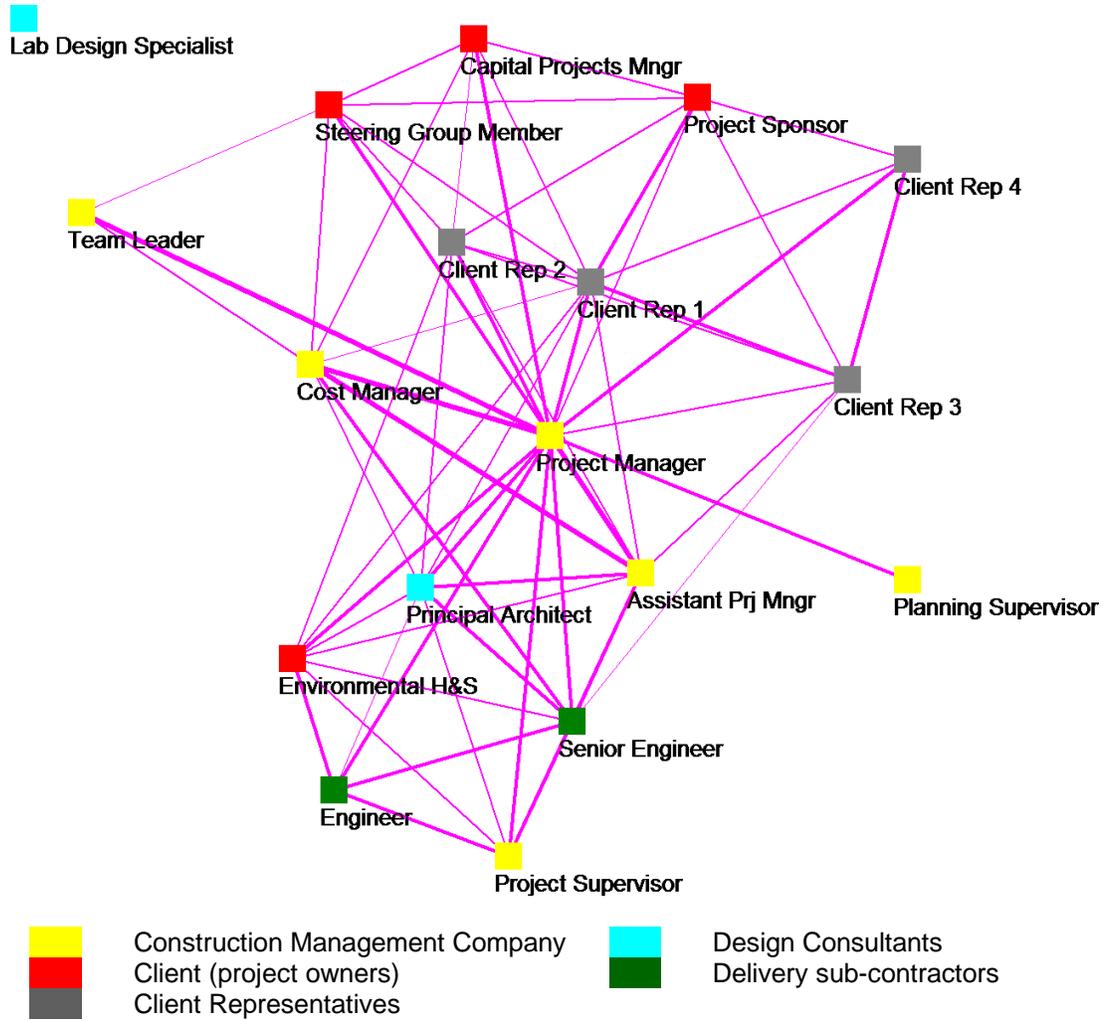


Figure 2. Project 2 Network Map(Esra Kurul)



Company Role	Actor role	Constr. Man.	Comm. Man.	Project Director (CM)	Project Director (DC)	Proj. Man. (struct.)
Construction Management (CM)	Construction Manager	0.00	0.56	0.61	0.43	0.62
Construction Management	Commercial manager	0.48	0.00	0.63	0.56	0.57
Construction Management	Project Director	0.54	0.64	0.00	0.52	0.61
Developer/ Client (DC)	Project Director	0.48	0.73	0.66	0.00	0.64
Construction Management	Project manager (structure)	0.57	0.61	0.65	0.52	0.00

Table 3. Project 1 Selected Dyadic Redundancy Results (Esra Kurul)

Company Role	Actor role	Senior Engineer	Partner/Principal Architect	Assistant Project Manager	Project Manager	Client Rep 3	Client Rep 1
M&E Engineering	Senior Engineer	0.00	0.57	0.63	0.73	0.36	0.64
Architect	Partner/Principal Architect	0.64	0.00	0.62	0.69	0.48	0.59
Project delivery	Assistant Project Manager	0.57	0.5	0.00	0.71	0.38	0.59
Project delivery	Project Manager	0.44	0.37	0.48	0.00	0.37	0.56
Client	Client Rep 3	0.4	0.48	0.48	0.67	0.00	0.66
Client	Client Rep 1	0.5	0.41	0.51	0.71	0.45	0.00

Table 4. Project 2 Selected Dyadic Redundancy Results (Esra Kurul)

Project 1			Project 2		
Betweenness Centrality	Company Role	Interviewee's Position	Betweenness Centrality	Company Role	Interviewee's Position
0.292	Construction Management	Project Manager (structure)	0.362	Project delivery	Project Manager
0.146		Construction Manager	0.059	Client	Client representative 1
0.127		Project Director	0.036	Project delivery	Cost Manager
0.124		Document Controller	0.029	Client	Client representative 2
0.082		Commercial Assistant	0.022	Architect	Partner/Principal Architect
0.061		Commercial Manager	0.021	M&E Engineering	Senior Engineer

Table 5. Top betweenness centrality scores (Esra Kurul)

Figure 3. Project 1 Network excluding the PM (Esra Kurul)

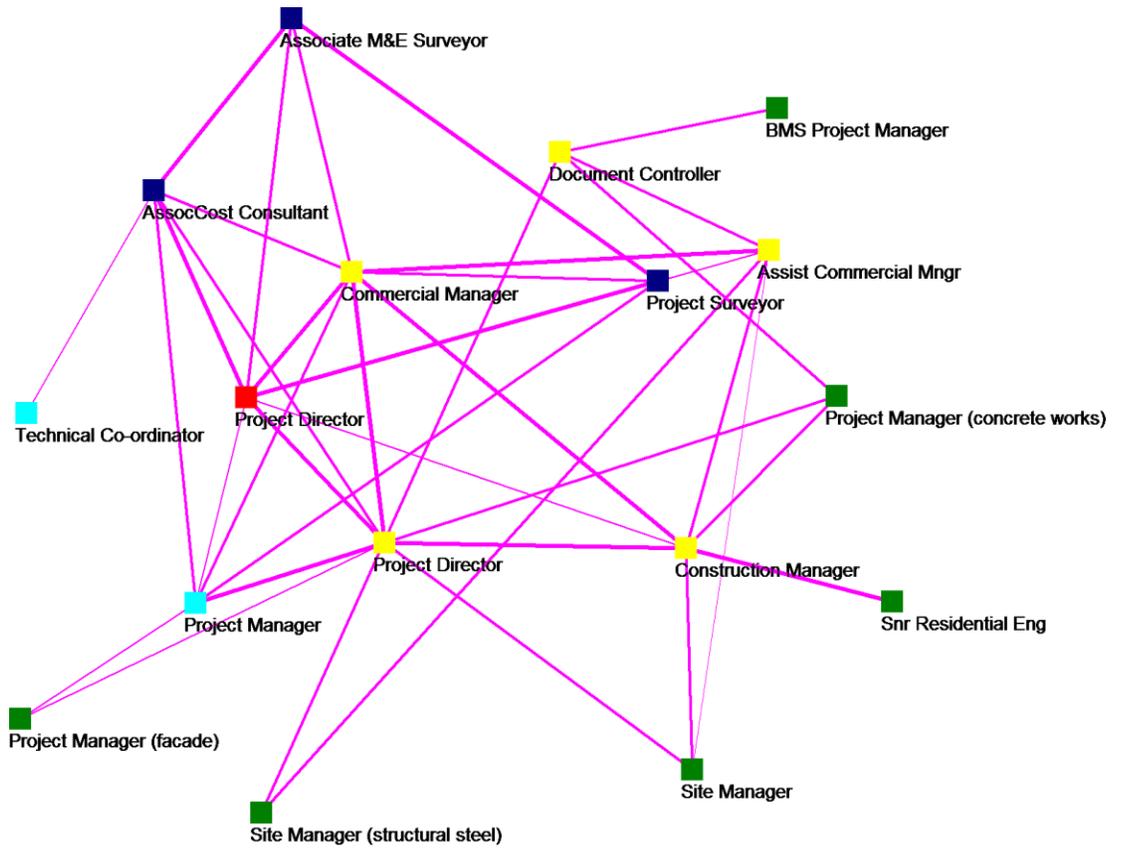
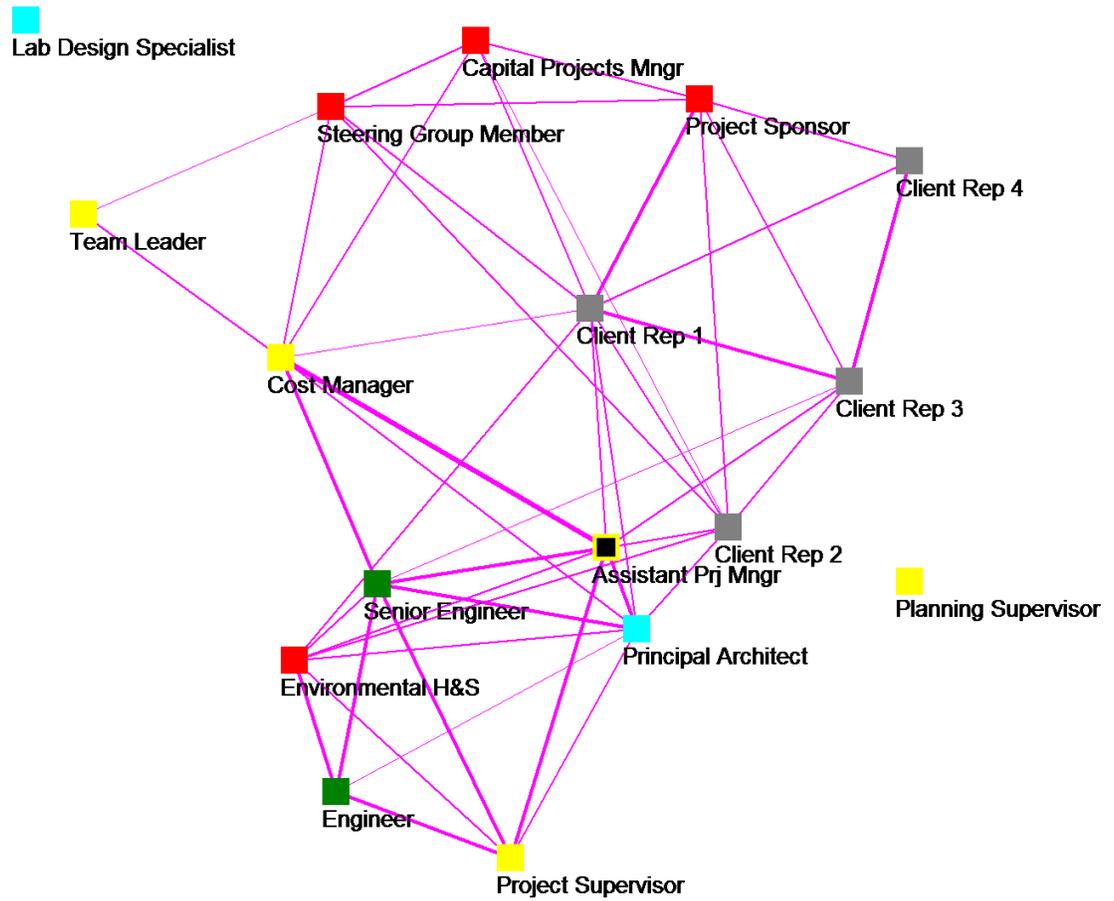


Figure 4. Project 2 Network excluding the PM (Esra Kurul)



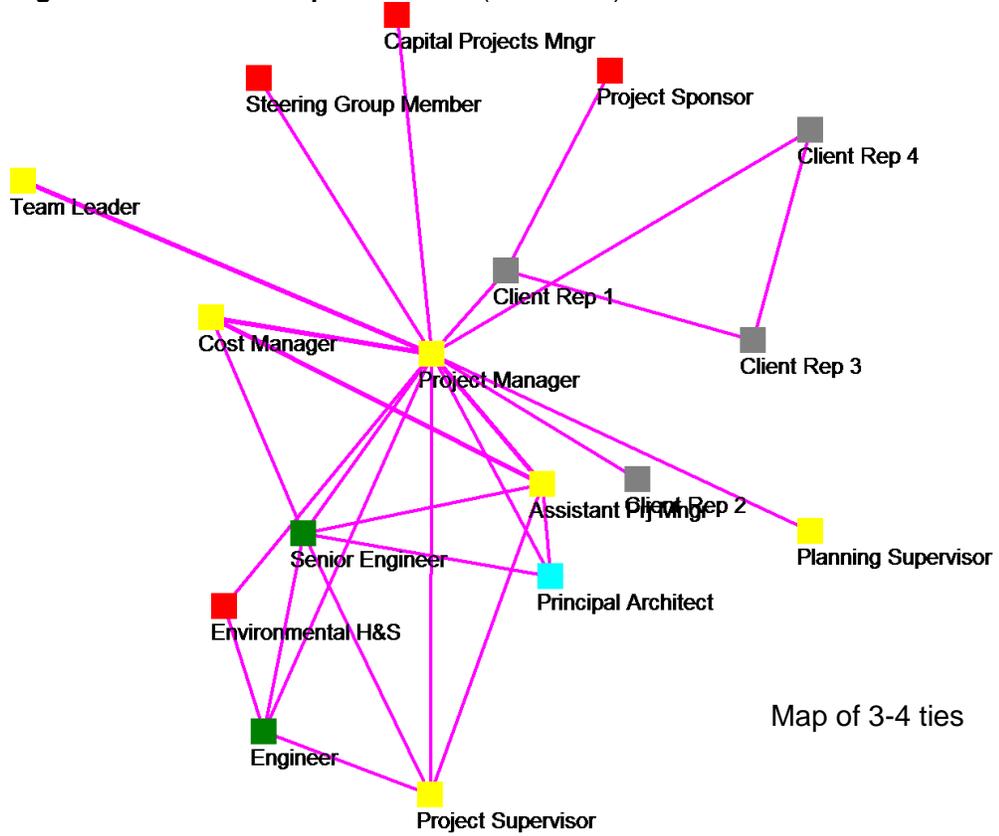
Project 1			Project 2		
Degree centrality	Company Role	Interviewee's Role	Degree centrality	Company Role	Interviewee's Role
0.706	Construction Management	Project Manager	1.000	Project delivery	Project Manager
0.529		Commercial Manager	0.688	Client	Client representative 1
0.529		Project Director	0.563	Project delivery	Assistant Project Manager
0.529	Developer/Client	Project Director	0.563	Architect	Partner/Principal Architect
0.471	Construction Management	Construction Manager	0.563	Client	Client representative 2
0.412		Commercial Assistant	0.500	M&E Engineering	Senior Engineer

Table 6. Top Degree Centralities (Esra Kurul)

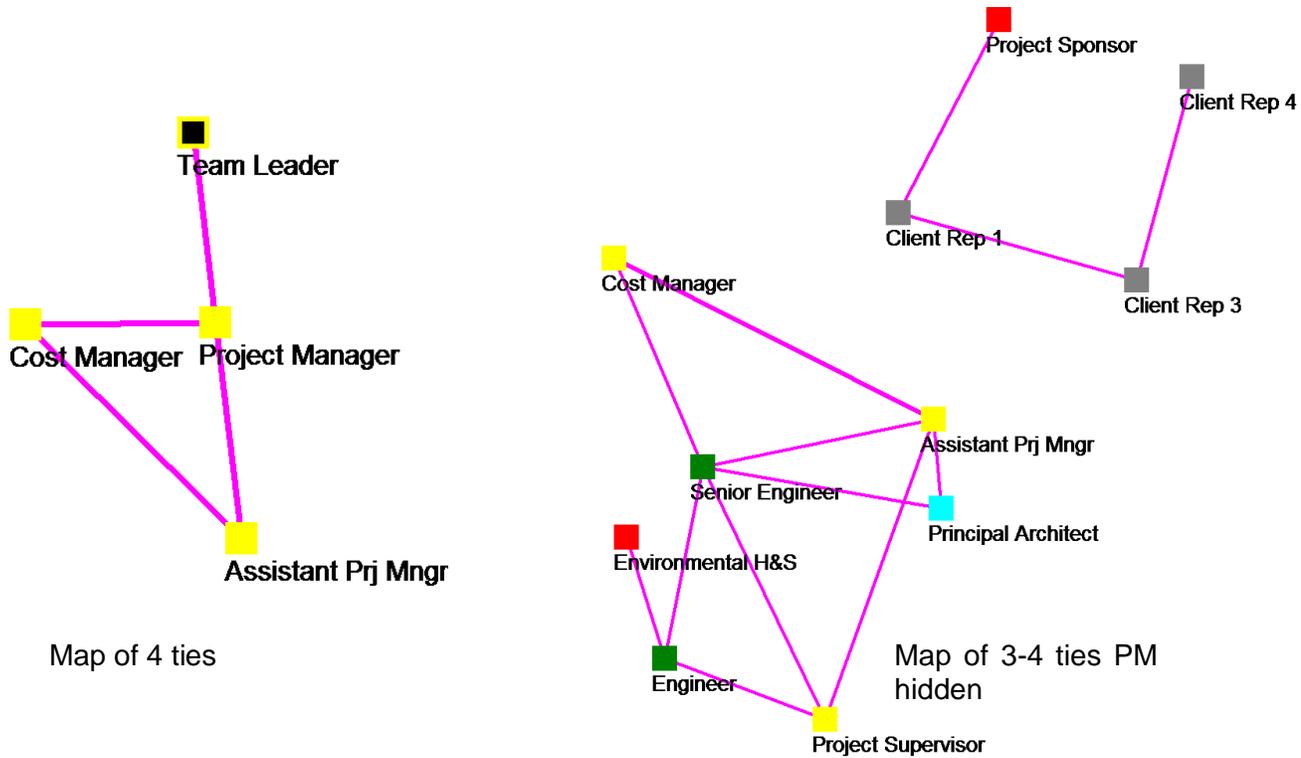
	<i>Project 1</i>	<i>Project 2</i>
<i>Tied Nodes</i>	18	17
<i>Potential Ties</i>	306	272
<i>Actual Ties</i>	98	124
<i>Density</i>	0.32	0.46

Table 7. Results of the Density Analyses (Esra Kurul)

Figure 5. Network 2: maps of 3-4 ties (Esra Kurul)



Map of 3-4 ties



Company Role	Actor role	opportunities to combine and exchange existing knowledge	First contact/ Why?	Spend free time with first contact?
Project delivery	Capital Projects Team Leader	informal chatting individual meetings with relevant team members	PM. 'Chain of command.	Yes. Badminton ladder.
	Cost Manager	informal chatting formal meetings (regular team meetings) individual meetings with relevant team members	PM. 'Chain of command.	Yes. Badminton ladder.
	Project Manager	informal chatting formal meetings (regular team meetings) individual meetings with relevant team members	Capital Proj Team Leader or Manager. Decision-makers.	Yes. Badminton ladder.
	Construction Manager	informal chatting formal meetings direct communication with relevant team members	Long-term colleague. Longevity of relation.	Yes.
	Planning Superv. & Safety Advisor	informal chatting formal meetings (regular team meetings) Post-Project Reviews	PM. 'Chain of command.	Yes.
Architect	Partner/ Principal Architect	informal chatting individual meetings with relevant team members monthly CPD events showing labs to end-users	Cost Manager. Longevity of relation.	Yes. Also, family friend of cost manager.
Eng. Consult.	Engineer	informal chatting individual meetings with relevant team members	Long-term colleague. Longevity of relation	No.
Client	Capital Projects Manager	informal chatting formal meetings (regular team meetings) individual meetings with relevant team members	PM. 'Chain of command.	Yes. Badminton ladder.
	Client Rep 1	informal chatting formal meetings (regular team meetings)	PM. 'Chain of command.	No.
	Client Rep 3	informal chatting formal meetings (regular team meetings)	Project Sponsor. Decision-maker.	No.

Table 8. KC Opportunities & SC (Esra Kurul)

Company role	Actor Role	First contact to find out something or need some information	Why that person?
Project Delivery	Construction Manager	Project delivery PM	their specific knowledge (management)
	Assist. PM		chain of command
	Cost Manager		their specific knowledge (general issues)
	Team Leader for Capital Project East		chain of command
	Project Manager		their specific knowledge
	Planning Supervisor & Safety adv.		chain of command
Architect	Partner/ Principal Arch.		chain of command
Engineering Consultancy	Project Liaison Technician		their specific knowledge (technical and area)
M&E Consulting	Senior engineer		chain of command
Client	Capital Projects Manager		
	Client Rep 1		chain of command
	Client Rep 2	Client/end-users	their specific requirement
	Client Rep 3	Project delivery PM	their specific knowledge (technical)
	Client Rep 4	Client/end-users	their specific requirement
	Project Sponsor	Project delivery PM	their specific knowledge (technical)
	Steering Group member	Client FM team	their specific knowledge
	Laboratory design specialist	Project delivery PM	monitor progress
	H&S Advisor	Project delivery team	their specific knowledge

Table 9. First points of contact for knowledge sourcing in Project 2(Esra Kurul)

	Project 1		Project 2	
	Number of paths	% of all paths	Number of paths	% of all paths
Path Length 1	98	16%	124	25%
Path Length 2	280	47%	364	75%
Path Length 3	200	33%	0	0
Path Length 4	24	4%	0	0
Path Length 5	0	0	0	0

Table 10. Path Lengths (Esra Kurul)

ⁱ Portes (1998) identifies Bourdieu (1986) as “the first systematic contemporary analysis of social capital” and “the most theoretically refined among those that studies it in contemporary sociological discourse”. Hence, Bourdieu’s discourse on Social Capital is taken as the basis in this paper.

ⁱⁱ The strength of a tie is a combination of the amount of time, the emotional intensity, the mutual confiding and reciprocating favours the individuals at its either end attributes to that tie.

ⁱⁱⁱ Members are termed as nodes or actors in Social Network Theory. Hence, members, nodes and actors are used interchangeably in this paper.