A REVIEW OF SOCIAL NETWORK ANALYSIS FOR THE IMI TRUST IN CONSTRUCTION PROJECT

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The issue of trust has been raised as a "gatekeeper" to problems of improving construction procurement (Latham 1994). The IMI Trust in Construction Project is an attempt to evaluate the levels of trust between individuals working together on construction projects. The project is currently undertaking pilot case studies applying Social Network Analysis. This approach has already been demonstrated as useful in reflecting the structure of construction teams (Pryke 1998). The Trust in Construction approach seeks to expand this to include cognitive and behavioural data based on the ideas of a Trust Inventory (Bromily and Cummings 1996).

The first stage of the Trust in Construction project is to develop networks built on objective measures, based on questionnaires and documentation (Scott 1991), to evaluate structure and information flow. The data collection methodologies are presented as a central factor in evaluating relationships and, ultimately, trust.

Social Network Analysis gives a number of analytical approaches to attempt to understand the data collected. The data allows the analysis of structural, transactional and linking concepts (Tichy 1979). Concepts such as distance and centrality can show roles and participation within the network providing a basis for further analysis. Cliques, clusters or cores can shows how individuals or groups of individuals operate within the context of the whole construction project (Scott 1991).

Keywords: networks, social network analysis, supply chain, trust

INTRODUCTION

Social Network Analysis has been proposed as the network modelling approach for the Trust in Construction research project. The purpose of the network modelling approach is to provide some analytical framework to identify the relationships in which trust can be measured.

The approach uses case studies: a design team on a large project (approx £25m) and a whole construction team on a small project (approx £2m). Presented in this paper are possible analytical approaches, some initial findings from one of the pilot case studies, and some preliminary conclusions as to how structure may be related to trust (Ho and Kochen 1987).

BACKGROUND OF SOCIAL NETWORK ANALYSIS

The work leading to the development of Social Network Analysis is derived from two main areas, psychology and anthropology. The psychological aspect developed from the concepts of gestalt psychology based on the ideas of Wofgang Kohler (1925 from Scot 1991). The core of the idea was an attempt to map social consciousness or shared schemas of different groups. Jacob Moreno, who undertook a sociometric analysis of the group in an attempt to map friendships and friendship choices, expanded this. Moreno noted,

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> *"In a topological approach, the social field is seen as comprising of points and paths. The points represent individual persons, their goals and actions, and the paths represent the interactional and causal sequences which connect them.(Kohler 1925 from Scott 1991)*

This gives us the basic concepts of the node and relationships forming the basis of the network.

In a second application using graph theory, the Hawthorne Studies undertaken by Elton Mayo looked at the impact of social structures in the workplace. Relationships, especially those undertaken within the bank wiring room were constructed into sociograms (fig1). It was noted, however, that though the sociograms were constructed, their use in the analysis of data was limited (Scott 1991).

The anthropological approach used a similar model to address the issues of kinship relationships within tribes and communities. The ideas may have developed separately, but there is a clear relationship between them. Siegfried Nadel (Scott 1991) notes,

> *"Social structure is an overall system, network or pattern of relations which the analyst abstracts from concretely observable actions of individuals"*

USING SOCIAL NETWORK ANALYSIS TO MAP CONSTRUTION NETWORKS

Social Network Analysis is to be used in the Trust in Construction project to build models of the different relationships within supplier chains. Trust essentially is an belief or attitude held by one individual concerning another. It is part of a relationship. Trust in Construction is attempting to find,

- How is trust built?
- Can trust have a financial value placed upon it?
- Are trust and risk associated concepts?

Network analysis has been used to address the problems of construction in the context of the Rethinking Construction (Egan 1998) agenda (Pryke 1999).

Defining the Network

The network is made up of nodes and paths. The network analysis defines the characteristics of the network, nodes and paths through a series of simple questionnaires. This data was used to define the structure network.

The network unit of analysis is the project, individuals working on the project were considered part of our population. The network is built of supply chains involving the client, consultants, main contractor, sub-contractors and suppliers. This could be considered a relational network focussed around the client organization (Paulson 1985). In the selection of the case studies the selection criteria were defined as follows,

- Project Name and Description – the identifying name of the project and a short description of the work being carried out.
- Location – where is the project being carried out
- Size – approximate value and timescale of the project being carried out.

- Complexity and uncertainty – how complicated is the project, what factors are not known about the project.
- Length of relationship – have the project partners had experience of one another during previous projects.
- Stage of the process – what stage is the project currently at, following the process protocol lifecycle for a construction project(Kagioglou *et al.* 1998).

The nodes within projects are individuals, who are defined through the attributes identified by the industrial partners as important factors as to why some individuals trust,

- Name – Name of the individual
- Organization – Name of the organization that the individual is contracted to.
- Process Role/roles – Following the process protocol (Kagioglou *et al.* 1998), the identified role that the individual takes in the project.
- Joined the project at which process stage (Kagioglou *et al.* 1998).
- Level in the organization – tiered levels from director to tradesman.
- Occupation/ Background – professional and educational qualifications
- Time in Construction – years in the construction industry.

The paths were defined using simple objective measures to define the structure. With each network containing 30 and 50 members respectively, which could potential mean anything from 500 –1000 paths, due to time constraints it was felt that too many variables would make the data analysis too complex at this stage.

- Existence of the relationship – is there any relationship to measure
- Type of relationship – managerial where there is no direct contract, such as within corporate boundaries, contractual where a direct contract exists, and social where there is a social relationship outside of the project.
- Media of relationships – is most of the communication carried out face to face or by other means.
- Quantity of relationship. This measure can be difficult to capture through perception (Krackhardt 1987) or documentation (Higgins *et al.* 1985), however for the purposes of the study, only a broad indicator is required, differentiating relationships of 3 main levels.

The analysis was undertaken over a 3 month period of time. The case study had a construction time of 10 weeks, which limited the changes that were made to the team, but one should be aware of changing populations in larger projects (Jacobson 1985)

Displaying the Data

The data will be displayed in two main formats, the matrix (Table 1) and the sociogram. The matrix can show simple patterns and clustering of relationships, although, using limited numbers of nodes the sociogram will show the relationships more clearly.

In this case the presence of a relationship is bi-directional i.e. if A relates to B then B relates to A, therefore the top half of the matrix is redundant. This can be translated into a sociogram, a line diagram to show the nodes and the relationships in figure 1.

Table 1: Sample Binary Matrix

	A	B	C	D	E
A	-				
B	x	-			
C			-		
D	x		x	-	
E	x	x		x	-

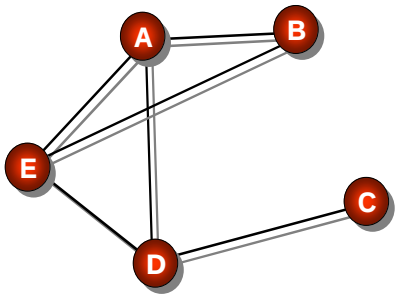

Figure 1: Sample Sociogram

This example sociogram shows very basic relationships between the nodes. It is possible to capture more information within the matrix. For example if we take the same table and view the frequency of the relationships we can see a different network pattern developing as in table 2.

Table 2: Frequency Relationship Matrix

	A	B	C	D	E
A					
B	3				
C					
D	2		1		
E	2	1		3	

If these relationships are determined on a scale of 1-3, 3 reflecting the highest frequency and the 1 reflecting the least frequency. This data shows us that A has strong relationships within the network. These relationships can be shown in a sociogram using one of two approaches, either line thickness, the thicker the line, the closer the relationship, or space, the nearer the closer the relationship (Figure 2).

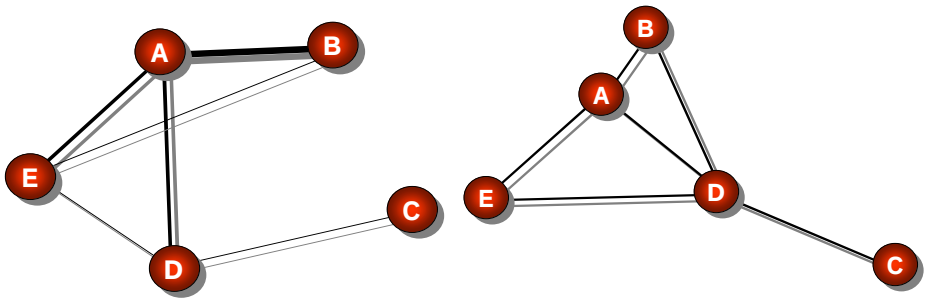

Figure 2: Relationships represented by line thickness and distance

The sociogram shows that A is the most connected member of the network, with relatively close relationships with E, B, and D. C is a relatively tangential member of the network.

Using the Sociogram and Matrices

The workshop, conducted with industrial partners at the start of the project, revealed that trust is developed through communication and action. The analysis of the network should show whom is communicating with whom and whether some partners are central to the operation of the network, while others may be more marginal members.

The level of importance of a particular supplier could be identified as their percentage of the contract. This may be problematic because some partners may receive money to manage a contract, which they then distribute to sub-contractors. The level of money received may not be an entirely reliable indicator of the level of risk borne by a particular organization. The use of the network analysis could show how the resources of the project are distributed through the supply chain and give some indication of the level of involvement, as well as contractual arrangements.

ANALYSIS OF THE SOCIAL NETWORK

Using case study 1, a small retail refurbishment, as a data source we can investigate some of the analytical principles of social network analysis. At this stage the data collection is incomplete so where required there has been some extrapolation of the data.

Density

Density is concerned with the completeness of a network. More dense networks will have greater levels of relationships between the different nodes. For each node (n), an undirected graph can have n(n-1)/2 possible lines. The calculation of density is a proportion of the possible lines against the existing lines. Using extrapolation giving approximately the same values of links to structural equivalents (those people in similar positions) the density of the network can be calculated as

$$742/\ 1128 = 0.658$$

There are issues of relativity and comparison between different networks. A larger network will tend to be less dense. A node, be it an organization or and individual, will have less capacity to make these links in larger networks. A measure of relative density is based on the geometrical value for calculating a sphere.

$$(4c\ r^3/6r\ )/l$$

where: r is the maximum eccentricity i.e. the furthest distance from the central point,
c is the longest path in the graph,
l is the total number of lines,

This issue is useful for later stages in the project where there are networks to compare, on the basis of a single case study (Yin 1994,), what impact density has on the development of trust can only be entirely speculative. Even if there are cross case comparisons it should be noted that different sized networks may display different structural qualities, even with the same densities (Friedkin 1981).

Centrality
Centrality is concerned with the location of a specific point in relation to the graph as a whole. There are two main forms of centrality, local and global. Local centrality is determined by the number of adjacent (only one line connecting the nodes) connections in terms of all possible connections.

Using the data from the Case Study 1 we can see the centrality values for some of the main individuals involved. One of the client representatives has a centrality value of 0.145, (7 of 48 possible connections), whereas the project manager has the highest connection of 0.625 (30 of 48 possible connections).

The concept of local centrality works well in small diagrams, but where there are longer paths it is a little blunt in only evaluating paths of one. A point that may have few adjacent points could be a more central point in a more complex network.

Global centrality works by looking at the position relative within the network. In this case we look at the whole network and the number of paths that will have to be followed to connect a node to all points within the network. In the case study the project manager has to follow 61 paths or 1.25 paths per node, whereas the client representative has to follow 107 or 2.22 paths per node. Both local and global centrality gives us clear differences between two individuals position in the network.

Centrality is a useful concept as it shows us how important an individual is in the flow of information and the structure of a network. Potentially in a study on trust a central individual could be vital to the formation and maintenance of trusting relationships. It should be noted not to discount the importance that weak ties have in the information flows within a network (Granovetter 1973, Friedkin 1982).

Cliques and Clusters
The principle of cliques and clusters is to observe sub-groups within the network and their role in the overall structure. It may reveal the operation of “virtual company” or “cluster group” type structures that may have occurred as a natural part of network formation (M4I 2000).

This can be done in a number of ways. The simplest way is to create sub-graphs on the basis of node or relationship type. For example, it may be possible to create sub-graphs for a specific profession such as designers or professionals and relate that to one for site workers. Alternatively, it may be possible to view relationships of a different type.

K-Cores and M-Cores
A k-core identifies strongest links within a graph forming a sub-graph. The process leaves only the nodes with k degrees of connection. This identifies the nodes with the strongest numbers of connections within the network, those that lend the network most cohesiveness.

The core collapse sequence shows the nature of this structure. The nodes are removed as k is increased. This will show that certain nodes or areas are linked into the network at certain level. This can show the importance of specific nodes. Larger networks should have a proportional core collapse, but the core collapse sequence may show that certain nodes are removed during clear stages.

Our collapse sequence using the current data and projected data shows our collapse sequence as follows.

Table 3 : Projected K-Core Collapse Sequence

Links	10 Links	20 Links	30 Links	35 Links
Nodes	44	22	7	2

With regards to this project specifically, if we analyse the individuals who remain, they are site manager, the project manager, the foreman and the managers for the foreman. The strongest links within the project are focussed around middle management.

The m-core is used where the line values have differing intensities This shows that certain links are stronger and how this impacts on the network as the value of m is increased. As with k-core all links with an intensity of 1 then 2 then 3, dependent on the weighting approach used will leave less lines, removing the ones of lower intensity at different stages.

The m-core sequence leaves a slightly different structure, where many people remain in the graph, but the lines of communication are rationalized, forming organizational clusters with links between the middle management holding the structure together.

Node Analysis

Another possible mode of analysis is to separate nodes of a specific type. We could see the structure of the network around the middle management or the directors of the various participating organizations. This may show us how the structural equivalents of a network are linked and allow us to investigate how these structures may impact project performance. Structural equivalence is defined as,

> *"The extent to which actor j perceives actor I as socially similar to himself within the network."* (Burt 1982 from Johnson 1986)

This means that we can investigate how the structure of a network operates at different organizational or functional levels, dependent on the node characteristic under analysis.

Initial Findings

The data collection phase is approximately 60% complete for the pilot stage of the project. This is concerned with developing partial networks for two pilot projects. The purpose of this phase is to test the principles of Social Network Analysis discussed previously.

Case Study 1 is a small retail project. This project was on site at the time of writing. The structure is shown in simplified version in figure 3.

Figure 3 shows the interaction between 4 of the main companies involved in the case study. The purpose of the case study is to see the effectiveness of Social Network Analysis as a mapping tool and look at the analytical framework that could allow the possible identification between trust and structure.

The network contains all levels of activity from director level to the tradesman, containing 49 members in the full version. The network is centralized around the middle management and foreman levels from three of the companies. The director level and tradesman levels form the extremes of the network.

The pilot stage of the data collection is partially complete. However, it is still possible to apply some of the analytical tools or project the possible use of the analytical tools in the later main case studies.

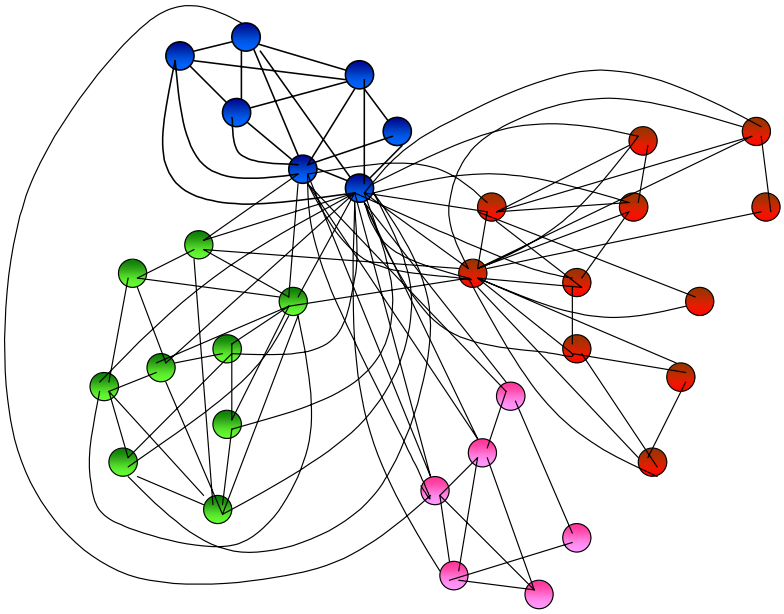

Figure 3: Case Study 1 Example Sociogram

The density of the network can be approximated, however, the usefulness of this in regards to measuring network formation on trust does leave problems on the basis of a single case study (Yin 1994, Friedkin 1981). On the basis of semi-structured interviews it is noted that good communications are important for successful projects. The definition of good communications should be noted as not necessarily being dense but with clear lines of authority. It is probably that the structural components of a network are more important to the successful undertaking of projects than a general measure of density. In the later stages of the project additional cases will be undertaken which should allow for cross-case comparison.

Issues of centrality showed, in both of the case studies, that middle management held project networks together. These individuals tended to know the majority the participants within their groups. These individuals could be identified as forming the key relationships around which these supplier chain networks are formed. It is these key relationships that will be under investigation. These relationships will be investigated further using the Organizational Trust Inventory (Bromiley and Cummings 1996). This information will increase the information concerning specific relationships within the context of Social Network Analysis.

CONCLUSION

The second strand of the research is concerned with the identification of how trust is built and it's impact on project processes. The concepts that have been identified, such as team building, relationships and communications can all be viewed through a network context. The impact of structure and key relationships has been shown through the semi-structured interviews, which were carried out alongside the Social Network Analysis.

Although there are issues of using conceptual data it should be noted that the perceptions play an important role in how individuals act,

> *"Perceptions are real in their consequences, even if they do not map one-to-one with behaviours."* (Krackhardt 1987)

The Trust in Construction Project is concerned with the impact of trust in relationships and the impact of this on project performance. It is clear that Social Network Analysis lends the requisite structure to the analysing of relationships within construction project teams (Pryke 1999). The approach does recognize some of the problems in analysis of networks where power, politics and social issues can have a real impact in the way in which projects are undertaken.

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