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NETWORK ANALYSIS OF A SIMULATED PROJECT OFFICE

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Abstract: This paper examines the relationships and interactions amongst students in a university class while they simulate a project management office environment. The project duration was thirteen weeks and the project was an actual construction project. The expected task outcome was exactly what one would expect from a professional project management firm. The tasks performed during this period were the tasks encountered during the construction contract procurement stage. The work distribution and structure were those of a network organization. The simulated office consisted of three senior associates responsible for leadership and management of the office team and approximately 25 team members with different interests and expertise relevant to the project. During the course of the project, each member of the team completed an online survey questionnaire. The data collected provides measures of variables that include information exchange, knowledge exchange, trust and the frequency of interactions amongst the members of the project network. The data was subsequently analyzed and studied using a Social Network Analysis (SNA) software. ***Keywords****:* Network Organizations, Organizational Structures, and Project Management. SNA, Simulation.

1 Introduction

Research to date has identified the structure of AEC project organizations as a network structure. These networks of individuals and/or firms are formed and are held together by links of reciprocal commitment to a shared goal and by the communication that takes place amongst the participants. The type of these links may be of one or more of the following categories: bilateral contractual nature, professional exigency, functionally dictated or informal. These links become channels of information and knowledge exchange as well as channels of exchange of goods.

For a network to function efficiently and effectively, sharing information and knowledge by the appropriate participants and at the appropriate time is one of the requirements. Another requirement is that the information and knowledge shared be reliable and that an appropriate level of trust exists between communicating participants. Thus trust and reliance are important constructs that govern the operation of networks. Additionally, the position of an individual or firm amongst others and its location on the overall network has an implication for the networks efficiency and the participant's effectiveness as a member of the network.

The communication and exchange links may be set up or fostered as a result of the networks mission and its ensuing composition set by the key member or members of the network (the nucleus or caretaker) while taking into account the range of capabilities and expertise of the orbiting organizations. Typical network configurations depicting a number of individuals, teams or organizations held together by communication links encountered in the AEC industry are shown in Figure 1 (Katsanis, 2004).

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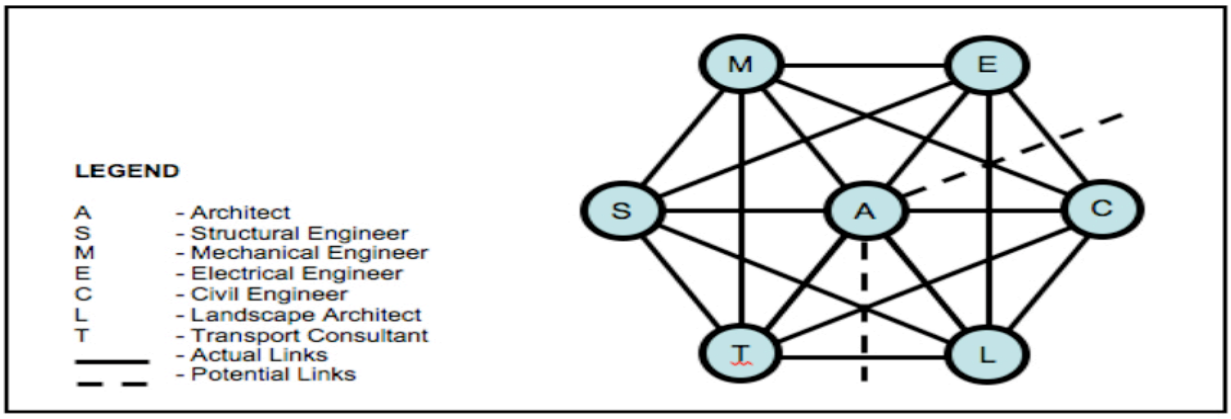

Figure 1. Typical Communication and Knowledge Exchange Links in the AEC Industry. Network Configuration for the Design and Engineering Sector.

Based on the concepts that govern the formation and operation of a network, simulation was conducted whereby, a class of university students assumed the roles of associates in a project management office. The project was the procurement of a lump sum (stipulated price) contract for an actual project staring with the call for tenders to bid evaluation and recommendation to award. Following the methodology described in this paper, data was collected and analyzed and key network attributes were determined and are discussed in this paper.

2 Literature Review

The application of SNA in engineering project organizations has been gaining followers in the research community (Chinowsky & Rojas, 2003 and Chinowsky et al., 2008 and 2010). Network organization theorists have identified how network attributes and the location of an individual in a network may affect the individual's ability to leverage his knowledge, power and influence on in his relations with others (Noria and Eccles, 1992). Several dimensions can be measured and the variables can be analyzed using social network analysis (SNA). Based on the instruments previously developed and used in this case study, several dimensions of interest can be revealed and analyzed (Chinowsky, 2009). Four such dimensions are used in this study and are described below.

Network density is a measure of the amount of interaction that exists between the network members. Density reflects the number of actual links that exist between members in comparison to the number of potential links that can exist if all members in the network were connected.

Centrality is a variable that reflects the distribution of relationships through the network. In a highly centralized network, a small percentage of the members will have a high percentage of relationships with other members in the network. In contrast, a network with low centrality will have relatively equal distribution of relationships through the network. An example of a highly centralized network is one where an individual such as the project manager serves as a filter for a high percentage of communications rather than communications being distributed throughout the network.

Power works in conjunction with centrality. Whereas centrality measures the total number of relationships that an individual may have, power reflects the influence of an individual in the network. Individuals who are giving information to others in the network, who are in turn passing along that information to others, has a high degree of influence or power. Individuals, who are mainly on the receiving end of communications may be central in the network, but have little power, as they do not influence the actions taken by others.

Betweenness measures the amount of information that is routed through an individual to distribute to the team. This rating indicates which individuals are involved in discussions that are occurring within the network.

The value and usefulness of applying social network analysis (SNA) to study network organizations, lies in the fact that the measurements of the network dimensions and the mapping provide powerful tools to assess the current state of knowledge sharing within an organization and where the organization can improve to achieve high performance.

While the data analysis is still in progress, it is expected that the findings will reveal attributes specific to this network organization with regard to its densities, and the degrees of its members' centrality, power and betweenness. Additionally, the network organization's attributes of professional density and specific communication density will be plotted on a two-dimensional matrix that maps the networks within four potential operating profiles: a) connected; b) isolated; c) integrated; d) fragmented.

3 Methodology

To study the dynamics and mechanics of network organizations a capstone course in the final semester of a four-year project management degree program served as the vehicle for the simulation of organization design and performance of a project organization. This entailed establishing a project office using the available recourses i.e., the 29 students participating in the course who were to assume the role of professional associates in a professional project management consulting office.

In this simulation, acting as a project executive, the instructor appointed three students to constitute the executive committee. The executive committee was mandated to organize the remaining members in an office to carry out the contract procurement activities for an actual public project described in a later section. The three members of the executive committee were to act as is they were the vice presidents in a professional organization and thus take complete charge of the mandate they were given by designing the project organization.

The functional groups formed were the following: a) Communication; b) Documentation, c) Quantity take-off and d) Sub-contracting and Bid analysis.

Figure 2, depicts a network diagram of the communication and exchange links at the functional division level. Figure 3, shows the division of the work by discipline and the management links. The associates are identified by a code. The code consists of a letter corresponding to the functional task and a number identifies the group member.

Similar to situations in actual project organizations, the team members involved in this procurement of the project were brought together for a short period of time (that of the duration of the semester which was 13 weeks). On week 1, the instructor acting as an executive project manager briefed the project team (entire class) and appointed the executive members giving them the mandate to proceed with all the tasks required to assemble and organize a project office the tasks assignments.

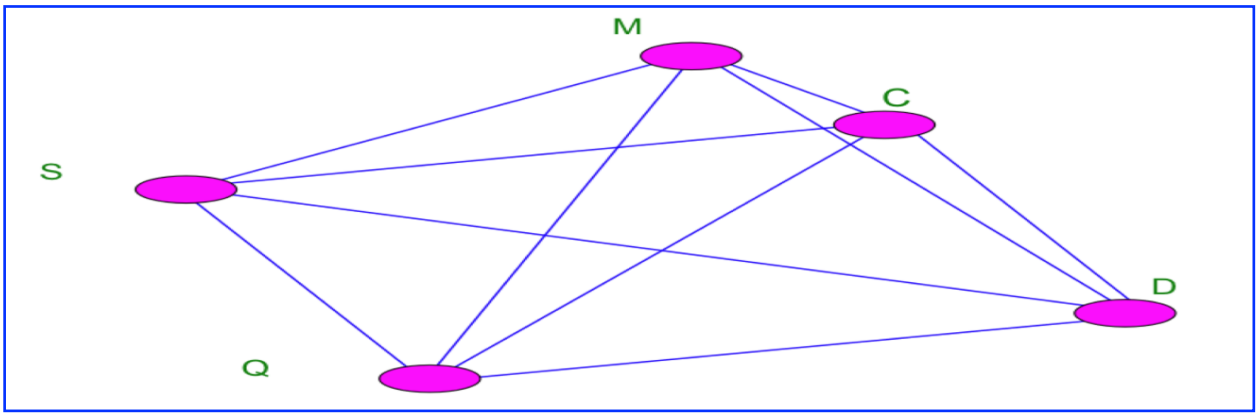

Figure 2. Network Diagram of Communication and Knowledge Exchange Links at the Functional Level. Legend: M-management; C-communication; D-documentation; Q-quantity take-off; S-sub trades and analysis.

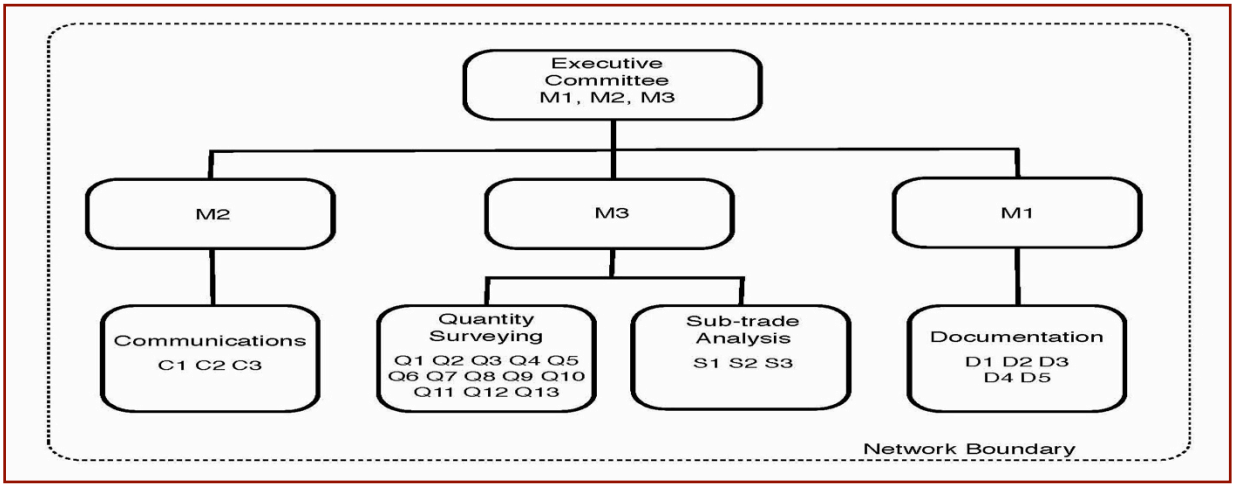

Figure 3. Conventional Organization Chart. Leadership and links to functional task divisions in the project organization.

Details of the assignments and responsibilities of teams and individuals are shown in Figure 4. At about week 8, the members of the office were asked to participate in the survey that collected the information required to carry out the social network analysis of the project organization.

The table below identifies the group members by their division code and provides details of the specific tasks assigned.

ID	Team Function	Responsibilities
M1(D) M2(C) M3 (Q&S)	**Executive Committee. Management (M) and Functional Division Leadership M (x)**	• Establish office tasks schedule & monitor progress • Establish communication deadlines • Co-ordinate teams • Evaluate bidders' schedule • Develop, Summary sheet & determine pre-bid cost estimate • Evaluate & mark submissions based on target price

C1 C2 C3*	**Communications (C)**	• Communication with bidders • Development-distribution-receipt & verification of participation forms. • Project accounting • Prepare & Issue communiqués (consult with exec. Committee) • Liaison with external parties, • Individual marking sheets & summary marking sheet • Assist execs in preparing the presentation for Awards Day
D1 D2 D3 D4 D5*	**Documentation & Evaluation (D)**	• Assemble specifications per division as selected • Prepare & issue addenda as required • Prepare evaluation forms • Evaluate & mark completeness • Evaluate & mark overall presentation, methodology, & approach of submissions • Evaluate & mark Bid form Appendix A: Bid Documents
Q1 Q2 Q3 Q4 Q5 Q6* Q7 Q8* Q9 Q10 Q11 Q12 Q13	**Quantity Take-off & Unit Prices (Q)**	• Quantity take off of required divisions • Establish unit prices from actual projects (bid prices) • Evaluate & mark bidders' quantities & extensions • Evaluate & mark bidders' organization & accuracy
S1* S2 S3	**Sub-trades & Analysis (S)**	• Prepare subcontractor quotations (min. 3 for each trade) • Prepare subcontractor Analysis sheets for comparison • Prepare Division 1 - General Requirements Unit Prices • Prepare General Requirements extension sheets • Evaluate & mark bidders' General Requirements and sub-trade Analysis sheets, • Evaluate & mark Bid form Appendix B: Subcontractors' List

**Designated Team Representative*

Figure 4. Organization members identified by division codes and responsibilities.

4 Survey Data Analysis and Discussion

Following established methodological procedures (Chinowsky, 2009), the organization's structure is examined in terms of its mechanics, (communication and knowledge exchange) and its dynamics, in terms of trust. The collected data are analyzed using the UCINET program to establish various measures for the concepts discussed earlier under Literature Review.

4.1 Communication and Project Organization Cohesion

As a starting point for understanding the role of communication in an organization is to establish the frequency of communication amongst members of the organization. The information was collected by

means of an electronic survey and the data was analyzed using the UCINET program for SNA per Borgatti *et. al.*, 2002.

Staring with the question "Which individuals have you communicated with on *any topic* in the last three months?" the communication ties amongst members of the organization were calculated and the resulting network density was 50.37% indicating a fairly high level of cohesion within the group. When considering the network's communications for *project specific* issues on a monthly basis, the density drops to 32.64%.

When the same questions were asked for weekly and then several times per week communication frequency, the networks shown in Figures 5 and 6, exhibited a density decline to 20.2% and 9.98% respectively. As seen in these diagrams, the management roles, indicated by Ms in the diagrams, are assuming greater communication roles in the network. Additionally, several Qs are seen to move to the periphery of the communication network.

The red lines indicate a reciprocal (two-way) communication, whereas the blue lines indicate a one-way in the direction of the arrowhead. The size of the node indicates the "in-degree" *i.e.,* the number of communications received by the member represented by the node. This convention applies to all figures in this paper.

Given the tight schedule of the project, and the short duration of the tasks the entire project organization (class) met formally twice a week and the members were expected to put significantly more effort beyond the scheduled class time.

Considering that the project communication is an essential element to the success of a project, an exploration of the communication mechanics within the functional subnet was sought and it is described in the next section.

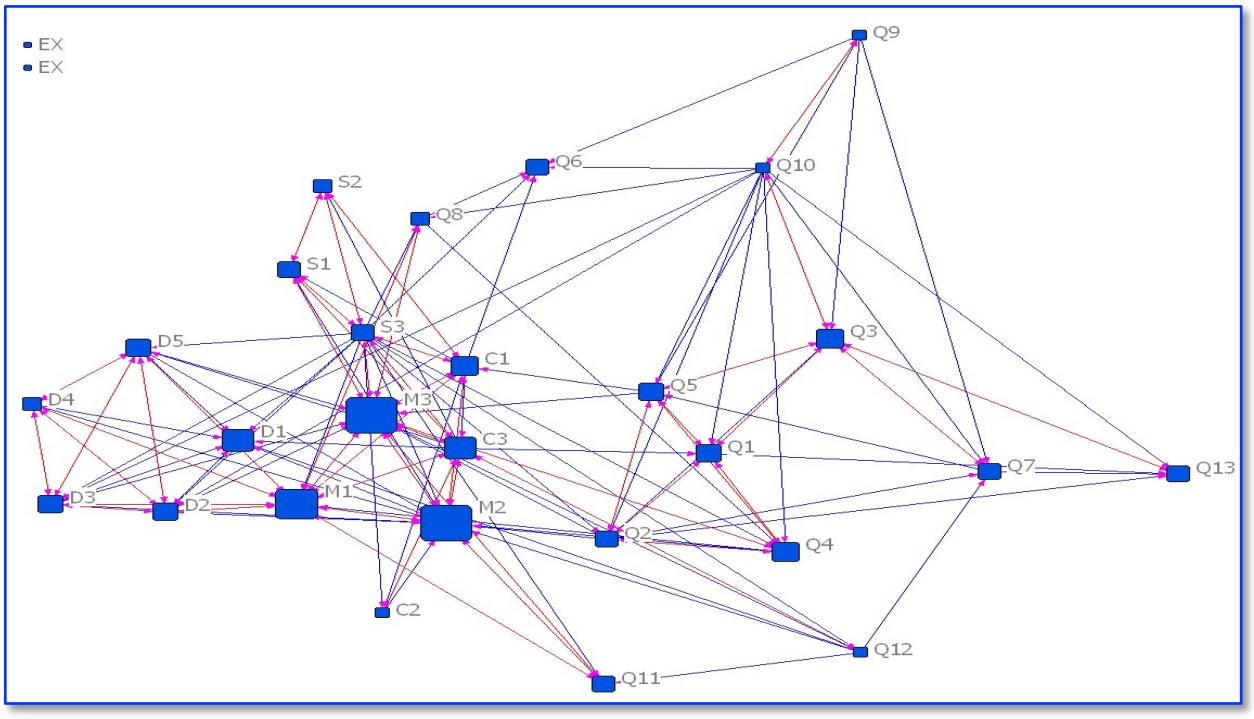

Figure 5. Weekly communication to discuss project specific issues

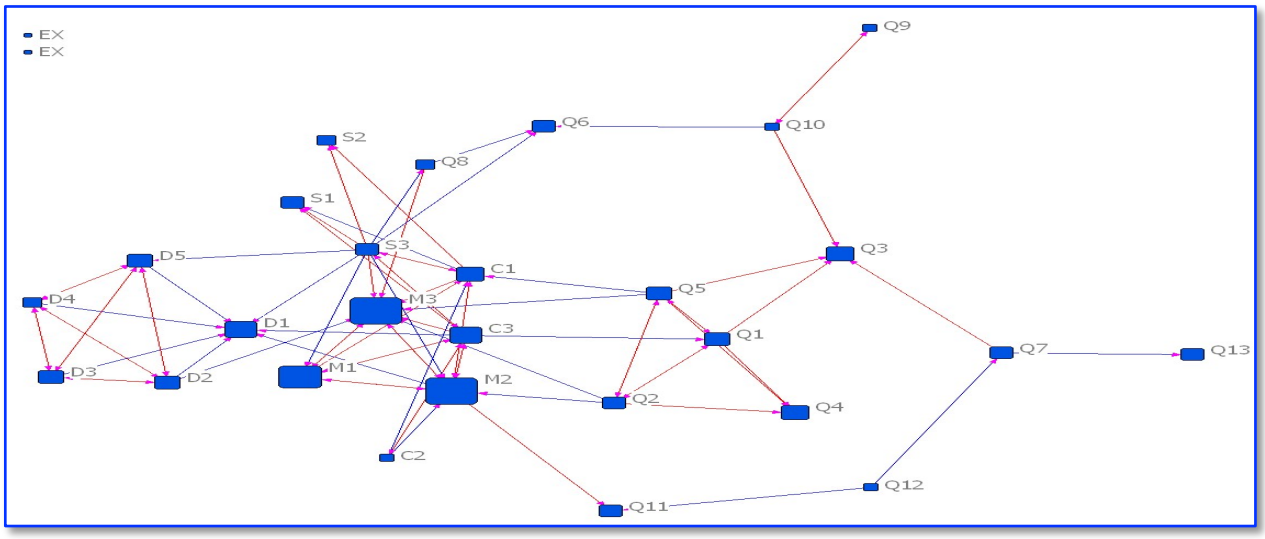

Figure 6. Communication to discuss project specific issues several times per week.

4.2 Leadership Analysis

The network structure of this project organization or perhaps the absence of (a rigid) structure as far as pre-assigned positions are concerned, may be responsible for the results observed in the leadership analysis shown in Figure 7. In this analysis, the relative position of each individual is ordered to determine how an individual rates in weekly communication measurements. The individual with the highest centrality ranking is placed in the chart as 1st and each individual is then ranked below this accordingly. The same method is used for the Power and Betweenness categories. This ranking is consistent with the expected norm that individuals who are in management and leadership positions should emerge at the higher end of the rankings in these categories if they in fact posses leadership characteristics.

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Functional Discipline within Project Organization	Member	Centrality	Power	Betweenness
Leadership/management	M3	1st	5th	5th
	M1	3rd	4th	6th
	M1	4th	8th	9th
Communications	C3	5th	3rd	3rd
Documentation	D2	8th	7th	17th
Quantity Take-off/Estimating	Q10	7th	2nd	7th
	Q3	1st	10th	2nd
Sub contract & Analysis	S3	2nd	1st	1st

Note: The designated group representatives D5*, Q6* AND S1* did not score significantly to be included above.

Figure 7. The leadership evaluations for the weekly organization communications.

In the current study, the executive members ranked in the top five for centrality, but fell slightly in the power and betweenness rankings. This indicates that the executives are central to communications, but may not be as effective in conveying their messages as clearly as others in the network. In contrast, the S3 member placed at the top in each category. This indicates that the task completion may have taken precedence in the communications network. This is consistent with findings by Chinowsky (2009) in studying engineering organizations, which indicate that task communications can overtake management communications when deadlines become the overriding concern.

A second underlying reason for the leadership rankings may be a reflection of the experience brought to the network by individual members. Both S3 and Q3 possessed quantity surveying (QS) experience, having previously worked for professional QS firms.

In order to further explore the leadership aspects in this project organization, it was decided to isolate the responses of the Q subnet study the communications values and compare these to the whole net.

The following section presents the communication mechanics of the Q subnet and it is followed by a brief return to Leadership Analysis in light of the findings afforded by the subnet.

4.3 Cohesion within Project Subnet

To explore the communication within the functional subnet, the largest of the four subnets was selected which consisted of thirteen Q members and their project leader M3. An analysis of their responses revealed densities of 30.22% and 12.64%, representing an increase of 10.02% and 2.66% over the weekly and multiple times per week communication frequencies respectively. The figures illustrate which individuals play a central role in the communications networks and which individuals move to the periphery of the network.

The network graphs for subnet Q are shown in Figures 8 and 9.

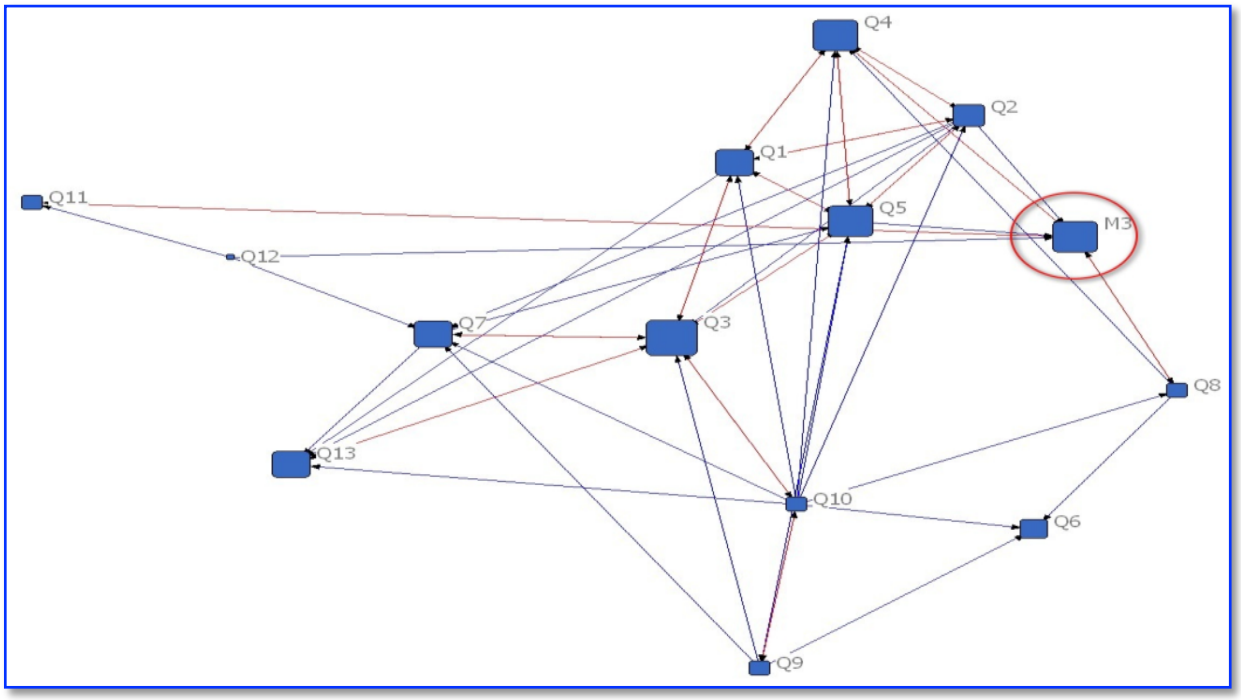

Figure 8. Weekly communication to discuss project specific issues. Q Subnet.

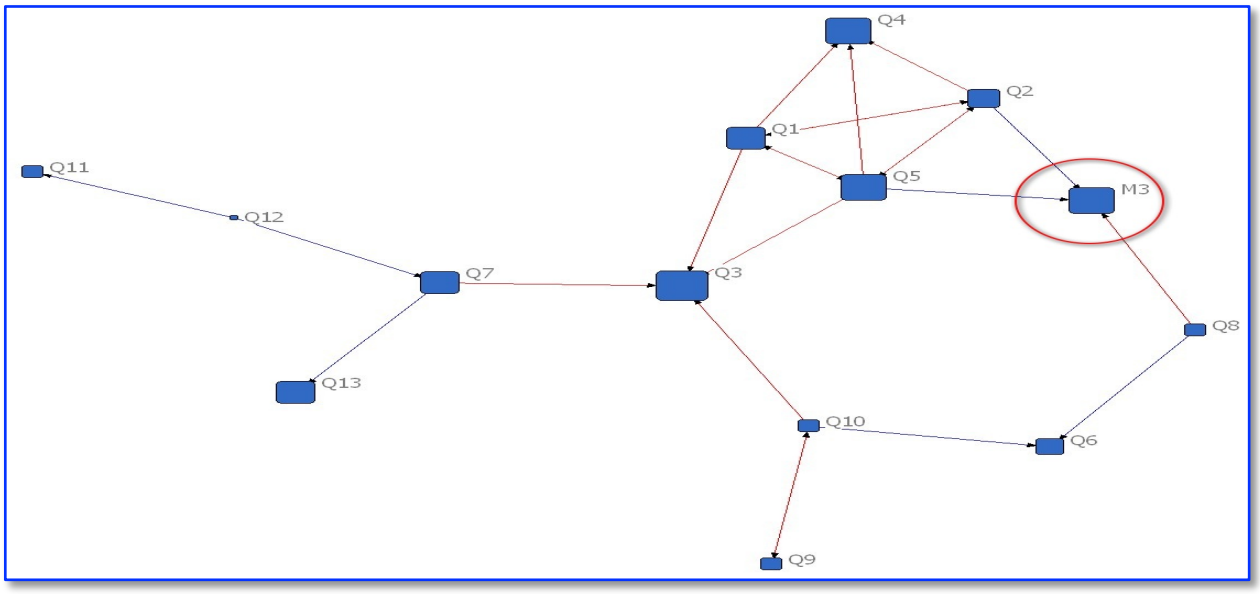

Figure 9. Communication to discuss project specific issues several times per week.

Figure 10, below, illustrates the leadership measurements for the subgroup. In the table, it is evident that five of the thirteen Q-members occupy the top three ranks and that three of these members are tied in first place. As for power and betweeness three of the same members hold the top three ranks. As for M2, who has a management role only in this subnet, he ranks, as expected, first in betweeness. These observations are consistent with the subnet centralization value of 25.44% (in-degree); the same value for the project organization net stands at 34.56%

Single Discipline Group	Person	Centrality	Power	Betweenness
Quantity Take-off/Estimating	M2	6th	6th	1st
	Q10	1st	1st	5th
	Q2	2nd	2nd	6th
	Q3	1st	4th	4th
	Q4	3rd	5th	3rd
	Q5	1st	3rd	2nd

Figure 10. The leadership evaluations for the weekly organization communications for subnet Q.

4.4 Knowledge Exchange and Professional Trust

A key element that distinguishes high performance organizations is the accessibility to and exchange of knowledge. The project organization in this study is examined from the perspective of a closed system; it implies that knowledge is exchanged amongst its members within the boundary of the network.

The network of weekly knowledge exchange is shown in Figure 11. When the frequency of knowledge exchange increases to several times per week, approximately half of the links disappear, resulting in two distinct subnets shown in Figure 12.

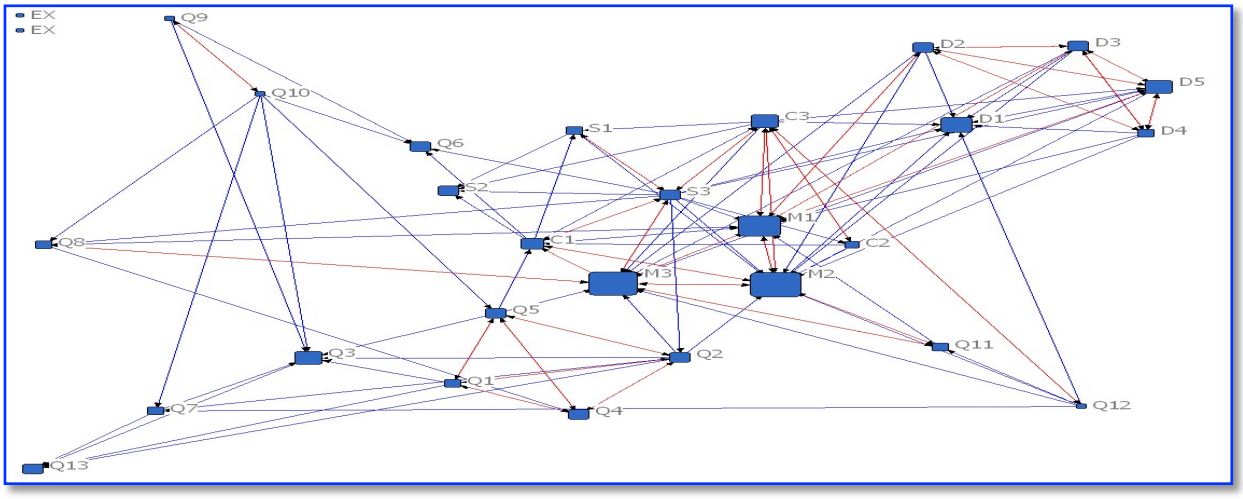

Figure 11. Weekly frequency of knowledge exchange.

The density values for the 'weekly knowledge exchange' and the 'multiple times a week exchange' are 15.76% and 8.37% respectively. These density values for knowledge exchange appear low considering the purpose of the project and the nature of the organizations environment. However they are not atypical. As reported by Chinowsky (2009), it is often a challenge getting professionals to openly exchange knowledge. In this specific project organization, possible reasons may include the following: All the members of the project organization have taken the same prerequisite courses and have been exposed to the same practices regarding the work in this capstone course. Thus, it is plausible that they consider, (correctly or mistakenly) that they know as much as the person next to them there is little if any additional knowledge to be gained from their peers. Transposing this explanation to the professional world it speaks to the value of differentiation and variety within the organization as means of encouraging knowledge exchange.

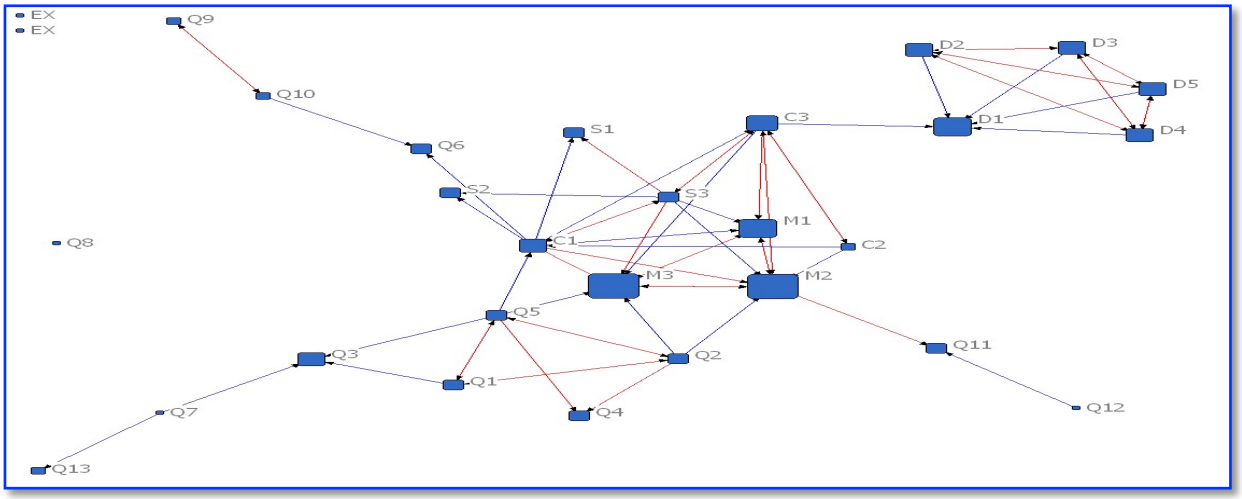

Figure 12. Frequency of knowledge exchange several times a week.

Another possible explanation may have to do with the prevailing level of professional trust within the group. The next two figures show the levels of professional trust that exist amongst the members of the project organization. Figure 13, shows the network for a moderate level of trust and Figure 14, for above average level of trust.

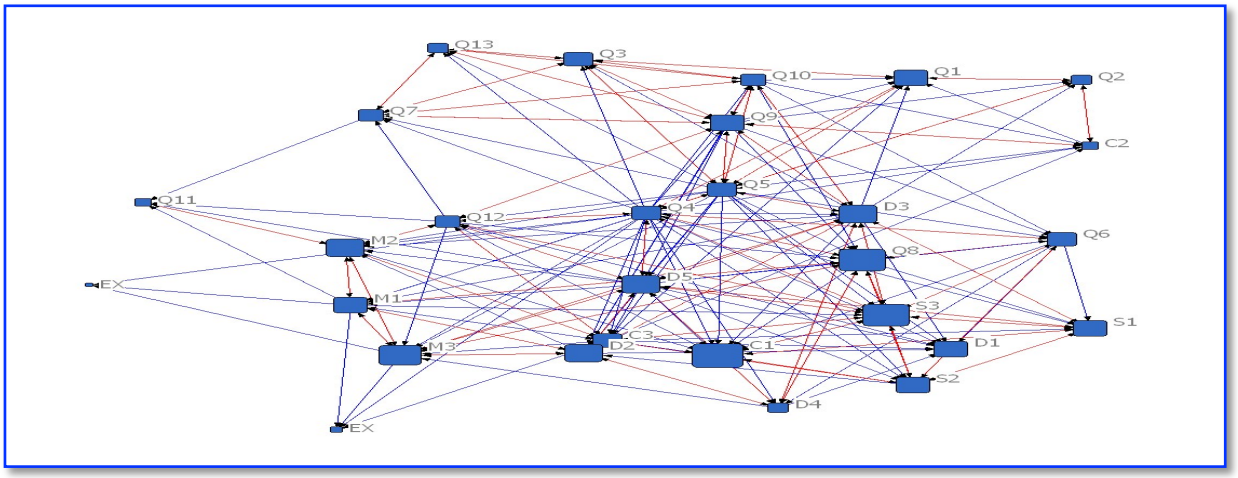

Figure 13. Moderate Level of Trust in Professional Interactions.

The density for the moderate level of trust for the above network is 29.31%, whereas the density for the above average network depicted in Figure 14, below is 20.57%. In both instances, the values are rather

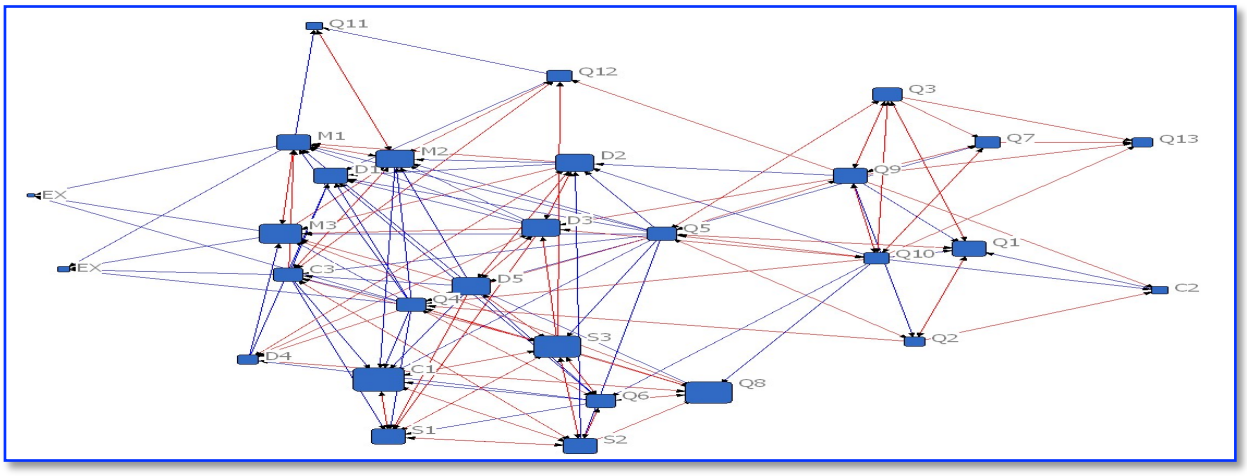

Figure 14. Above Average Level of Trust in Professional Interactions.

low and most likely acted as an impediment to the free exchange of knowledge within the project organization. Once again, specific individuals begin to emerge as having high levels of trust, while others move to the periphery indicating potential trouble with trust and subsequent knowledge exchange issues. A desirable level of network density would be above 50% (Chinowsky, 2009).

5 Conclusion

Network organizations as a form of organizational design has established itself as an archetypal form in the AEC industry. In the dynamic project environment of AEC projects it is imperative that the organizational dynamics that can potentially yield high performance project organizations are vigorously explored by researchers and fully understood by practitioners.

The findings of this case study revealed the dynamics of the teams within the network organization. Additionally, the mapping revealed the attributes of the sub-networks and provides a vehicle for study and

optimization of teams and by extension organizations in general and specifically simulated organizations used in class exercises. A comparison of the findings in this simulation with the findings of extant literature on SNA in network organizations has identified the limitations of simulations with respect to generalizations applied to actual projects.

This study demonstrated the usefulness of a simulated project organization in the sense that it affords an "start to finish" set of observations on the interactions of its members as they occur in a project environment. The scale of the scope of the project was sufficiently large to emulate an actual project yet not so large as to hinder complete and continuous observation by the researcher. Consequently, the size of the team enabled personal observation of the dynamics of the relationships.

As illustrated, issues of trust and communication frequency influence the level of knowledge exchange that emerged in the network. Additionally, the ability of the executive team to retain central positions in the communication network emerged, as traditionally task oriented managers assumed greater leadership roles. These findings demonstrate the importance of conveying role responsibilities to each member of the network at the beginning of the project. The network in this study illustrates the issues that emerge when roles and responsibilities may not be clear or when responsibilities are not fully executed.

Based on the experience gained from the application of the SNA in this particular simulated project organization, it appears that simulation is highly recommended as a research methodology and should be pursued in the future in order to explore the dynamics of relations in networks and sub networks.

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