SOCIAL NETWORK ANALYSIS ON THE INTER-ORGANIZATIONAL INTERACTIONS IN GREEN BUILDING PROJECTS

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Green building projects are collaboration intensive in nature, and construction of a green building involves execution of complex tasks that are different from those in conventional construction projects. Therefore, collaboration among stakeholders is critical to the success of a green building project. This paper aims to study the inter-organizational interactions among key project stakeholders in green building projects and to investigate the relationship between the interactions and the project performance. To achieve these aims, social network analysis techniques were used to analyse the organizational relationships in green building projects. Considering the nature of green building projects, network measurements were classified into four different aspects – (1) Design, (2) Sustainability, (3) Construction, and (4) Finance. Social network analysis metrics like density, centrality and degree were defined and used respectively to measure the organizational relationships, key players, and powerful and influential players in each network. The developed social network model was applied to a case study green building project in Hong Kong and the outcome is presented in this paper. First hand data concerning communication frequency and information exchanges were collected from key project participants involved in the green building project through interviews and questionnaire. The results show that over-involvement of the client due to the lack of trust in the design team and the strained relationship between the client and the project manager affected the overall project performance. Key players and potential bottlenecks in organizational relationships for each aspect in this green building project are discussed and suggestions for improving project performance were provided.

Keywords: green building, high-performance teams, organizational relationships, project communications, social network analysis.

INTRODUCTION

The number of green buildings has continuously increased in recent years and successful delivery of green building projects requires innovation and strength in the collaborative teams. In contrast to traditional construction projects, green building projects requires a better communication, trust and information exchange among their participants. Multi-disciplinary involvement of project participants causes differentiation in project roles and leads to adversarial relationships between the participants (Chan 2003). In addition, coordination between the project participants was found to be a critical factor in determining green building project success (Li 2011). However, the fragmented nature of the construction industry hinders the inter-

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organizational interactions in green building construction projects and causes more risks in project communications and information exchange. Increased performance in inter-organizational relationships will be beneficial to the industry and help delivering successful green building projects.

BACKGROUND

The multi-disciplinary nature and complexity of green building projects often cause conflicts among stakeholders, project delays and cost overruns. Despite these challenges, the demand for green buildings in the built environment has increased and has become popular among a diverse set of stakeholders. Mollaoglu-Korkmaz *et al*. (2011) stated that a higher level of integration in the project teams affects the project outcome. Valentin and Abraham (2010) concluded that the impacts of stakeholders and organizations in a construction project are crucial to ensure project success. Network based evaluations were used to identify and enhance organizational relationships and project performance (Mandell and Keast 2008, Keung and Shen 2012). These studies have identified the outcomes and importance of inter-organizational interactions towards the success of building projects.

Social network analysis (SNA) has been an instrumental tool for studying the interactions of groups since its early introduction (Moreno 1960). Wasserman and Faust (1994) defined a social network as a social structure made up of actors represented as nodes that are connected by one or more specific type of relation represented as ties, such as friendship, firm alliance, or international trade. A tie can be divided into two types: non-directional and directional (Wasserman and Faust 1994). SNA has been successfully applied to investigate various relationships among individuals and organizations, and knowledge diffusion in multiple domains, including construction. For example, Pryke (2004) proposed a SNA approach that enabled identification and classification of the ways in which construction procurement and methods were evolving in response to demands for reform within the construction industry. Chinowsky *et al*. (2010) proposed an approach to measure the organizational and task performance in a project network for improving project effectiveness.

Previous studies have not studied the collaboration of green building project team relationships, and the impact of different roles in a project. This study aims to fill this gap by considering different aspects of a green building project and studying their respective project team relationships and dynamics. Special role players like the green building consultant, commissioning agent, etc., were included and their functions in different aspects were studied. The design, sustainability, construction and finance aspects were considered and the organizational relationships in those aspects were analysed individually to identify a relationship with project team performance. SNA techniques can visualize and quantify inter-organizational relationships, and therefore can provide useful insights on project participants and their team relationships. A methodology framework was developed for measuring the team performance and applied to a case study in Hong Kong. The methodology framework and the case study will be discussed in the following sections.

METHODOLOGY FRAMEWORK

A high-performing construction team should have strong trust, collaboration and free flow of information exchange between their participants. The inter-organizational interaction social network model that we developed for green building projects is

illustrated in Figure 1. In the model, individual project participants are treated as nodes and their relationships are measured based on the trust bestowed upon each other, the importance of their relationship, communication frequency, and information exchange between the participants for all the four different aspects. Importance refers to the amount of trust, communication and information exchange required between the participants. The relationships between the nodes are directional and marked with arrows. This representation of the project participants as nodes and their interactions as ties form a network of inter-organizational relationships. The inter-organizational social network is then analysed using three network analysis metrics, which are (1) density, (2) degree and (3) centrality.

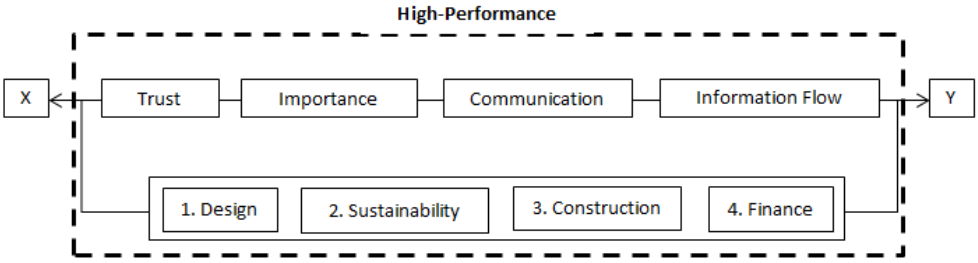

Figure 1: The Social Network Model Developed for Green Building Projects in this Study

Density

Density is the ratio of the number of edges in the network over the total number of possible edges between all node pairs. It is a common approach to measure how well connected the network is. The equation for density is given as

$$Density = \frac{\mathrm{L}}{\mathrm{n} * \frac{\mathrm{n}-1}{2}} \quad (1)$$

where L = number of existing lines and n = number of existing nodes. The value of density falls between 0 and 1, with 0 being a poorly connected network and 1 being a well-connected network. The implication of the density measure may vary depending on the project and network characteristics. Density can be a very useful measure in comparing different network configurations within a single project.

Degree

Degree is defined as the number of nodes connected to one particular node. In directed graphs, degree can be classified into in-degree and out-degree. In-degree represents the number of incoming ties to a given node, whereas out-degree represents the number of outgoing ties from a given node. A node with a high in-degree in a construction information exchange network indicates power, whereas a node with a high out-degree indicates influence within a network.

Centrality

Centrality is an indicator that describes the prominence and power of a node in the network depending on its relationships with the other nodes. This measure will identify the key players in a network and the relationships with other project participants. The equation for centrality is given below,

$$C_a = \sum_{b=1}^{n} \frac{Z_{ab} + Z_{ba}}{\sum_{a=1}^{n} \sum_{b=1}^{n} Z_{ab}} \quad (2)$$

Where, Z_{ab} is the number of degrees that node *"a"* receives from node *"b"* and n represents the number of existing nodes.

The nature of construction and management of a green building project is different from a traditional construction project. Starting from the project team selection, material selection and building practices, the differences range over to extensive documentation and obtaining environmental certification. Green building projects have specialist role players in their project team and executing green building project activities are complex. A green building project will require more collaboration than a traditional construction project, which is of the same type and size. Therefore, we divided a green building project into the following four different aspects:

1. Design focusing ONLY on the structural, mechanical, architectural and other specialized design aspects,
2. Sustainability issues run through the design and construction stages of the project. This aspect focuses on issues like managing pollution, C&D waste, innovative techniques to reduce energy and water use, preparation and submission of green building certification, etc. This aspect will also help identify the different roles played by organizations for improving sustainability. ,
3. Construction focusing ONLY on the construction process, progress, safety and resource management, and
4. Finance focusing ONLY on the project budget and construction cost control.

The scope of these aspects is strictly limited to the definitions to avoid duplication. The chosen social network analysis metrics are applied to all these four aspects individually to measure the network performance of the project team.

CASE STUDY – RESULTS AND DISCUSSION

A green building project in Hong Kong is presented in this paper for illustration and validation of the proposed methodology framework. The case study is a public commercial office building delivered through the traditional project procurement method, with a total gross area of around 100,000 square meters. The project was awarded a Provisional BEAM Plus Platinum certification, which is the highest achievable grade in the Hong Kong BEAM Plus environmental assessment system.

Assumptions

Before conducting the analysis, the following assumptions were made in respect to the nature of the project.

1. In this project, the client appointed the project manager in coordinating the design and construction activities and therefore the project manager is expected to play a major role in project team communication.
2. Since this project was conducted using the traditional procurement method, the architect and the contractor having their own design and construction team.

Therefore, it is expected of them to lead their team communication in the design and construction aspects respectively.

3. This project will be collaboration intensive in nature since it is a green building project.

Data Collection

The project team consists of 21 organizations. Collecting individual responses from every project participant is practically impossible. Since this study is focusing on analysing the inter-organizational relationships, one person from every organization was selected for interview. The selected participants were chosen after thorough background study and preliminary discussions with the project team executives. ,. The selected members were the key representatives of the organization and they were directly involved in all the inter-organizational communications. The selected project members were interviewed face-to-face and both qualitative and quantitative data were collected through a research questionnaire. Collected quantitative data included trust, importance of relationship, communication frequency and information exchanges. A Likert scale measurement of 1 to 5 was used for collecting trust and importance of relationship data with 1 being the lowest and 5 being the highest value. Communication data was measured by the frequency of communication existed per day/week/month and information exchanges were measured by the number of times information was exchanged during communication. Considering the scope of this paper, communication frequency and information exchanges data were used for analysis. Trust and qualitative data were used to support the quantitative analysis and for a better inference of the organizational relationships. Data concerning importance of relationship was not used in this paper.

Inter-Organizational Interactions

The questionnaire responses were extracted and inputted to a SNA software tool, UCINET 6.2. Communication and information exchange networks (for all the four aspects) were plotted using the software. The network diagrams are supported by mathematical analysis and qualitative responses from the project participants for network inferences. Firstly, the overall communication frequency of the project team is illustrated in Figure 2.

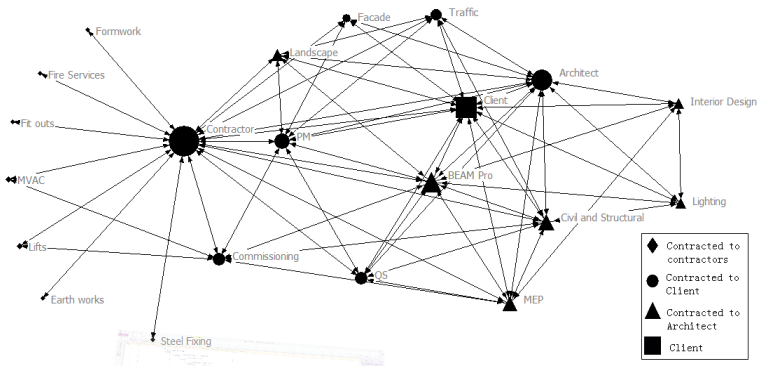

Figure 2: Overall Communication Frequency of the Project Team

This network is comprised of nodes representing the project participants and ties representing the communication between the participants. This study classified the nodes into four different shapes as shown in the figure. The shapes indicate the

contractual relationships between the project participants. This differentiation was used to easily identify communications that occur without any contractual relationships.

The communication graph illustrated in Figure 2 shows a reasonably well-connected network in which most of the project participants know and collaborate with each other to execute project activities. The size of the nodes indicates the frequency of communication of a particular node with other nodes. A larger node size represents a higher communication frequency, and vice-versa. In this network, the project manager was assumed to take a central role, coordinating work with the architect and the contractor, and reporting to the client. However, due to the inefficiency of the project manager in the later stages of the project, the contractor took an active role in project communications with the client, executing complex design activities successfully by effective communication.

Information exchanges help participants share key project knowledge with one another for successful project completion. The information exchanges network will illustrate the exchanges of project information to and from the project participants and identifies important participants during key decision making. All the four networks will be illustrated and explained in the following sections.

Design

The design network shows the information exchanges associated with the structural, architectural, mechanical, landscape and other design aspects of the project. The diagram represents a high level of connectivity and interdependency among the design team. The size of the node indicates the amount of information received by that particular node. Since the project is delivered through the traditional procurement, the architect was expected to play a key role in this network but due to the client's lack of trust in the design team, the client was majorly involved and the architect was a close second. The contractor was also included in key design decisions to effectively carry out the tasks to his sub-contractors. Nodes without any ties are called outliers and they are not part of the network despite being the part of the project team. In the design network, the Commissioning team was not included in the major design decision making issues.

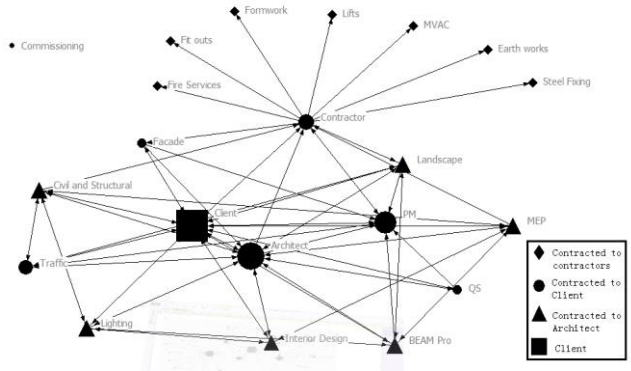

Figure 3: Information Exchanges for the Design Aspect

Sustainability

Sustainability issues were given prime importance subject to the nature of the project. This aspect focuses only on issues related to green building practices, technologies, documentation and certification. Few design related sustainability issues were

considered in the design aspect rather here, to avoid information overlap. A strong collaboration among the project team is necessary to achieve a higher level of sustainability. The case study project achieved the Platinum certification - the highest achievable level in the BEAM Plus assessment system. The client appointed a green building consultant and both were actively involved with the design team to carry out issues related to sustainability. The involvement of the contractor was also a reason for executing all the sustainable design successfully and achieving a higher grade. The over involvement of client once again indicates the lack of trust in the design team. This network also has a few outliers in Traffic, Steel fixing, Earthworks and Formwork sub-contractors.

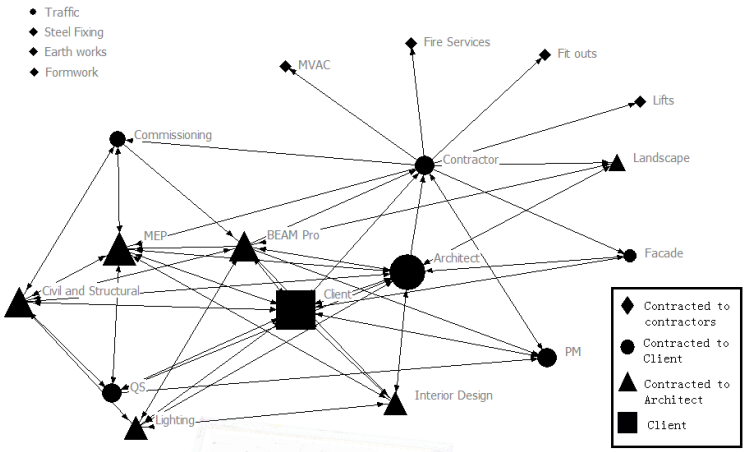

Figure 4: Information Exchanges for the Sustainability Aspect

Construction

The construction network was dominated by the contractor who took a central position. From the qualitative responses of the client, it was learnt that the project manager was expected to involve heavily in this network but due to the project manager's inefficiency in the later stages of the project, the client had to take a more active role in this aspect. This led to the strained relationship between the client and the project manager and caused considerable time delay and cost overrun. This network does not have outliers with all the project participants involved in some sorts of information exchanges.

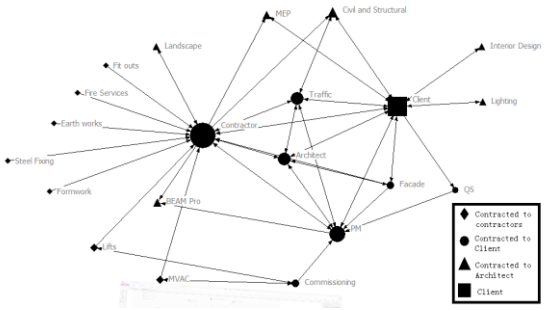

Figure 5: Information Exchanges for the Construction Aspect

Finance

The finance network represents the cost and budget issues of the project. The finance network appears to have multiple subgroups – a primary group under the client and

two secondary groups under the architect and the contractor. The interactions can be related to the contractual agreements of the project team tying the major actors to their pool of associates. There are no isolates in the group and all the nodes maintained an appropriate level of communication.

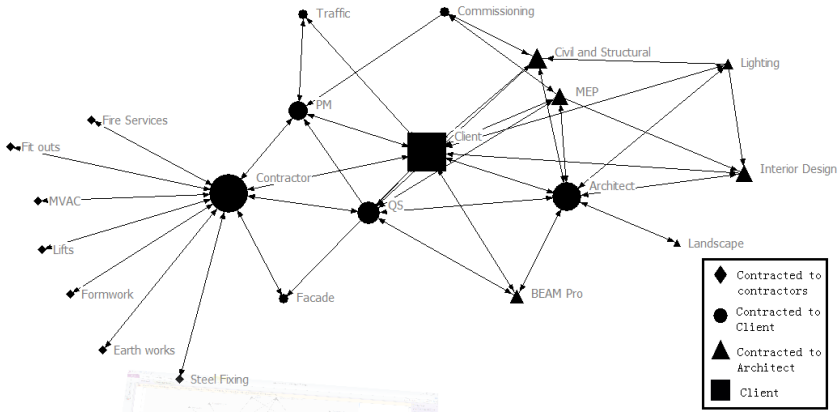

Figure 6: Information Exchanges for the Finance Aspect

Results of the SNA Metrics

The graphs in the previous sections helped us understand the project team dynamics in each of the four aspects. This section will present the mathematical results and discuss the findings of the study. Firstly, Table 1 shows the densities of the four different networks.

Table 1. Density of the Information Exchanges Network

Network Type	Density
Design	0.19
Sustainability	0.18
Construction	0.10
Finance	0.17

In absolute terms, the density of each network is low. The reason for a low density network is because of the contractual arrangements among project participants and the traditional procurement delivery method. In this project, the design and construction team are led by two separate entities and their contractual relationships does not oblige for collaboration.

The centrality metric gives the prominence and actively involved nodes in a given network. Table 2 represents the major role players in each of the four analysed network. The centrality measure considers the amount of collaboration of a particular participant with the entire project team. The contractor played a key role in the design, sustainability and construction networks due to his involvement with both the design and the sub-contractor teams. The client had an in-house QS team and kept close control over the financial issues with the architect and contractor. The results shows that the project delivery norms were not followed properly and it had a direct effect in the team project interactions.

The in-degree and out-degree metrics indicate the powerful and influential actors in a network, respectively. Table 3 illustrates the most powerful and influential node in each network. Due to the lack of trust in its design team, the client was coordinating

with every one of its design team members and played a major role in transferring information. This caused a major imbalance in executing project activities. Too much involvement of the client affected the performance of many project participants. The green building consultant, BEAM Pro worked closely with the client and the design team to achieve a higher certification level. The client's strained relationship with the project manager is the reason for the involvement of the client in the construction issues. The client and the contractor had to play an active role in coordinating construction and financial aspects of the project in the later stages.

Table 2. Top Centrality Measurements of Information Exchanges Network

Network Type	1st	2nd	3rd	4th	5th
Design	Contractor	Architect	Client	Project Manager	BEAM Pro
Sustainability	Contractor	BEAM Pro	Client	Architect	MEP
Construction	Contractor	Client	Project Manager	Architect	QS
Finance	Client	Contractor	Architect	QS	Project Manager

Table 3. Highest In-degree and Out-degree of Information Exchanges Network

Network Type	In-degree	Out-degree
Design	Client	Client
Sustainability	Client	BEAM Pro
Construction	Client	Contractor
Finance	Client and Contractor	Client and Contractor

Discussions

Qualitative data from the project participants were collected to compare the results with actual project performance. The relationship between the project manager and the client strained over the course of the project and it affected the original team dynamics. The client took control over project coordination and many project participants felt that too much involvement of the client hindered participant's work tasks and brought down productivity. Lack of trust on the design team was also a reason for excess client involvement. Ambitious targets were set by the design team initially and there was a scope creek in the later stages of the project. Lack of efficient coordination and supervision caused accidents on site. These factors created adversarial effects on the overall project performance. The project was delayed and exceeded the initial planned budget. Thus it has been found that adverse project relationships between key project participants have a negative effect on key project metrics like cost and schedule. Trust between project participants and collaboration was found to be vital in effective management of green building projects.

CONCLUSIONS AND FUTURE WORK

With the growing trend of green buildings, this study proposed an innovative method to study and analyse green building project interactions. The proposed model will be an effective tool in analysing project team interactions and will help identify potential bottlenecks in project relationships and dynamics. The communication and information exchanges of different aspects of a case study project were discussed and the mathematical results were compared with the qualitative responses. The project team's communication and interaction dynamics deviated from its adopted delivery method and it resulted in a negative effect in project performance. Trust between project participants and collaboration was found to be a vital factor in creating high performance teams. Forming project team with prior work relations and adopting collaborative procurement methods are potential alternatives to enhance project performance. This paper identified potential bottleneck in project relationships in a case study project and provided insights for creating better teams. Future work will include additional case study projects with different project types and procurement strategies to understand their relationship between project team interaction and project performance for deeper analysis.

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