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² Now Dean of the College of Engineering

Dedication

I dedicate this work with all my love to my life partner, Marcia Smith, who was...and
continues to be... always there for me no matter what.

Abstract

Collaborative groups are important both in the learning environment of engineering education and, in the real world, the business of engineering design. Selecting appropriate individuals to form an effective group and monitoring a group's progress are important aspects of successful task performance. This exploratory study looked at using the concepts of cognitive social structures, structural balance, and centrality from social network analysis as well as the measures of emotional intelligence. The concepts were used to analyze potential team members to examine if an individual's ability to perceive emotion in others and the self and to use, understand, and manage those emotions are a factor in a group's performance. The students from a capstone design course in computer engineering were used as volunteer subjects. They were formed into groups and assigned a design exercise to determine whether and which of the above-mentioned tools would be effective in both selecting teams and predicting the quality of the resultant design. The results were inconclusive with the exception of an individual's ability to accurately perceive emotions. The instruments that were successful were the Self-Monitoring scale and the accuracy scores derived from cognitive social structures and Level IV of network levels of analysis.

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Glossary

adjacency matrix. A means of representing the relationship between nodes of a graph and the nodes that are adjacent to them.

alters. Those in a network with whom the individual of interest (ego) interacts.

balance index. The number of balanced triads in a network divided by the total number of triads in the network.

centrality. Several measures that describe an individual's position in a network; the greater one's centrality, the more power the individual is likely to have.

Cognitive Social Structures (CSS). A person's perceptions of affect in others (Krackhardt, 1987).

ego. The individual from whose point of view a network is examined.

Emotional Intelligence (EI). The ability to monitor one's own and other people's emotions, to discriminate between different emotions and label them appropriately, and to use emotional information to guide thinking and behavior.

high resolution. Refers to the ability of a mathematical construct to give accurate results with small numbers.

low nonlinearity. The ability of a mathematical construct to produce accurate results with very large numbers.

MSCEIT (Mayer, Salovey, Caruso Emotional Intelligence Test). An emotional intelligence test based on the theory that emotional intelligence is associated with IQ.

Self-Monitoring (SM). A personality trait that is considered by some to be a form of emotional intelligence.

Situational Test of Emotional Management (STEM). An emotional intelligence test based on the theory that emotional intelligence is an actual intelligence associated with IQ. Based on the same theories as MSCEIT.

Social Network Analysis (SNA). A means of analyzing social relationships in terms of network theory, consisting of nodes, representing individuals (actors) within the networks, and ties that represent relationships between the individuals.

sociogram. A visual representation of a person's social links that show the structure of interpersonal relations in a network.

structural balance (balance). A theory related to three people or to two people and some entity (like a political philosophy, an art object) that determines if a person in such a relationship is comfortable. If an individual is uncomfortable due to the combination of relationships, he/she will attempt to change either his/her perception of the relationships or the nature of the relationships themselves.

1. INTRODUCTION

Synthesizing solutions to ill-formed problems is a core attribute of engineering. Problems rarely fall neatly into disciplinary boundaries, and the ability to design solutions as part of an interdisciplinary team is a critical skill for engineers (Brito & Cianti, 2012). Throughout their professional careers, most civil engineers will find themselves working in groups. Hence, an important part of an engineer's education is to learn how to work on design projects as part of a team. The importance of design and teamwork in an engineer's education is reflected both in the Accreditation Board for Engineering and Technology (ABET) requirements and the course structure of most engineering undergraduate curricula that culminate in a capstone design course (ABET, 2014).

Because there is a direct correlation between how well a team works together and the successful outcome of an engineering project (Kichuk & Wisner, 1997), many engineering education researchers have explored how individual attributes affect team performance (Shen, Prior, White, & Karamanoglu, 2007). However, only recently have social science tools been used to analyze the structural and social characteristics of civil engineering teams and their members (Chinowsky, Dickmann, & Galotti, 2008).

This thesis explores the relationships among the team members' individual characteristics, the social networks created during a design project, and the outcome of the project. In particular, the focus is on the role of team members' *emotional intelligence* (EI) and how the social networks formed within the team can be used as tools to understand the functioning of the group. Further, the relationship EI has with team members' ability to

perceive others on an emotional level, is examined, as is their ability to control and use their emotions to further the team's goals (Jorden & Troth, 2004).

Social network analysis (SNA) is used to determine the subjects' roles in the class network and the accuracy of their perceptions of their networks, and how that may affect a project's outcome. Measures used in SNA examined here are:

- *Levels of network analysis*: identifies individuals with the ability to lead and integrate with a group. Figure 1 shows a friendship network from the Carnegie Mellon University engineering class examined in this study. Table 1 describes the five levels of network analysis.
- *Structural balance*: determines tension within a group. Knowing the participants' relationships to each other may prevent unsuitable teaming of individuals.
- *Centrality*: an individual's position within his/her network.

It has been demonstrated, both theoretically and empirically, that an individual's ability to accurately detect the informal network in an organization has value in predicting that individual's reputational power. Krackhardt (1987) made this determination using the concept of *cognitive social structures* (CSS). A CSS is a person's perception of process (e.g., advice) or affect (e.g., friendship) in the network in which he/she is embedded (whether that network is organizational or social, formal or informal).

There are five levels of analysis in social network theory. Krackhardt examined Level III, the individual's perception of the structure of the network in which he/she is embedded. This perception affects the individual's attitude and behavior in the network (Krackhardt, 1990).

The next level of analysis, Level IV, is an individual's deeper view into his/her network. This level of analysis is explored for the first time in this dissertation. Analyzing a person's perceptions from a Level IV standpoint provides insight into the person's beliefs about the tenor of their netmates' view of the network as a whole.

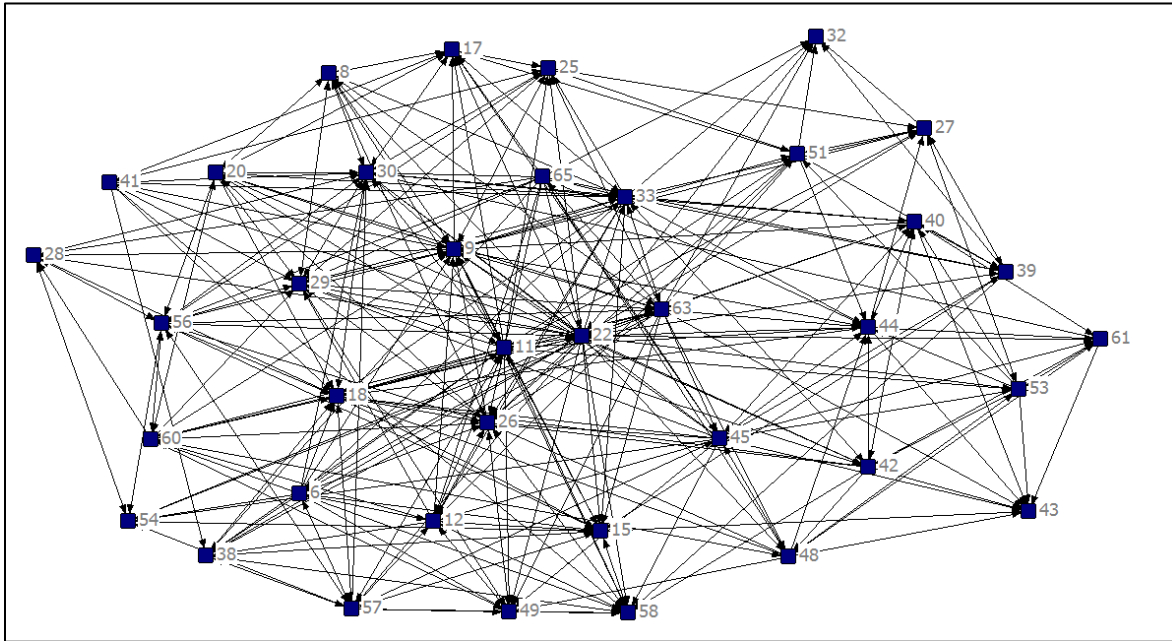


Figure 1. Social network diagram of who likes whom. Square dots are the subjects of the study. Lines with arrows between dots indicates that A reported that he/she liked B. (Note: Subject identification numbers do not reflect the number of subjects in the study.)

Table 1. Social network levels of analysis

Level	Description
0	Attributes of the network itself, including size, shape and density.
I	Individual (<i>ego</i>) and his/her attributes (gender, age, length of time at an organization, etc.).
II	Ego's relationships with others (<i>alters</i>) to whom he/she has direct ties.
III	Ego's perception of alter A's ties to alter B (or any other pair of alters).
IV	Ego's perception of alter C's perception of alter A's ties to alter B (or any other combination of alters).

While SNA is used to analyze different types of networks, this dissertation considers the individuals' networks of affect (*emotions*), in particular, feelings toward other people in the network. Perception of emotions is the most fundamental of the four branches of *ability EI* (Mayer, Salovey, & Caruso, 2008). Emotions must be perceived before they can be used, understood, or managed. EI, in turn, has been shown to be an important determinant in the quality of organizational leadership, as measured by the efficacy of work teams (Prati, Douglas, Ferris, et al, 2003).

For this analysis, task teams were formed based on the theory of *structural balance* (see section 2.3). Affective relationships among those in a pool of prospective teammates (the subjects of the study) were determined using structural balance, and subjects were placed in teams accordingly. Once chosen, the teams worked on a design task with a quantifiable outcome. The relative quality of their efforts was then correlated with 1) the team's structural balance, 2) the team members' emotional intelligences, 3) the accuracy of their Level III and Level IV perceptions, and 4) the members' network centrality.

Chapter 2 reviews the literature that applies the theories of EI and SNA to the formation of groups and group efficacy. Specifically, the chapter examines social network theory and identifies recent analyses that highlight variables that may affect group performance both in and out of the classroom.

Chapter 3 identifies the particular focus of the study, the research questions. EI, structural balance, centrality, and the accuracy of a team member's network perceptions are defined as key variables that can affect the quality of the team's performance.

Chapter 4 describes the methods used to select team members, form the teams, and collect the data used in the study of the groups' performances. The chapter also describes the task.

Chapter 5 focuses on the results. The sample sizes were small—32 subjects and 8 teams. Because of this, the results are meaningful largely in qualitative terms.

Chapter 6 discusses the potential significance of those results for the education of groups in the performance of engineering tasks as well as suggestions for future work that can be based on this study.

2. LITERATURE REVIEW AND BACKGROUND

Preparation for working in teams starts long before engineers enter their practice. Learning in the classroom does not simply entail the transfer of knowledge from teacher to student or, in the case of collaborative learning, from student to student. Classroom learning takes place in a sociocultural context.

In collaborative engineering design classes where students work in groups, the instructor's role is to present the task, provide ongoing clarification of the assignment, facilitate the functioning of the group, and assess results. If the instructor is aware of problems within the group, he/she can facilitate by stepping in to attempt to correct that which is causing the group to go off on an incorrect path or otherwise be dysfunctional. In order to know when to intervene, he/she must understand the dynamics of the group interactions. For instance, the instructor would want to know if there is an effective leader, if there are too many "free riders," or if tensions between individuals are interfering with the work. This can be determined partially from intermediate output (e.g., reports, presentations, work logs) or from students coming to the instructor to discuss the inner workings of their team. The state of ongoing team relationships can also be determined by social network analysis if the appropriate data are acquired on a regular basis.

This study looks at one dependent and nine independent variables (Table 2). A Pearson-r correlation was run on every variable versus every other variable. The results are discussed in Chapter 5.

Table 2. List of variables.

Variable	Meaning
Network data (matrices)	
Time 1 Level II social network - friendship (NxN)	Degree to which class members like each other (at week 2 of the semester). (Scale of 1 to 5).
Time 2 Level II social network - friendship (NxN)	Whether team members dislike, neither like nor dislike, or like each other (at week 12 of the semester). (Scale of -1, 0 or 1, respectively).
Independent variables (vectors)	
Balance Index	Structural balance
Indegree	Centrality measure
Outdegree	"
Betweenness	"
Closeness	"
Level III accuracy score	Accuracy of <i>C</i> 's perception of whether <i>A</i> likes <i>B</i> .
Level IV accuracy score	Accuracy of <i>D</i> 's perception of <i>C</i> 's perception of whether <i>A</i> likes <i>B</i> .
STEM	Situational Test of Emotion Management (STEM) score
SM	Self-monitoring (SM) scale
Dependent variables	
Team Performance	Team results of design task

2.1 Social Networks

A *social network* is the web of relationships between entities that form a group of a particular type, such as the employees of a company or a subset of them working on a specific project. A group might also be made up of the firms in a particular industry, or non-profit organizations addressing a common problem (e.g., world hunger). The types of relationships between entities that comprise a social network can vary. The most familiar may be the formal ties of hierarchy as shown in the ubiquitous organization chart (Figure 2). Alternatively, the relationship type might be the friendships between employees, or who goes to whom for advice within an organization. Friendship, trust, and advice are common relationships examined by social network theorists.

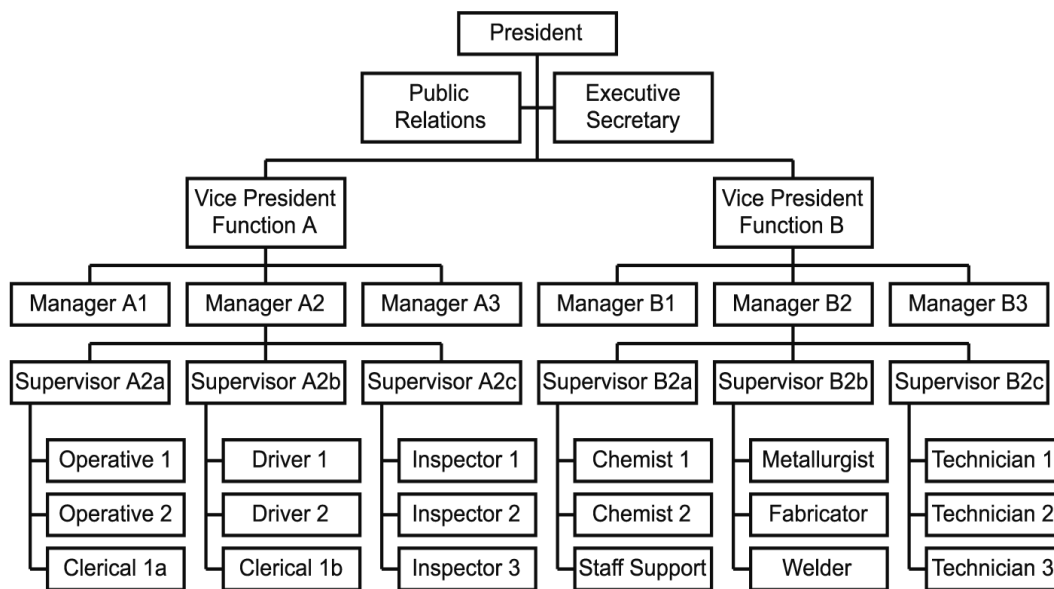


Figure 2. Organization chart. An organization chart is a sociogram of a hierarchical social network.

Social network analysis (SNA) studies the relationships between individuals or entities such as groups of individuals or companies. The study of these networks provides

information on how relationships between group members impact the group as a whole and sheds light on how the structure of the relationships, the network itself, affect the individuals within the group. Using SNA, a researcher can visualize networks and examine their structures. It is useful for identifying key individuals (or any other entities of interest) to determine the effect of moving them to a different part of the network or removing them altogether. The ramifications of other actions that could affect the dynamics of the organizational structure are also frequently examined.

Among other things, SNA can be used to predict what path(s) information will take in the process of information dissemination (Haythornthwaite, 1996), and to determine who in the network the early adapters will be (Ibarra & Andrews, 1993).

Social networks are represented by both a matrix and a *sociogram*. An example of each is shown in Figure 3 and Figure 4. The nodes in the example sociogram represent any kind of entity that is embedded in a network, such as individuals in an organization. The lines between the nodes represent the ties that the entities share. An arrow at one end means the tie is directed to that node. A line with arrows at both ends means that the tie is reciprocated. The cells in the matrix could represent simply the presence or absence of a tie (0 or 1). The quantity in the cell could also indicate the strength of the tie (e.g., *A* went to *B* for advice three times). The width of the tie could represent that strength. The type of line (e.g., solid, dotted, dashed) could be used to communicate other attributes of the tie (e.g., whether it is positive or negative) as could color.

2.2 Centrality

One attribute of a member of a social network is his/her *centrality*. Centrality can be thought of as a measure of a person's importance, "power," or role in a network. Five types

of centrality are commonly measured. They are indegree, outdegree, betweenness, and two kinds of closeness (Freeman, 1979)³. *Indegree* is the number of individuals (*alters*) who have affective ties with the individual of interest (*ego*). *Outdegree* is the number of relationships that originate with the ego that flow toward the alters. For example, if only individuals *A*, *B*, *C*, and *D* like ego, his/her in-degree is four. If ego likes only individuals *D*, *E*, and *F*, his/her out-degree is three.

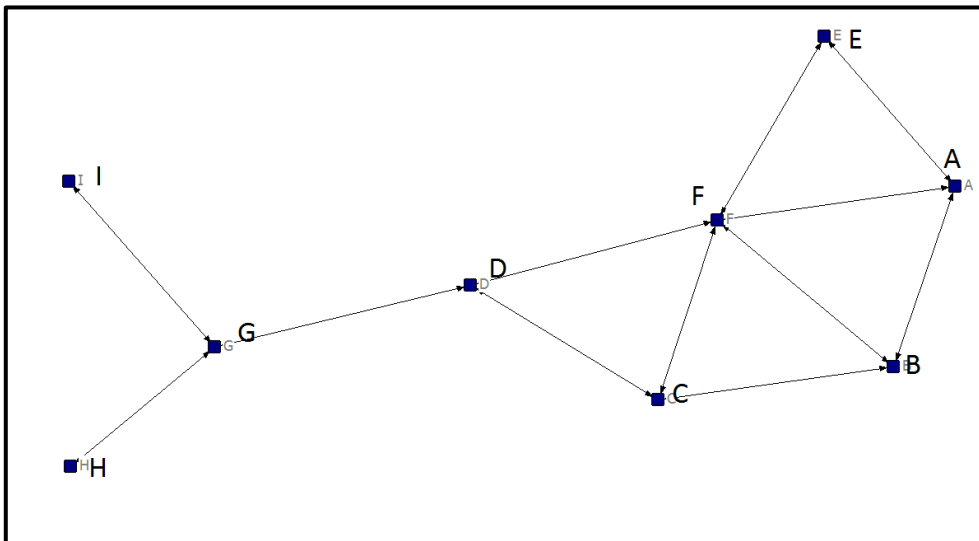


Figure 3. Example of a sociogram. This graph is equivalent to the matrix in Figure 4. Squares represent, e.g., “people.” The lines between people represent, e.g., “knowing.” That is: *D* knows *C*, *F*, and *G*.; *B* knows *A*, *C*, and *F*, and so forth.

³ Freeman (1979) defines these terms in the formal language of graph theory.

Betweenness can be thought of as a probability that information or resources that pass between alters will go through ego. *Closeness* is the inverse of *farness*—which is the sum of the distances between a node and all the other nodes.⁴

In Figure 3, *F* has an indegree of five and an outdegree of five (all ties in the figure are reciprocal), the highest closeness of all the nodes, and the third highest value of betweenness. *D* has a degree of six (three in and three out) but the highest value of betweenness by virtue of being a "gate keeper" between the main body and *G*, *H*, and *I*. *H* and *I*, each with a degree of one, have the lowest value of closeness and a betweenness of zero.

		Receiver								
Sender		A	B	C	D	E	F	G	H	I
	A	0	1	0	0	1	1	0	0	0
	B	1	0	1	0	0	1	0	0	0
	C	0	1	0	1	0	1	0	0	0
	D	0	0	1	0	0	1	1	0	0
	E	1	0	0	0	0	1	0	0	0
	F	1	1	1	1	1	0	0	0	0
	G	0	0	0	1	0	0	0	1	1
	H	0	0	0	0	0	0	1	0	0
	I	0	0	0	0	0	0	0	1	0

Figure 4. Matrix representing a social network. The sender is the person from whom the tie (e.g., advice, liking) originates. The receiver is the recipient of that action. (i.e., sender gives advice to receiver). A "1" in an intersection indicates the presence of a tie. A zero means there is no tie.

⁴ Distance is measured by the number of direct ties between one node and another (one tie equals one unit). The tie between two adjacent nodes equals one unit.

2.3 Structural Balance

Heider (1946) posited that a relationship between two people is not formed in a vacuum; a third entity has an effect on how they feel about each other and the entity. This entity could be something such as an idea or political philosophy, or it could be a third person. He asserted that people in dyadic and triadic relationships prefer to minimize tension, and tension occurs when a dyad, triad, or larger network is not balanced.

The SNA concept of *structural balance*, conceived by Heider and expanded and formalized through the use of graph theory by Cartwright and Harary (1956), can be used to explain, in part, the social dynamics of a group, and predict how group members' attitudes towards each other can change. Structural balance is a function of ties of affect (e.g., emotions such as love, like, and trust and their opposites) between two individuals, and either a third person or ties of association (e.g., ownership) with an object. Balance may be defined as a set of simple social "rules."

- The friend of my friend is my friend.
- The friend of my enemy is my enemy.
- The enemy of my friend is my enemy.
- The enemy of my enemy is my friend. (Anonymous).⁵

If it appears to the individual from whose standpoint the triad is being examined that any one of the rules is not followed (e.g., "the friend of my friend is my enemy"), that individual will feel tension. To allay the discomfort, the individual will either change his/her perception of the situation or try to change the situation itself. In the case of "the friend of

⁵ Old Arab saying (Reported by, among others, Rapoport, 1963)

my friend is my enemy,” the perceiver might attempt to distance him/herself from his friend, or begin to believe that his enemy is not so bad after all.

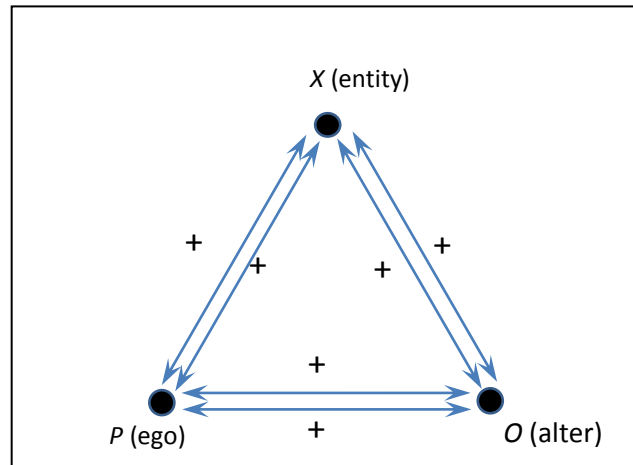


Figure 5. Triad.

In Heider's terms, if the triad in Figure 5 is not balanced, *P* will change how he/she feels or what he/she believes about the other entities in the triad so that balance will be restored.⁶ If *P* likes *X* and *O*, but *O* does not like *X* (Figure 6a), one of several changes may take place to restore *P*'s perception of balance. One, *P* will begin to think less of *O* (Figure 6b). Two, *P* will no longer like *X* as much as he/she originally did (Figure 6c), or three, *P* will change his or her perception that *O* does not like *X* (Figure 6d). Note that *P*'s discomfort and his/her actions to alleviate it are based on his/her *perception* of the relationships, not what the actual relationships are.

The number of positive and negative dyads determines whether a triad is balanced (Figure 7). A positive affective tie between two people would be something such as liking or trusting. Conversely, a negative affective tie would be disliking or mistrusting. Feelings

⁶ Heider originated the *P*, *O*, *X* notation. *P* is now commonly called "ego" or "actor," *O* is now "alter" or "actor," as is *X* (which originally stood for an entity that could be a person or a thing).

must be reciprocated for a dyad to be balanced. For instance, if person *P* likes person *O*, person *O* must like *P* in return. If *P* and *O* like each other, the dyad is positive; if they dislike each other, the dyad is negative. In both cases, the dyad is balanced. If one likes the other, but the other does not like him/her, the dyad is unbalanced.

Necessary conditions for a triad to be balanced are that its three dyads must be balanced, and the algebraic product of the signs of the three dyads must be positive (Figure 7). In other words, a triad is balanced if it contains either no or two negative dyads (Figure 8). It is unbalanced if it contains one or three negative dyads (Figure 9).

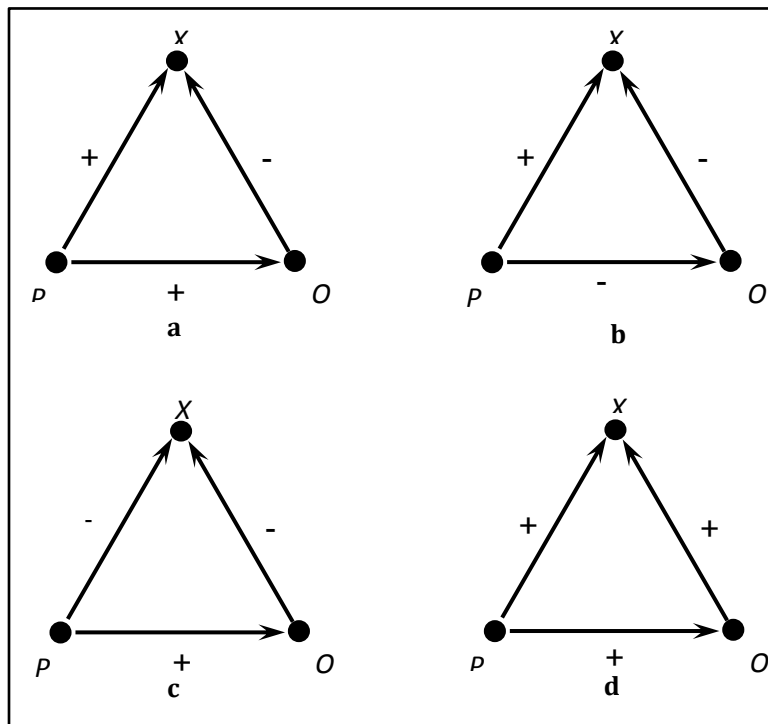


Figure 6. Unbalanced (a) and balanced (b, c, d) triads.

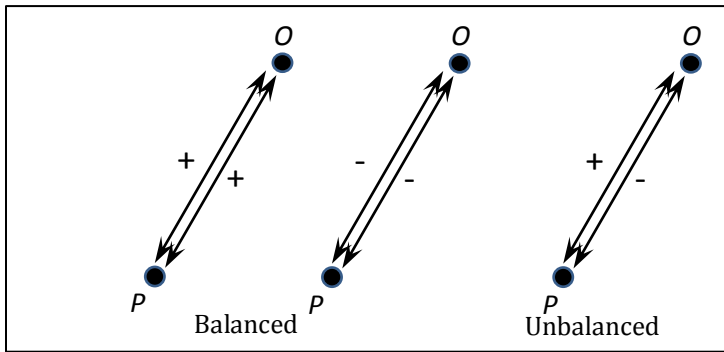


Figure 7. Balanced and unbalanced dyads.

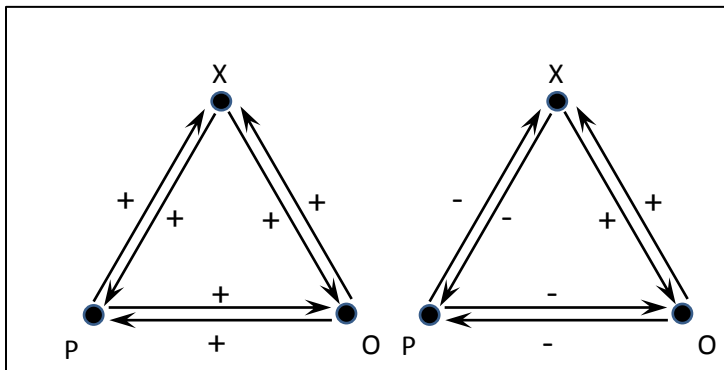


Figure 8. Balanced triads.

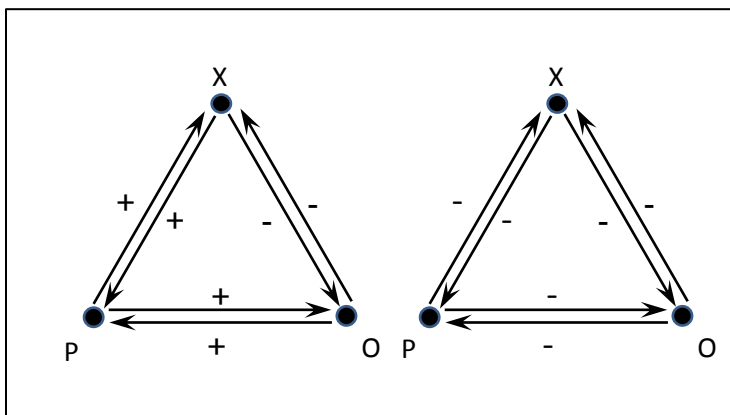


Figure 9. Unbalanced triads.

Various indices have been proposed to determine the degree of balance in networks that comprise more than a single triad. The simplest one, proposed by Cartwright and Harary (1956), states that if:

G = a set of nodes (people, in this case) and edges (relationships) in a network

$C_T(G)$ = total number of triads in G

$C_B(G)$ = number of balanced triads in G

$B(G)$ = balance index of G

Then

$$B(G) = \frac{C_B(G)}{C_T(G)}$$

That is, the number of balanced triads divided by the total number of possible dyads.

There is also a type of triad in which A has reciprocal relationships with B and C , but B does not have a relationship with C , nor C with B (Figure 10). Cartwright and Harary (1956) call this type of triad “vacuously balanced.” Heider (1958) theorized that the missing relationships between B and C will be filled in (p. 205).

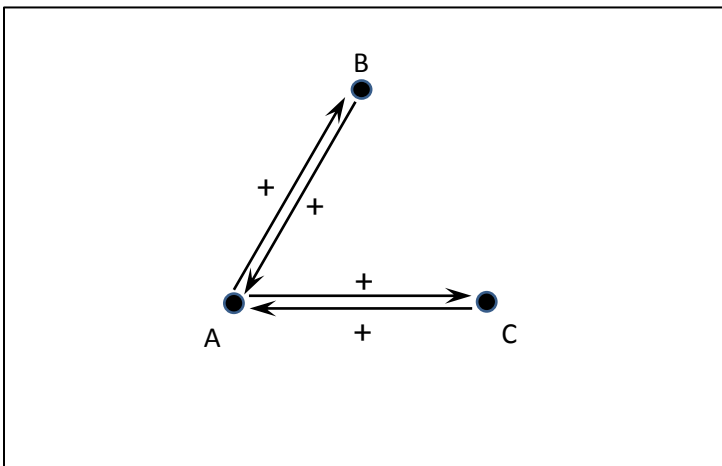


Figure 10. Vacuously balanced triad.

2.4 Level III and Level IV of network analysis

An actor's actual ties of liking, trust, advice, etc., are not the only significant factors in the functioning of the network of which he/she is a part. The actor's *perception* of those ties is also of interest (Krackhardt, 1987). These perceptions form an actor's *cognitive social structure* (CSS). That is, actor *C* may perceive that actor *A* likes actor *B* (or any other actor in the group), whether or not *A* likes *B*.

An actor's perception may also reach deeper into his/her network. That is, actor *D* may perceive that actor *C* perceives that actor *A* likes actor *B* (regardless of what *C* actually perceives, and whether or not *A* likes *B*).

In a network study of the employees of a small high-tech start-up firm ($N = 36$), Krackhardt (1990) demonstrated that the greater the accuracy of an actor's cognitive social structure *vis-a-vis* the advice network, the more powerful they were rated by others in the organization. In addition, the study showed that the higher or more central an actor's position in the network was, the greater his/her ability to perceive accurately the presence or absence of advice ties between others.

The Thomas Theorem (1931) states that, "If men define...situations as real, they are real in their consequences." This is the basis of the usefulness of CSSs. How actors *view* relationships in their social networks is as important as the *actual* relationships within their networks for predicting formal positions, centrality, network roles, and behavior. Krackhardt (1987) introduced the concept of the cognitive social structure in response to assertions by Bernard, Killworth, and Sailer (B-K-S) that "behavioral measures of interaction are not very closely related to participants' self-reports of the same interactions" (B-K-S, 1984). What is

interesting in the context of this thesis is Krackhardt's substitution of "perception of the network within which this behavior takes place" for "accuracy of self-reported behavior." He claims that what B-K-S see as the problem of inaccuracy of self-reported behavior will go away if it is replaced with observing how actors' reports of their perceptions' affect their observed behavior.

The five levels of analysis of social networks (Levels 0-IV) refer to the breadth and depth of the analysis (Table 1). The levels used are Level II through IV. Level II is simply what an individual reports his/her relationship with others in the network is. It is represented by a two-dimensional matrix such as the one shown in Figure 4.

2.4.1. Representation of Levels

Representation of Level III, ego's CSS, requires a three-dimensional matrix. That is, $M_{A, B, C}$. (Figure 16). The subscripts represent C , the "responder,"⁷ A , the "sender," and B , the "receiver." This is equivalent to saying that C believes that A likes (or dislikes or any other relationship such as "trusts," "seeks advice from," etc.) B . The matrix is made up of stacked two-dimensional matrices representing C 's perceptions of A and B 's relationship. There is one of these two-dimensional "perception" matrices for each C in the network.

Level IV is described by a four-dimensional matrix: $M_{A, B, C, D}$. The subscripts represent D , the "responder,"⁸ C , the "perceiver," A , the "sender," and B , the "receiver." This represents the statement " D believes that C perceives that A likes (dislikes, etc.) B ."

⁷ "Responder" because this is C 's response to the network questionnaire asking what he/she perceives A 's tie to B is.

⁸ In this case, Level IV, D is the responder to the network questionnaire asking what he/she perceives C 's perception of A 's tie to B is.

The four-dimensional matrix is N (the number of responders) cubes stacked one on top of another.

The importance of Level IV can be shown through Level III sociograms.⁹ Figure 11 shows the friendship network of a high-tech company called here Silicone Systems.¹⁰

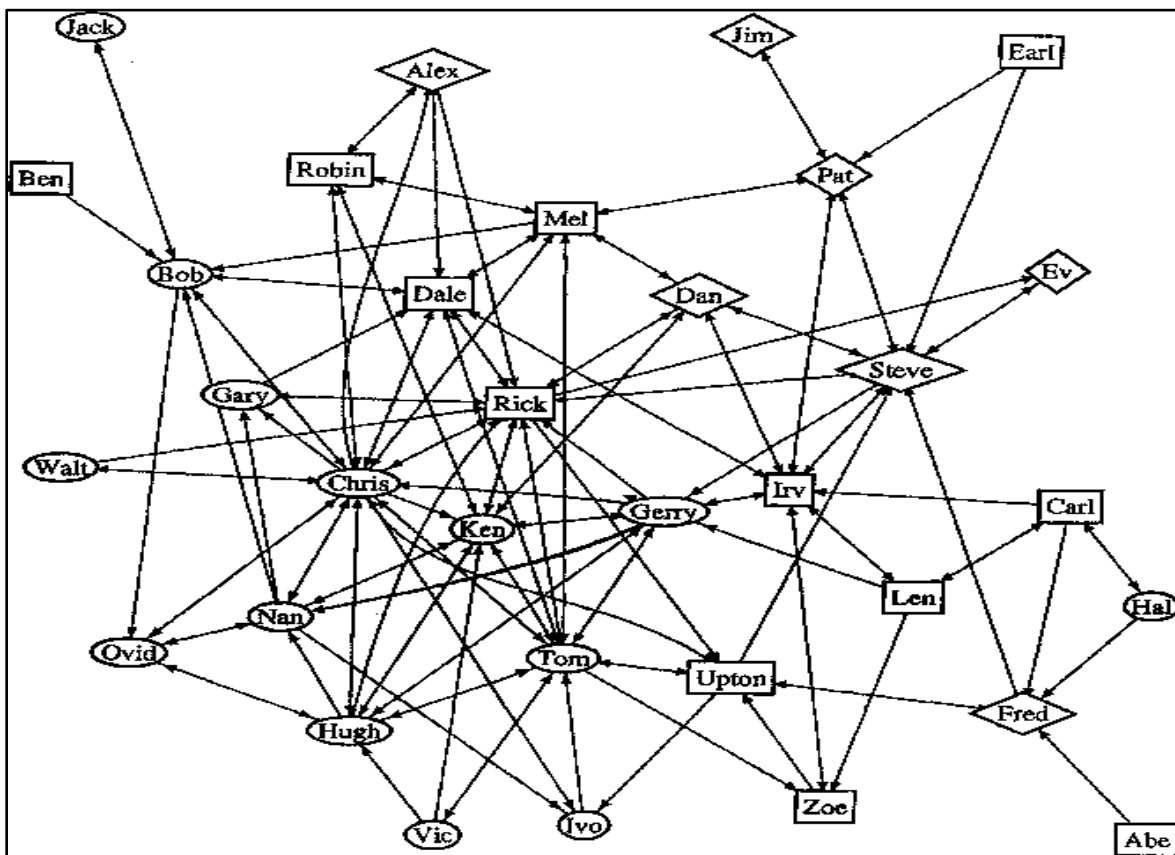


Figure 11. Sociogram of Silicone Systems friendship network. The ovals contain the names of employees who are in favor of forming a union. The diamonds have the names of the managers (including the three owners). The rectangles represent employees who are either against a union or indifferent to the idea.

The data, from which the graph was drawn, came from a questionnaire that first asked, “Whom do you consider to be a personal friend?” The second question asked was the Level

⁹ Data is from Krackhart (1992). Includes responses from a questionnaire and interviews.

¹⁰ Information about Silicone Systems from Krackhardt (1987).

III question, “Whom do you think *B* considers to be a personal friend?” In other words, what is *A*’s (the respondent’s) perception of *B*’s (and *C*’s, *D*’s, *E*’s, etc.) friendships. Taken in sum, this is *A*’s picture of the network structure of which he/she is a part.

Level III analysis provides insight into people’s perceptions of the actual network structure. For example, Figures 12 through 15 show Level III pictures of the network from the points of view of several of the employees. Figure 12 shows how Zoe sees the friendship structure of the company. Zoe is an average employee who either is against the union or is indifferent. She has a reasonably cohesive (although not necessarily accurate) picture of the network. She sees the union supporters as a tight group of friends. The managers are also seen as a group who stick together, while the non-union supporters are perceived as randomly placed between the union supporters and managers.

Figure 13 is a picture of an out of touch manager, Ev. It was because of him that the union movement was started. He sees a fragmented organization in which he does not know the majority of the employees, even some who work for him. He thinks only two people like him, the president, whom he likes in return, and another employee who he apparently does not care about. Other than that, he is only cognizant of a small clique of union supporters, three dyadic friendships, and an incomplete triad of friends.

Figure 14 is the perception of one of the central union supporters, Chris. He sees himself as in the center of a pro-union clique. He believes that the non-union types are a cohesive group, as are the managers. It is notable that he sees his union supporters only indirectly connected with the managers through the non-union supporters.

Figure 15 is the perception of the company’s president, Steve, (and one of the three owners) of Silicone Systems. His is a very much “us and them” picture, with the managers

sticking together, and the union members grouped on the other side with the non-union people between them. What we can infer from these four examples is that people vary widely in their perception of the network structure. And, as these examples illustrate, each picture provides insight into the person's view of how their firm is organized.

What we learn from the sum of these pictures is the employees' "worldview" of their organization, with specific indicators of their sense of groups, of cohesiveness, or the lack of integration. Such knowledge could also be useful to the leaders of the organization. If Steve (the president) knows that Zoe perceives a relatively integrated firm (via friendships) and he sees that Ev's view is that the place is fraught with divisions, then that could inform Steve on how to approach each of these employees in their assignments.

Level IV analysis, then, provides us with knowledge about how each actor understands the "worldviews" (in terms of network structure) of their fellow employees or organization members. But, this is useful knowledge, especially for leaders, only to the extent that they (as leaders) have *accurate* understandings of these people's perceptions.

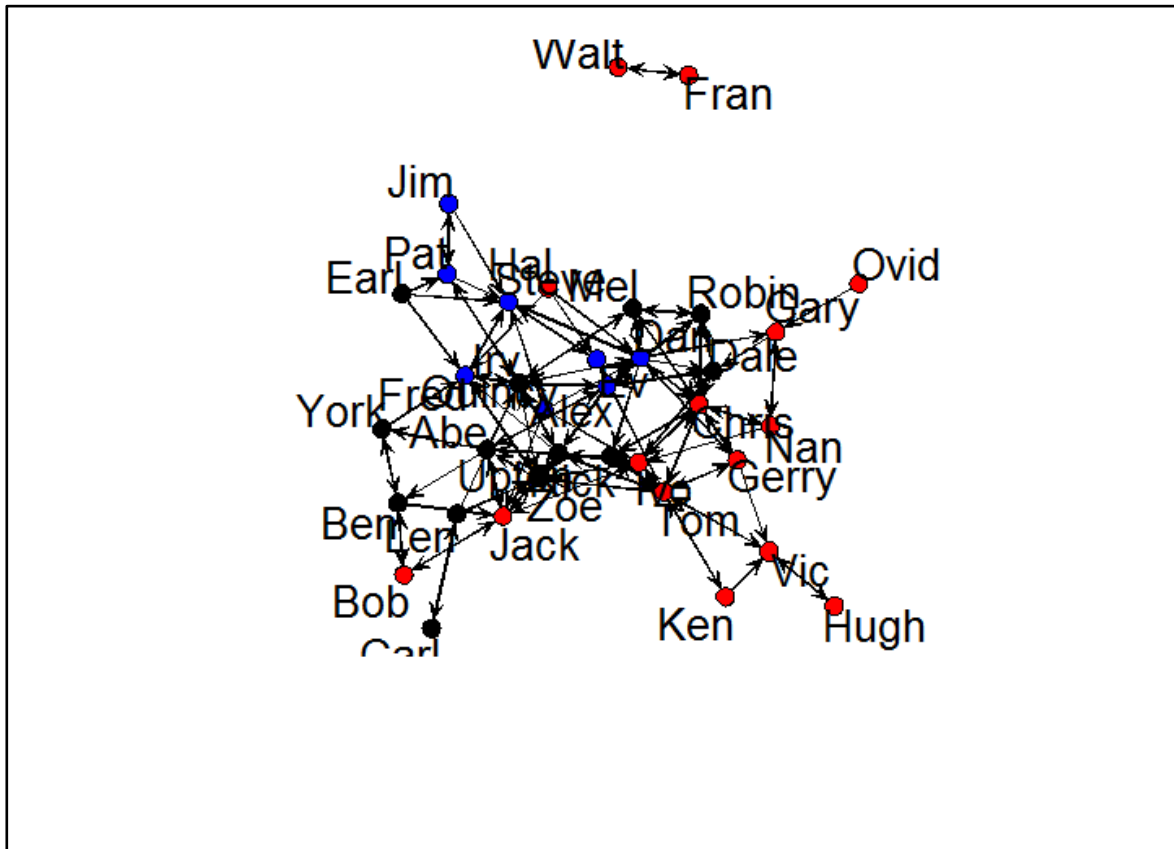


Figure 12. Zoe: A fairly typical employee picture. *Note:* Blue nodes are management. Red nodes are pro-union employees. Black nodes are employees who are either against the union or indifferent.

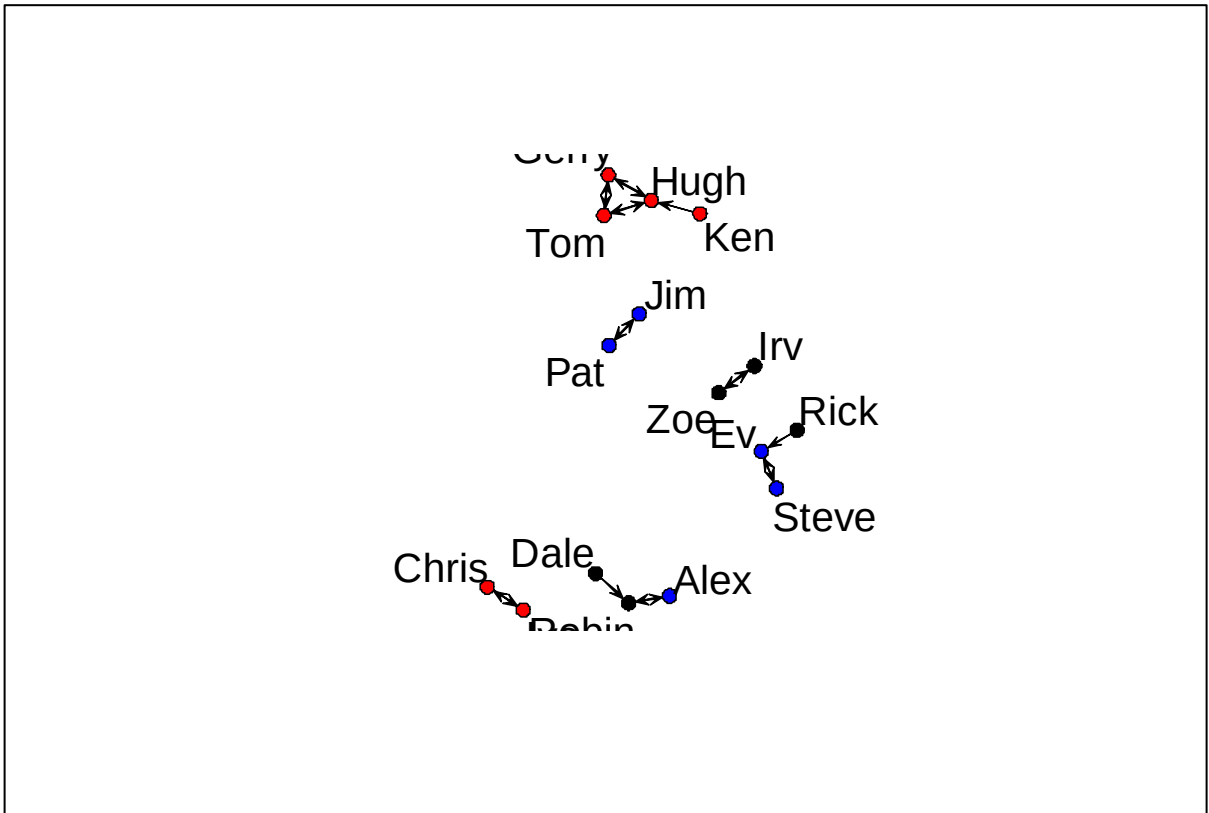


Figure 13. Ev: an out-of-touch manager. *Note:* Blue nodes are management. Red nodes are pro-union employees. Black nodes are employees who are either against the union or indifferent.

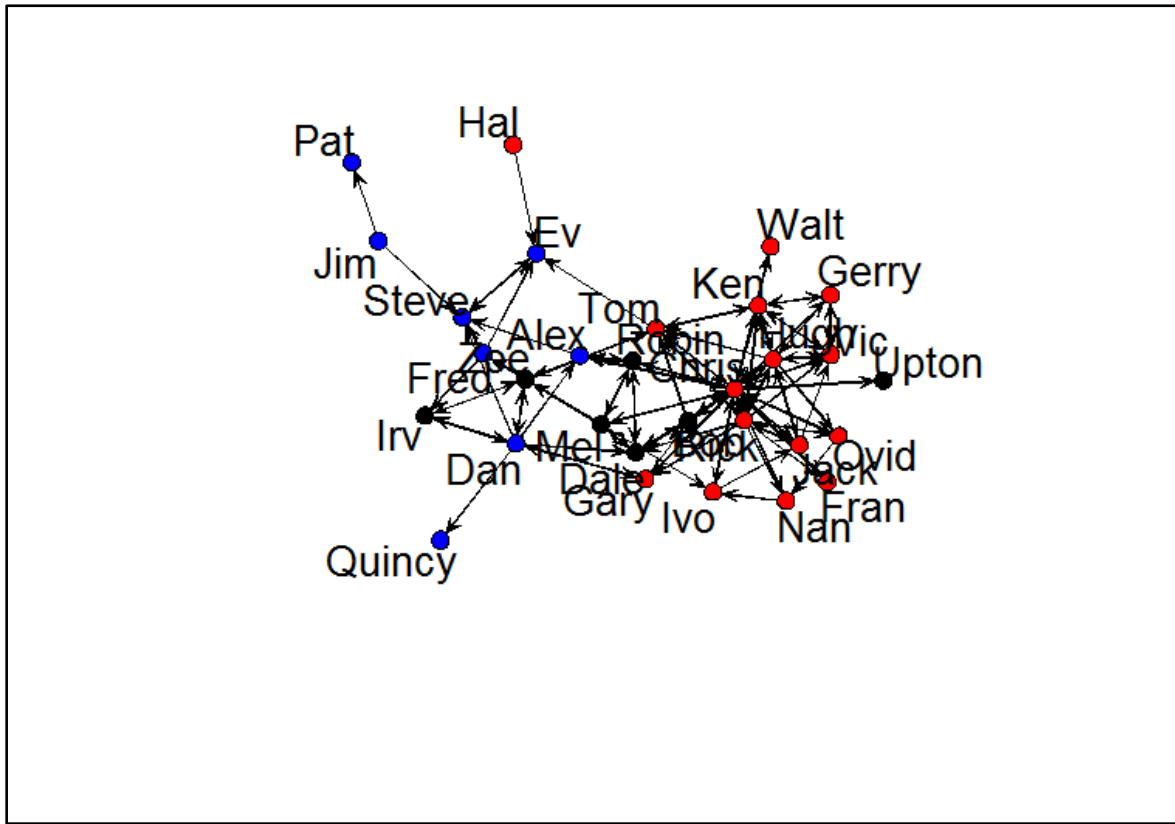


Figure 14. Chris: a central union supporter. *Note:* Blue nodes are management. Red nodes are pro-union employees. Black nodes are employees who are either against the union or indifferent.

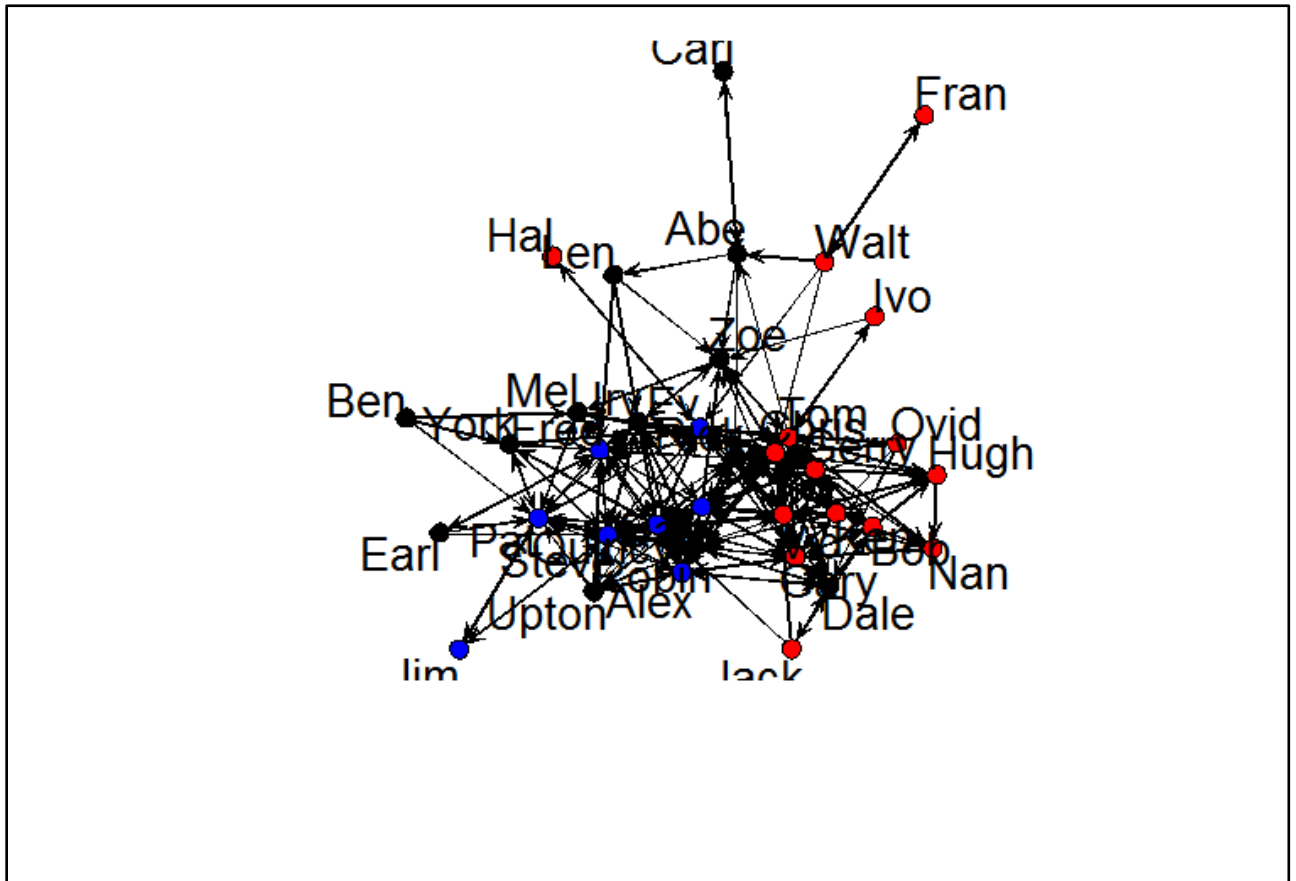


Figure 15. Company president's view. Note: Blue nodes are management. Red nodes are pro-union employees. Black nodes are employees who are either against the union or indifferent.

2.4.2 Level III and Level IV Accuracy

The truth of Level II is what ego *A* reports that he/she feels about alter *B*. Level III accuracy is based on Level II's truth. That is if *C* believes that *A* likes *B* and it is true that *A* reported that he/she likes *B*, *C*'s belief is accurate.

Level IV accuracy depends on Level III's "truth."¹¹ That is, *D* is correct in believing that *C* believes that *A* likes *B* if *C* actually believes that *A* likes *B*, (regardless of how *A* feels

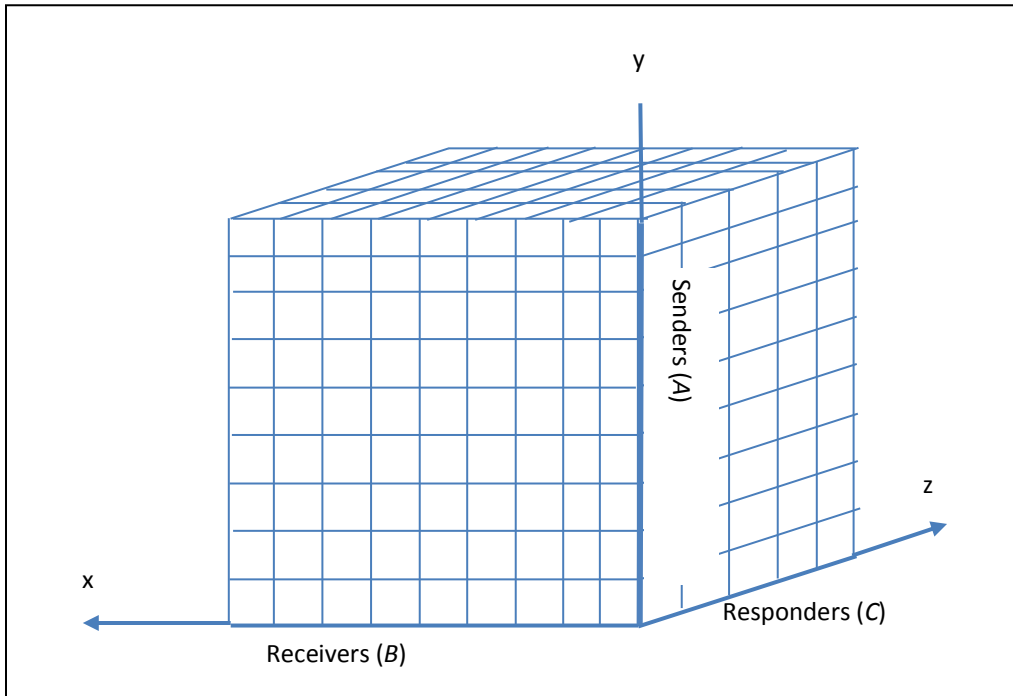


Figure 16. Matrix of Level of Analysis III (Cognitive social structure)

towards *B*). Level III and Level IV are about perceptions, not objective reality.

To measure the accuracy of Level III and IV, I used a variation of the point correlation coefficient that Krackhardt (1987) used to calculate Level III cognitive accuracy in

¹¹ "Truth" is in quotations because it does not matter if the Level III's "truth" is correct, only that *D*'s perception of *C*'s perception is, in fact, what *C* believes that *A*'s feelings towards *B* are.

the study of Silicone Systems. Gower and Legendre (1986) analyzed 15 equations measuring the accuracy of the data that exists in a 2 x 2 matrix (Figure 17). Krackhardt selected equation S_{14} because of its high resolution and low nonlinearity.

		Truth	
		0	1
Perception	0	a	b
	1	c	d

Figure 17. 2 x 2 Matrix of Truth versus Perception.

The measure Krackhardt used for the 2 x 2 case is:

$$S_{14} = \frac{ad - bc}{\sqrt{(a + c)(b + d)(a + b)(c + d)}}$$

S_{14} has a major disadvantage, however. If any of the terms in the denominator are zero, S_{14} is indeterminate. In its stead, equation S_9 was selected for this study.

$$S_9 = \frac{(a + d) - (b + c)}{a + b + c + d}$$

It is impossible for the denominator to be zero and its characteristics of resolution and non-linearity are similar to those of S_{14} . Since the data comprise "-1" (dislikes), "0" (neither likes nor dislikes), and "1" (likes), a 3 x 3 matrix is required to tabulate the results of the Level IV question (Figure 17) and S_9 becomes:

$$S_9^* = \frac{(a + e + i) - (b + c + d + f + g + h)}{a + b + c + d + e + f + g + h + i}$$

If perception matches truth, the value in one of the diagonal cells (a, e, i) will be increased by one. An incorrect perception will fall in one of the off diagonal cells. For

instance, if *A* believes that *B* likes *C*, but, in fact, *B* dislikes *C*, the value in cell *g* (Figure 18) would be increased by one. If there are more correct than incorrect perceptions, S_9^* will be positive. If more are incorrect than correct, S_9^* will be negative. If all perceptions are correct, S_9^* will be equal to 1.0. If all of the perceptions are incorrect, S_9^* will equal -1.0. A worked example is shown in appendix F. A Pearson correlation was calculated for the S_9^* vector (one result per subject), *versus* the other independent and dependent variables. The correlations are illustrated in Chapter 4 and discussed in Chapter 5.

		Truth		
		-1	0	1
Perception	-1	a	b	c
	0	d	e	f
	1	g	h	i

Figure 18. 3 x 3 Matrix of Truth *versus* Perception.

2.4.3 Perceptual Traits

Using the matrix to tally the results allows a much finer analysis than just the S_9 measure. It can be used, for instance, to determine the propensity of a subject to perceive consistently that *As* like *Bs* when even though *As* dislike *Bs*, and *vice versa*; or is more likely to be correct when the truth is that *As* like *Bs* than when *As* are actually indifferent to *Bs*.

The people with these perceptual traits can be classified into eight different types, four for their biases in their Level III perceptions, and four for their biases in their Level IV perceptions. See Table 3 for the list of types. (See also appendix C1 and C2).

A great deal of work has been done on people's ability to recognize emotions (Aviezer, Hassin, et al, 2008; Cf. Cowie, 2009, for a history). People use facial expression, tone of voice (Massaro & Egan, 1996), and body language (Van den Stock, Righart & Gelder, 2007) to both show and discern emotion. It is not unreasonable to believe that if *A* and *B* are observed interacting, the observer *C* could tell what their feelings towards each other are. Whether a person, *D*, can correctly perceive what person *C* perceives about *A* and *B*'s relationship has not been examined before now. It is unknown what skills, innate traits, and neurological activity would be required to do so. This study introduces the concept of Level IV to encourage future studies of these skills, traits, and activity.

2.4.4 Level III types

It is possible to categorize subjects (in Level III, call them *C*) by their perceptions of how *A* feels about *B* and, in Level IV, of *D*'s perceptions of *C*'s perceptions. Leaving out any perceptions of negative ties between *A* and *B*, there are eight types, as described below and summarized in Table 3. The reason for discounting negatives is that there were so few subjects (3) that disliked a teammate, and so few perceptions (4 out of the total of 2560) of dislike, that they were considered inconsequential. If future experiments were to turn up a greater percentage of dislike (or other types of negative responses), the list can be expanded.

Table 3. List of Level III and Level IV perceiver types

Level	Type	Perception
III	Neutral Empath	More often perceives correctly that there is indifference, less accurately perceives that there is liking.
	Positive Empath	More often perceives correctly that there is liking, less accurately perceives that there is indifference.
	Oblivious	More often perceives incorrectly that there is indifference when there is liking.
	Pollyanna	More often perceives incorrectly that there is liking when there is indifference.
IV	Neutral Mentalist	More often perceives correctly C's perception of indifference, less accurately perceives that there is liking.
	Positive Mentalist	More often perceives correctly C's perception of liking, less accurately perceives that there is indifference.
	Pessimist	More often perceives incorrectly that C perceives indifference.
	Optimist	More often perceives incorrectly that C perceives liking.

Note: There are so few subjects who dislike their teammates and so few perceptions (right or wrong) of "dislikes," that "dislikes" are not referenced in this table. See appendix C for the analysis from which the above types are determined.

Neutral Empaths are people who have an affinity with others who are indifferent to other people; that is, they guess correctly when *A* is indifferent to *B*. They may have an indifferent worldview, or are indifferent in their own relationships. In any event, they are

particularly good at perceiving when *A* is indifferent to *B*, but not as good at perceiving when *A* likes *B*.

Positive Empaths are the opposites of Neutral Empaths. They have an affinity for others who like their fellow man/woman. They are more likely to have the correct perception when *A* likes *B* than when *A* is indifferent to *B*. They may be positive about relationships in general or have a positive worldview. They are particularly good at perceiving when *A* likes *B* but not as good at telling when *A*'s tie is indifference.

The *Oblivious* are not sensitive to the emotions of people who like others. They tend to perceive indifference even when liking exists. That is, they perceive that *A* is indifferent to *B* when the truth is that *A* likes *B*. They may be indifferent in their own relationships, or they may have an indifferent outlook on life in general.

The *Pollyannas* tend to believe that *A* likes *B* when the truth is that *A* is indifferent to *B*. They may like everybody and be reluctant to believe that people can be indifferent to each other.

2.4.5 Level IV types

The Level IV types are much like their Level III counterparts, except that they are sensitive to perceptions that *others* have of *As* and *Bs* feelings of friendship. The *Neutral Mentalists* can discern when *C* perceives that *As* and *Bs* are indifferent to each other, but are not so accurate when *C*'s perceptions are that *As* and *Bs* like each other. This might reflect that the Neutral Mentalist has a worldview of indifference, or is indifferent in his/her own relationships, as is the Neutral Empath of Level III.

The *Positive Mentalists*, on the other hand, know when *Cs* perceive that *As* and *Bs* like each other. They are, however, hazy when it comes to *Cs* who perceive that *As* and *Bs*

are indifferent. Again, this might reflect a general worldview that people generally like each other or that Positive Mentalists have an innate ability to detect liking.

The *Pessimists* incorrectly believe that *Cs* perceive there is indifference between *As* and *Bs* when, in fact, *As* and *Bs* like each other, reflecting the Pessimist's own experience with relationships or their pessimistic worldview.

The *Optimists* incorrectly believe that *Cs* perceive that *As* and *Bs* like each other when they really dislike each other or are indifferent to one another. Optimists choose to believe that other people's views of relationships are positive.

Ascribing reasons why types may be either perceptive or biased is guessing how they think or feel. However, to do so indicates the sort of analyses that can be performed using CSSs and Level IV analyses given well thought out psychological experiments.

2.5 Emotional Intelligence

This study also examines the emotional intelligence (EI) of the actors to determine its effect on a team's performance. Emotional intelligence is controversial among social scientists (Cherness, 2010). Numerous instruments have been created to measure what the various instruments' creators have defined EI to be, and dozens of books and hundreds of articles have been written about it.¹² Roughly speaking, EI is the measure of an individual's ability to perceive emotions in others and themselves, and how they use those perceptions. For instance, can he/she handle the emotions of others and control his/her own? Can these perceived emotions be used to further a goal?

¹² Estimate arrived at through searches of "emotional intelligence" using www.scholar.google and www.books.google.

The importance of the concept of EI lies in its ability to predict outcomes in work groups and leadership performance (Daus & Ashkanasy, 2005). The idea that there are forms of intelligence—other than that which is commonly known as IQ and measured by tests such as the Stanford-Binet—has been around at least since the early nineteen-twenties. Thorndike (1920) wrote, “The facts in everyday life...indicate that a man has not some one kind of intelligence, but varying amounts of different intelligences” (p. 227). He named three types: mechanical, social and abstract. Of social intelligence, he said “[it is] the ability to understand and manage men and women, boys and girls—to act wisely in human affairs” (p. 228).

Leuner (1966) was the first to use the phrase *emotionale intelligenz*. The first use with its current meaning was in an unpublished thesis in 1985 (Payne). Salovey & Mayer (1989-90)¹³ were the first researchers to look at emotional (vs. social) intelligence as an area worthy of serious academic study and they began building a coherent theory. They defined EI as the ability: 1. to perceive and express emotion, 2. to assimilate emotion in thought, 3. to understand and reason with emotion, and 4. to regulate emotion in the self and others (Mayer, Caruso & Salovey, 2000). They called these abilities “the four branches of EI,” and devised the Mayer-Salovey-Caruso EI test (MSCEIT) as a performance test to measure them.

EI was popularized by Goleman in 1995, and the meaning expanded to include emotional *traits* that correlate highly with personality traits (O’Connor & Little, 2003). Both Goleman (1995) and Bar-On (1997), rather than thinking of emotional intelligence as a cognitive ability, considered it a disposition (an innate trait) or an affect (a felt emotion). In contrast to Mayer, Salovey & Caruso’s MSCEIT test for ability EI, which is performance

¹³ Publisher’s dating.

based, the various tests for trait EI are self-report instruments. The difference between a performance-based ability test and a self-report trait test can best be shown by a comparison of the test questions in appendices D and E.

This study examines the extent to which EI predicts Level III and Level IV accuracy. It is hypothesized that the greater an individual's EI, the greater sensitivity he/she has to others' relationships and perceptions. The accuracy of his/her perceptions, then, would be greater than that of someone with a lower EI.

2.5.1 Ability EI

Ashkanasy and Daus (2005) contend that researchers should adopt the Mayer-Salovey-Caruso (M-S-C) model as the true measure of EI. The M-S-C model is the most likely to measure an actual cognitive EI, while the "mixed-models" measuring trait EI, largely measure personality traits such as the Big 5.¹⁴ This author maintains that Mayer-Salovey-Caruso (M-S-C) make the most convincing argument that what they are measuring is intelligence. The M-S-C model is by far the most completely thought out and most rigorously studied. The Situational Test of Emotional Management (STEM), which is used in this study, is based on the M-S-C theory (Cherniss, 2010).

Mayer and Salovey (2000) state that the ability emotional intelligence test MSCEIT, (Mayer, Salovey, Caruso Emotional Intelligence Test) is measuring an actual intelligence equivalent to IQ. They make this claim because the results of the MSCEIT correlate poorly with tests of both traits EI and personality tests, but weakly with standard intelligence tests.

¹⁴ The "Big 5" refers to the personality traits of openness, conscientiousness, extraversion, agreeableness, and neuroticism. Other personality traits are, e.g., empathy and self-confidence.

The weak correlation with the latter suggests that there is a correspondence with standard intelligence while not measuring the same things (Mayer et al., 1990).

This study used both ability and a trait test in the analysis. One test followed the MSCEIT model of ability performance while the second used self-reporting to measure the trait of Self-Monitoring.

2.5.2 Trait emotional intelligence

Self-Monitoring (SM) is a form of EI, but it is a personality trait rather than ability related to cognition (ability EI). This does not invalidate it as a legitimate measure of an individual's being able to navigate in the world of people. SM, first introduced in 1974 (Snyder), has been used widely in both studies and applications since then and has been correlated with success in organizations (Day, Schleicher, Unckless & Hiller, 2002). Gangestad and Snyder (2000) describe it as:

Concern[ing] differences in the extent to which people value, create, cultivate, and project social images and public appearances. High self-monitors can be likened to consummate social pragmatists, willing and able to project images designed to impress others. Moreover, they seem to believe in the appearances they create and to take stock in the fact that these appearances can and do become social realities. By contrast, low self-monitors seem not only unwilling but also un-able to carry off appearances. They live as if put-on images are falsehoods, as if only those public displays true to the privately experienced self are principled (p.531).

In other words, high self-monitors are constantly scanning the social dynamics going on around them and behaving in such a way that they “fit in.” Low self-monitors are far less

reactive, behaving as dictated by their internal dispositions. To be able to react to social cues, the high self-monitor has to be able to perceive and act on the basis of the emotions and actions of others. While the low self-monitor may be equally perceptive, he/she is less prone to react.

SM has been studied extensively in the context of social networks and is highly linked to network centrality (Mehra, Kilduff & Brass, 2001). Kilduff (1992) and others have shown that self-monitoring plays a significant role in the success or lack thereof of individuals in organizations. It is in the context of perception of emotions in others that it is included in this study.

3. RESEARCH QUESTIONS

As this is an exploratory study, the research questions ask what the relationships are among the variables in general, and, specifically, how they relate to the quality of the design task's outcome.

1. Structural balance can have an effect on the affective ties between design team members. What effect does balance have on items *a* through *d*?

- a. *Centrality* (degree, betweenness, and closeness)

Structural balance *per se* is an attribute of the triad and, as networks are made up of triads, it will usually affect the network as a whole. Changes in a triad's balance may cause a change in the balance of an abutting triad, as abutting triads share a tie. That change would be propagated throughout the entire network. This could change the centrality of any or all of the persons in the network. *Is there a correlation between degree of structural balance and any of the centrality measures?*

- b. *Cognitive social structure*

A cognitive social structure is, by definition, a person's perceptions of affect in others. Whether a triad is balanced also depends on perception. *What is the relationship between the triads (structural balance) and the cognitive social structures in a network?*

- c. *Emotional intelligence*

The defining aspects of emotional intelligence are a person's sensitivity to, understanding of, and control of the feelings of themselves and others. *Does*

an individual's emotional intelligence have an effect on his/her perceptions of and actions towards the structural balance of his/her social network?

d. *Quality of design*

For the outcome of the design task to be even partially successful, team members must cooperate. This cooperation may depend on how they feel about each other, which may depend on how they perceive others feel about them, which brings us to structural balance once again. *What effect does structural balance have on performance?*

2. Centrality measures are indicators of a person's position in a network, which may indicate his/her importance or power.

a. *Cognitive social structures*

Krackhardt (1987, 1990) has shown that a person's position and perceived power in an organization, both formally and in terms of other's perceptions about him/her are correlated with how observant they are of the organization's informal advice network¹⁵. However, perception of friendship ties did not have an effect on a person's position or power. *In this study, does an individual's centrality have an effect on or is it affected by his/her cognitive social structure?*

b. *Emotional intelligence*

Emotional intelligence may be an indicator of an individual's leadership potential, or how well he/she gets along with others. *Does a higher emotional intelligence score mean greater prestige or power as measured by centrality?*

¹⁵ "Position" in Krackhardt's study was determined by the organization's formal organization chart. "Power" (the ability to influence organizational decisions) was determined by asking the study's subjects who they felt was influential.

c. *Quality of design*

Centrality has implications for a person's leadership potential and others' perception of them. *Is this reflected in a correlation between centrality and the quality of the design that his/her team produces?*

3. Cognitive Social Structures are individuals' perceptions of their social surroundings.

a. *Emotional Intelligence*

Emotional Intelligence is a measure of an individual's sensitivity to the emotions of others. *Does a greater accuracy of social perception indicate a higher emotional intelligence, or vice versa?*

b. *Quality of design*

The quality of an engineering design is determined by a variety of factors. Among them may be the team members' perceptions of the feelings of liking and trust toward each other. *Does the accuracy of the team members' cognitive social structures correlate with the team's performance?*

4. Emotional Intelligence

a. *Quality of design*

This question has been asked in various forms above. *Do sensitivity to and control of one's own and other's emotions, as reflected in one's relationship with and to others, have an effect on the quality of one's team's design?*

5. Quality of design.

The scores that the design teams earned for the quality of their designs were correlated against all of the independent variables discussed above. The only independent variable that could be varied was the balance index of each of the teams.

The overall question, as indicated by the preceding individual questions, is which, if any, of the above variables contributed to the relative success of a team's design?

4. METHOD

4.1 Subjects

The subjects in the study were students in a Carnegie Mellon University inter-departmental course that taught rapid prototyping of computer systems. The course comprised the design of hardware and software components and system integration. An important component of the course was that students were introduced to working in teams, requiring both inter- and intra-team coordination. At the beginning of the semester, students were given the specifications for the desired outcome of the system, at which point the students assigned themselves to functional teams of four to six individuals. Each team was responsible for one aspect of the system (e.g., operating system, hardware/software integration). The course was structured collaboratively, allowing the students to learn with and from each other. The instructors took the role of advisors, keeping the students on track, and guiding them when needed rather than lecturing to them.

Of the 37 students in the class, 36 were assigned to nine teams. Of those, 32 were present for the study's design exercise, decreasing the number of teams to eight. Those present were from the Information Networking Institute (3), the Electrical and Computer Engineering Department (24), the Human-Computer Interaction Institute (4), and the School of Computer Science (1). The group comprised one junior, six seniors, one fifth-year student, and 24 master's students. There were 23 males and 9 females. Two of the students who did the exercise, both male, did not complete the SM questionnaire. They were treated as missing data when SM was correlated with the other variables. One team's instance of

Delta Design froze during the exercise, and their scores had to be treated as missing data in certain analyses as well. The omissions are reported in Chapter 5, Results.

4.2 Data Collection

The subjects responded to two questionnaires and completed two EI scales during the semester. The first, given during week 2 of the term, was a social network questionnaire. Because these questions were asked early in the semester, many of the subjects did not know each other very well, if at all.

The first questionnaire asked three questions: 1. How well do you know [name]? 2. How much do you like [name]? And 3. To what extent do you trust the information you get from [name]? The answers were put into three 32 x 32 matrices, one for each question, for analysis. The questions with the wording of the selections from which they could choose an answer are shown in appendix A. Each respondent was asked these questions about each of the other students in the class, meaning each question had to be answered 36 times. A picture of each of the persons being asked about was shown at the top of the questionnaire for easy identification. The resulting sociograms are shown in Figures 19 to 23.¹⁶

The second questionnaire was administered immediately after the design exercise was performed (week 8). At this point, the subjects had had a chance to become acquainted with each other and had worked on the exercise together.

¹⁶ The numbers in the labels on sociograms do not correspond to the number of participants in the study. These numbers were randomly assigned to participants.

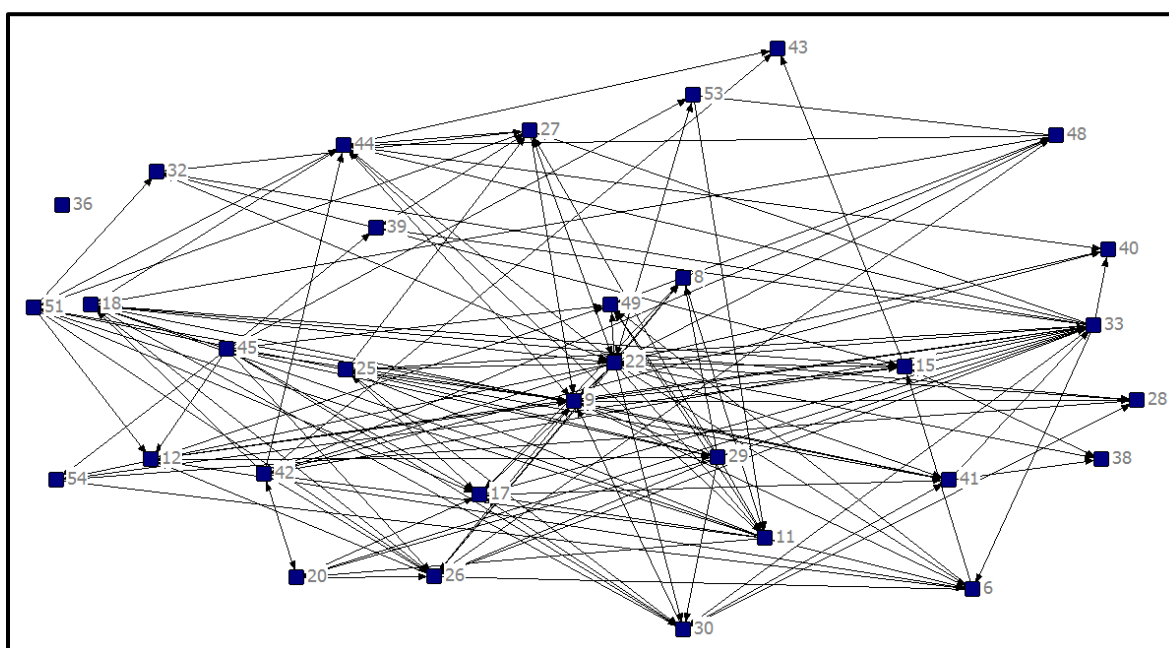
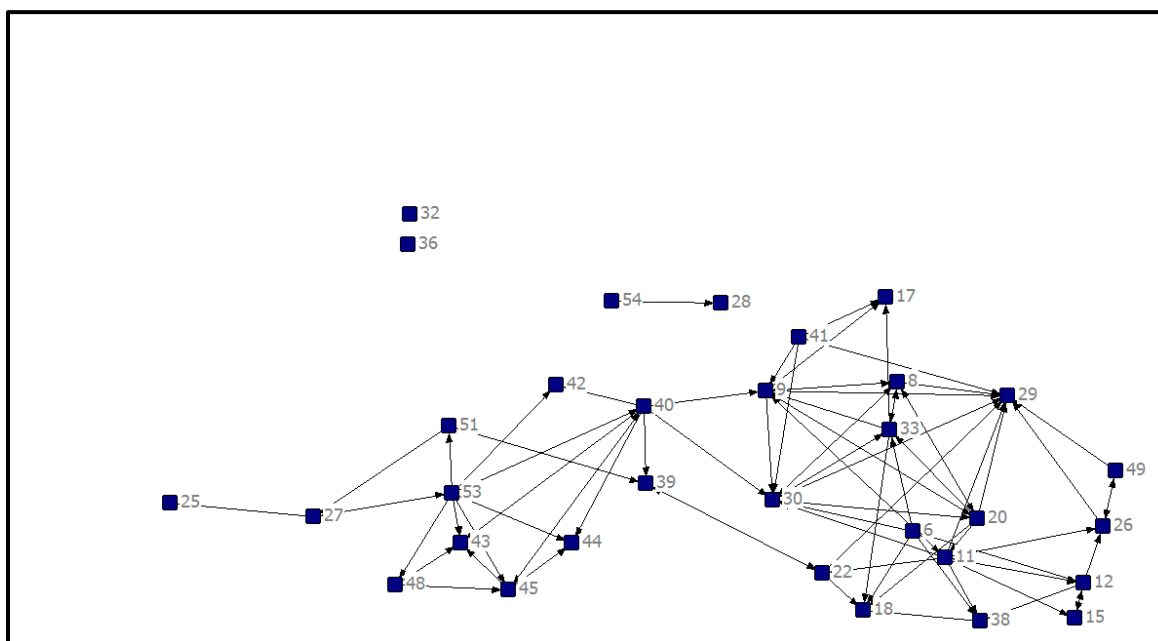
Three questions were asked, but only about the three teammates that the respondent worked with on the design exercise. The first question asked whether the respondent liked, disliked, or was neutral toward each of his/her teammates. This yielded the Level II data for the team, and was the “truth” for Level III.

The second question asked how his/her teammates perceived the relationships between each other, including their relationships to the respondent him/herself, e.g., how does teammate *B* feel about you? How do you think teammate *B* feels about teammate *C*? How do you think teammate *B* feels about teammate *D*? How do you think teammate *C* feels about you? How do you think teammate *C* feels about *B*? And so forth. The answers were the data for Level III and the “truth” for Level IV.

The third question for Level IV was more difficult. In fact, I was not sure that respondents could answer it or would even try.¹⁷ The question was, "What do you think *C* perceives about the relationship between *A* and *B*?" The subjects from the class were neither compensated nor were they required by their instructor to complete the questionnaire. The questionnaire is shown in appendix B.

Based on the variance of the responses, it is likely that most of the respondents gave some thought to the questions and answered to the best of their ability. However, there was no variance in the responses of Team #7. Their perceptions were invariably that *A* neither liked nor disliked *B* (Level III), and their perceptions of what *C* perceived was that *A* neither liked nor disliked *B* (Level IV).

¹⁷ A small pilot study was run (N=4) that showed that subjects could and would answer the question if they were suitably motivated. Each subject in the pilot study was paid \$15.



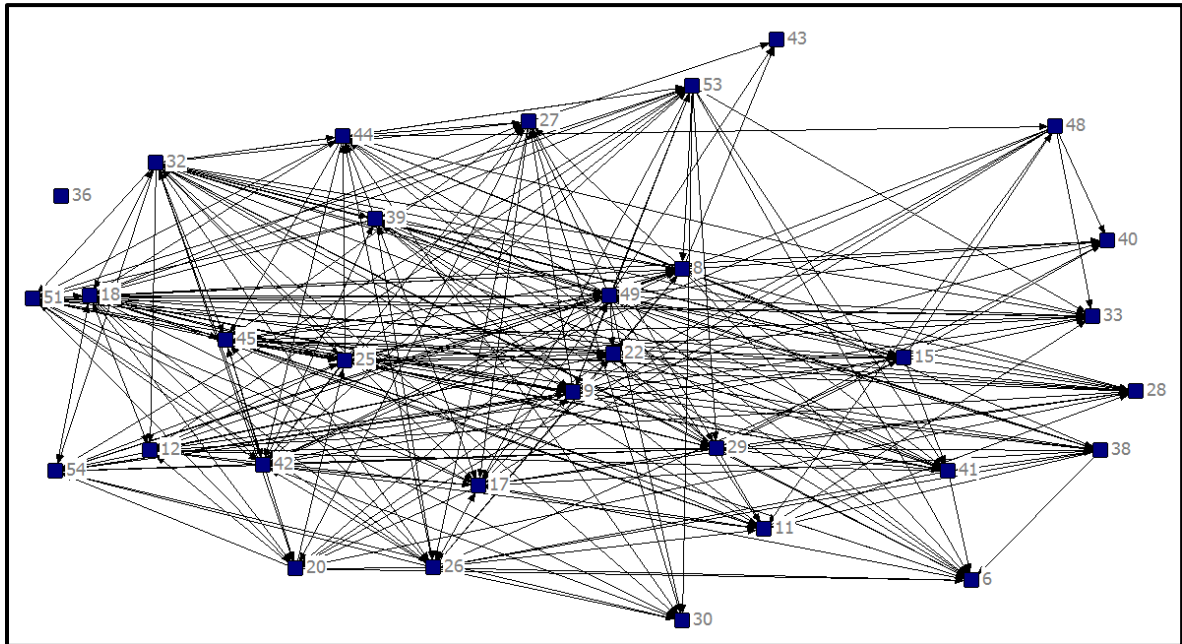


Figure 21. "I neither like nor dislike B." This diagram is hard to read because of its density. It could be surmised that the indifference is caused because the individuals do not know each other very well. This could be determined by ANDing the "know" network with this, the "like" network.

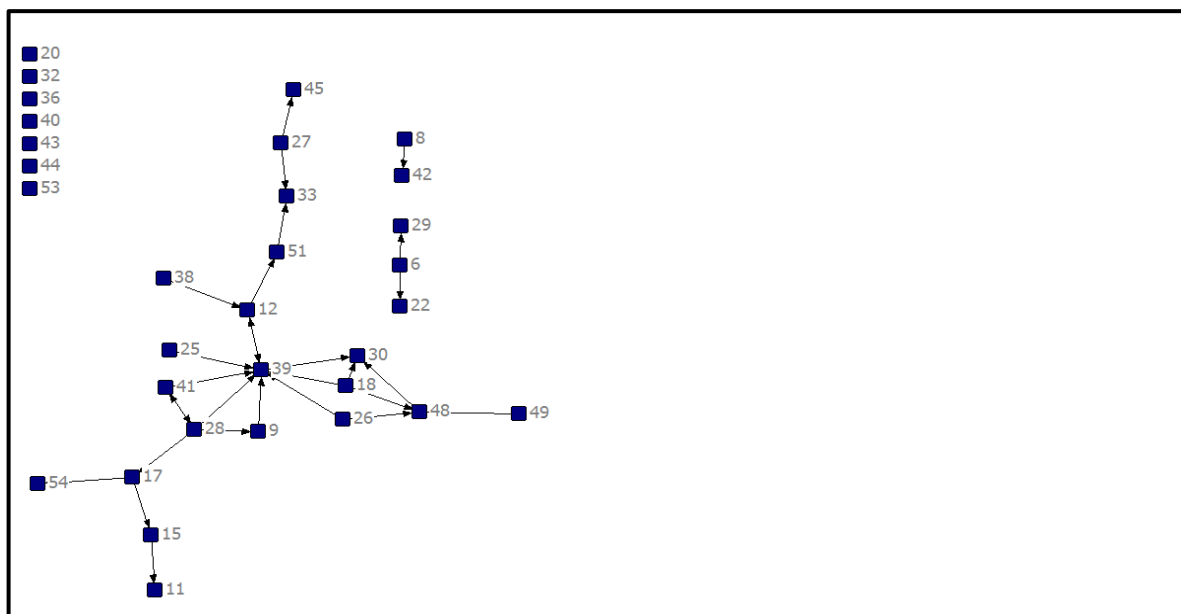


Figure 22. "I dislike B." "39" is disliked by eight classmates and dislikes three in return. The reason for this could be determined if there was enough Level I information. The unattached nodes in the upper left neither dislike anybody nor are they disliked.

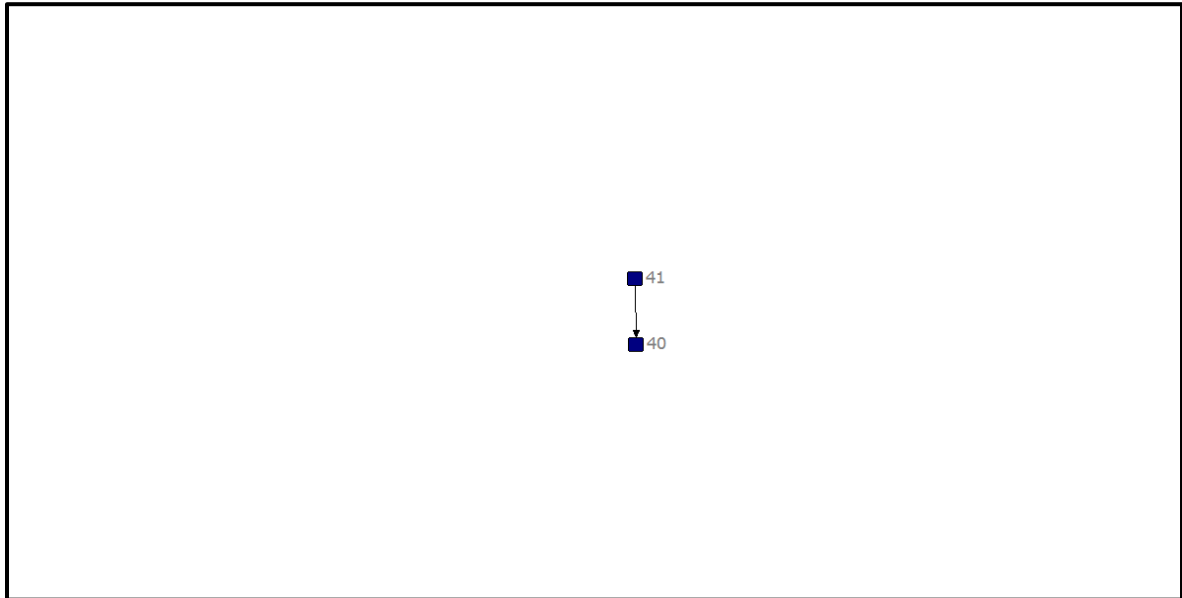


Figure 23. "I really dislike B" "41" really dislikes "40." However, "40" does not feel the same way about "41." As can be seen in Figure 22, "40" does not even mildly dislike "41."

The first test they were given measures ability EI. It is the Situational Test of Emotion Management (STEM). There are 20 multiple-choice questions, which all but two of the respondents answered. ($N = 30$, $M = 10$, $SD = 3.1$). The minimum score is zero. The theoretical maximum score is less than or equal to 1. However, due to the complex way STEM is scored, the maximum cannot be known with certainty (except that it will not exceed 1).

The second test was the Self-Monitoring scale that measures trait EI. All of the respondents answered the 25 questions on this test. ($N = 32$, $M=12$, $SD =4.0$). The maximum possible score equals 25. The range of the responses was 4 to 16. Based on the variance of the responses, it is likely that most of the respondents gave some thought to the questions and answered to the best of their ability. However, there was no variance in the responses of the members of Team #7. Their perceptions were invariably that A neither liked

nor disliked *B* (Level III) and their perceptions of what *C* perceived was that *A* neither liked nor disliked *B* (Level IV).

4.3 Task

The task given to the subjects was a design exercise developed by L.L. Bucciarelli (1995) called the Delta Design exercise. It was created to introduce engineering students to collaborative design practices. The object of the exercise is to design a residence on the alien planet of DeltaP that is two-dimensional (a la *Flatland*).

The fictional residence must conform to certain specifications such as a minimum area, an average temperature range, maximum allowable cost, time-to-build, etc. (the complete specifications can be found in appendix G). The inhabitants of Delta, the Deltans, use different units than those used on earth, and the Deltan unit of area is the equilateral triangle instead of the square foot. The planet also has a gravity system that acts at 30° or 210° horizontally (rather than vertically) and is liable to switch orientation at any time. This makes the placement of doors problematic since they must be placed so that Deltans do not fall out of their residences should the gravity shift. The floor plan is made up of triangular tiles that can be created, moved, deleted, have their orientation changed (pointed up or down), and have their thermal characteristics changed. A grid is laid over the floor plan that, with an arrow indicating the orientation of gravity, facilitates placing the tiles. The plan view of a building configuration was given to the subjects at the beginning of the game (the example building does not comply with any of the specifications) and is shown in Figure 24.

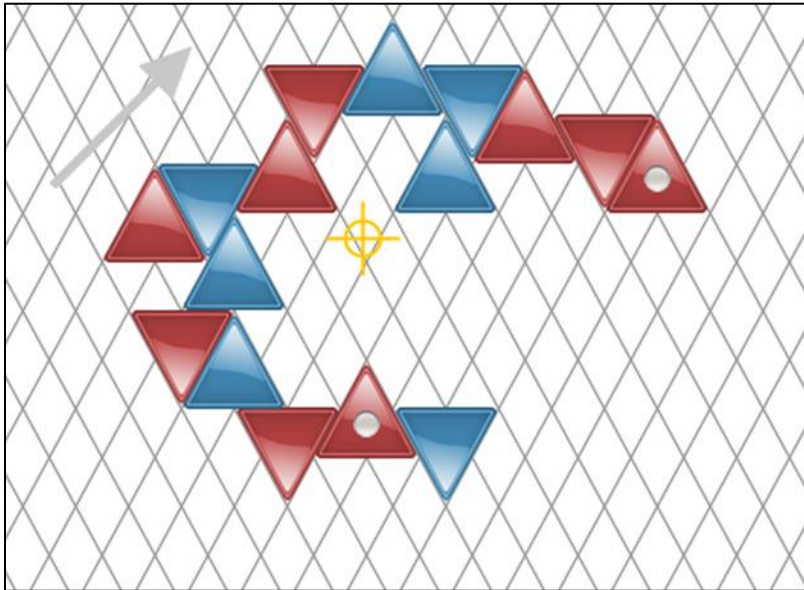


Figure 24. Initial floor plan

The exercise was undertaken by teams of four, each subject on a team being assigned a specific role. The roles are Project Manager, Architect, Structural Engineer, and Thermal Engineer. Subjects undertaking each role are responsible for meeting his/her subset of the overall specifications. The list of responsibilities for each role is given in appendix G.

The teams were formed prior to the exercise, taking into account the friendship ties of the participants as determined from the social network questionnaire filled out earlier in the semester. The assignments of teams were blind to everything except the balance index that would occur for a given combination of participants. Ideally, the eight teams would span a range of balanced versus unbalanced triads. A tetrad contains four triads, limiting the values of the index to 0.0, 0.25, 0.50, 0.75, and 1.00. However, because of the limited number of subjects, the ties of the participants did not allow a uniform spread of indices (the balance index of each team is shown in Chapter 5, Results).

The day prior to the exercise, each subject was given the description of the exercise, a description of his/her role, and the specifications he/she was expected to meet. To prevent collusion, the subjects did not know what team they were assigned to until immediately prior to commencing the exercise. Each subject sat in front of his or her own computer in a university computer cluster large enough to hold the 32 subjects, their instructors, and the people administering the study. The subjects were assigned seats such that they could neither see their teammates' screens nor talk to them. All intra-team communication was via a chat window. There was communication between teams..

The roles are interdependent so that an action by one team member might affect the parameters of one or more of the others. Thus, it is necessary to communicate specific information to each other and negotiate over what action will be taken. In moving tiles to get the reactions within specifications, the Structural Engineer might compromise the thermal balance. The Structural Engineer would then have to have a discussion with the Thermal Engineer via the chat window about how to meet both of their needs. Their decision might have an impact on the footprint of the residence, the responsibility of the Architect, so he/she would have to become part of the discussion. The interaction continues in the same vein throughout the exercise. A team member can lock the screen for five minutes so that only he/she can make the changes necessary to bring the residence into the specification for which he/she is responsible. Thus, who "has the screen" is also subject of negotiation.

The exercise was undertaken during the regular class time of 80 minutes. The actual time taken to complete the task was not used in the final scoring. When all of the roles in a team were within the bounds of their specifications, the team was finished and could leave.

Teams were allowed to go over the scheduled class time, although only one team took advantage of this option.

Scoring was done by calculating the percentage within which each of the specifications was met. A bonus was given for exceeding a specification and a penalty levied when a specification was not met. For instance, if the floor space was, say, 120 triangular units, the score for that specification was 1.2. If the floor space was only 90 triangular units by the time the team finished, the goal for that team only scored 0.90. The team's score comprised the sum of the specification scores.¹⁸

Note: Delta Design was originally a board exercise. It was reconceived as a computer-based task under the direction of Professor Susan Finger at Carnegie Mellon University. This change allows the focus to be on collaboration rather than number crunching, as all of the equation solving is relegated to the computer and the only way the exercise can be completed is through collaboration.

¹⁸ The minimum score could be 0. A realistic maximum would be approximately 12 to 14.

5. RESULTS

As this was an exploratory study, there were no strong expectations for the significance of any of the results. And, indeed, there were no strong results. However, there were a number of interesting correlations, some of them unexpected.

There were nine independent variables, only one of which, structural balance, was controlled. There was one independent variable, which was the outcome of the design task. The correlations between each of the ten variables (Table 2) are reported below.

5.1 Structural balance, performance, accuracy, and centrality.

The initial intent of this study was to determine whether balance in collaborative student engineering design teams affected the quality of a design. Ideally, the balance index would have been distributed evenly among the teams, from 0.0 to 1.0 in steps of 0.25. However, due to the lack of density of the class social network,¹⁹ it was not possible to get this distribution (Table 6). As Table 4 shows, there is a significant correlation between balance and performance. This was expected, but with such a small N, the correlation is not significant and could be due to chance alone. Given Civettini's 2007 study that showed positive results between balance and performance, another study using Delta Design, conducted with a larger sample and a denser network, might yield more significant results.

The significant negative correlation between balance and Level IV accuracy is not intuitive, as both balance and accuracy depend on the perception of the emotions of others. This is another result worth pursuing. Performance is also negatively correlated with Level

¹⁹ Network density is defined as the actual number of ties in a network divided by the total number of possible ties (N-1).

IV accuracy. There is no discernable reason why this would be true, but, again, the correlation is not significant.

Table 4. Balance, Performance results vs. Accuracy III & IV – Group level

	Group accuracy III	Group accuracy IV	Balance	Results
Group accuracy III	1			
Group accuracy IV	0.102	1		
Balance	0.173	-0.705*	1	
Performance	-0.130	-0.476	0.542	1

Note. N = 7

* $p < .1$

The balance index and performance scores are computed at the group level. Centrality scores are computed for individuals, so that the balance index and performance scores must be divided by the size of a task team (4), with the resultant quantity then assigned to each team member. This is justified on the basis that each person on a team contributes equally to both the balance index and performance scores.

Table 5 shows the correlations of centrality versus accuracy, balance, and results (individual level). Outdegree centrality has a significant negative correlation with Level III accuracy. Outdegree is the number of people with whom an individual reports that he/she has a tie. Betweenness has a significant negative correlation with Level IV accuracy. These are not intuitive results. One might expect that a person with accurate emotional perception would be better able to position him/herself in an organization so that information and resources flowed through him/her. The significance of the negative correlations between accuracy and centrality deserves further study.

Table 5. Centrality vs. accuracy, balance, and performance. Individual level.

*p < .1 ** p < .05	<i>Indeg</i>	<i>OutDeg</i>	<i>In- close- ness</i>	<i>Out- close- ness</i>	<i>Between ness</i>	<i>Level 3 accu- racy</i>	<i>Level 4 accuracy</i>	<i>Bal- ance</i>	<i>Perform- ance</i>
Level 3 accuracy	-0.223	-0.076	-0.173	-0.395**	-0.198	1			
Level 4 accuracy	-0.051	-0.281	0.001	-0.153	-0.424**	0.030	1		
Balance	0.013	0.237	-0.009	0.231	0.242	-0.150	-0.401**	1	
Prfrmnc	0.252	0.087	0.247	0.077	0.100	-0.024	0.006	0.311*	1

Note. * = p < .1, ** = p < .05, *** = p < .01

Table 6. Performance scores and balance indices.

Team	Performance Score	Balance Index	Notes
1	9.2	0	Fastest build time
2	10.0	0	Least Cost
3	9.7	0.25	
4	10.2	1	
5	N/A	0.75	Unable to complete due to computer problem
6	9.4	0.5	
7	8.7	0	
8	9.6	0	

Table 7. Performance and Balance: Descriptive Statistics.

	N	M (SD)	Range	Max.	Min.	Max. Range of task
Performance	7	9.5 (0.050)	1.5	10.2	8.7	0-~15
Balance	7	.25 (0.38)	1.0	1.0	0.0	1.00

5.2. Emotional Intelligence

In this section, the relationships between EI vs. centrality, accuracy, and subject types are discussed. There is no relationship between STEM and SM vs. centrality (Table 8). This is not surprising in the case of STEM, which is an ability EI measure. Researchers have had difficulty finding any relationships between ability EI and almost anything with which they have attempted to correlate it. That SM (a trait EI) does not correlate with centrality is surprising, as high self-monitors are frequently found in higher and more powerful positions than low self-monitors. However, it is possible that self-monitoring is context dependent, or at least context sensitive, and what applies in corporations does not apply with collaborative work groups. This is an important observation. Since this study ostensibly examines the usefulness of EI (among other constructs) as a tool to increase the efficacy of collaborative groups, it behooves the author to suggest further study of the context sensitivity of self-monitoring.

Table 8. Situational Test of Emotion Management (STEM) and Self-monitoring scale (SM) vs. Centrality.

	In degree	Out degree	In Closeness	Out Closeness	Betweenness
STEM	0.034	0.104	0.159	0.004	0.016
SM	0.142	-0.162	0.138	0.081	-0.055

Self-monitoring is significantly correlated with both Level III and Level IV accuracy (Table 9). As self-monitors are highly perceptive of their social/emotional surroundings, this would be expected. That STEM is again not correlated is not surprising, as discussed above.

Table 9 EI vs. Level III & IV accuracy

	Level III accuracy	Level IV accuracy
STEM	-0.042	-0.076
SM	0.382**	0.300*

The STEM and SM correlations with Level III and Level IV subject types are shown in Table 10. The significant negative correlation with the Pollyannas is intuitive. A Pollyanna perceives relationships incorrectly, believing that relationships are positive when they are indifferent, while the high self-monitor would correctly perceive both liking and indifference.

With respect to the Level IV subject types, there is a small negative correlation between STEM and Neutral Mentalists, which is not significant. The correlation between SM and the Optimists is small, also, but the fact that the signs are the opposite of each other is intuitive. The Optimist has an incorrect, but positive, view of relationships in the network, while the high self-monitor again would tend to see relationships correctly. The relationship between the high self-monitor and the Neutral Mentalist is positive. The Neutral Mentalist perceives perceptions correctly (when there is indifference) as would the high self-monitor. The relationship between SM and the Optimist is negative. Optimists perceive perceptions incorrectly (seeing liking when there is indifference), whereas the self-monitor would be more likely to perceive liking as liking. This explanation contradicts the fact that there is a negative correlation between SM and the Positive Mentalist, who sees things correctly, as does the high self-monitor. This correlation is not significant, though, and could be due to chance.

These were the most noteworthy findings of the study. While I was disappointed in the weakness of some of the correlations, I am convinced that future studies will provide

insight into the anomalies and that by increasing the size of the sample we can obtain results that are more reliable.

Table 10..EI vs. Levels III& Level IV respondent types.

		Level III				Level IV		
	Neutral Empath	Positive Empath	Oblivious	Pollyanna	Neutral. Mentalist	Positive. Mentalist	Pessimist	Optimist
STEM	-0.183	0.127	0.132	-0.114	-0.214	0.282	0.120	0.014
SM	0.265	-0.123	-0.109	-0.384**	0.296	-0.142	-0.169	-0.282

6. DISCUSSION

The concept of situational awareness is usually applied in contexts of complex, high stress, high-tech settings such as aircraft cockpits and nuclear power plants, as well as in active military environments. However, that hominids have always had situational awareness is illustrated by the fact that a primitive biped that existed millions of years ago evolved into *Homo sapiens*. It continues to be a necessary survival trait in the modern world. People who have well-developed situational awareness in terms of being able to discern the emotional and social tenor of their organizational environments, tend to be more successful in that context. Studies have shown that they rise higher in the corporate structure and control more information and resources (Mehra, Kilduff & Brass, 2001).

These studies have determined that high self-monitoring is a personality trait that is akin to trait emotional intelligence. It is an accurate predictor of where in an organization a person who is a high self-monitor will most likely be found. High-self monitors are more likely to be influenced by and adapt to their organizational surroundings than low self-monitors who march to the beat of their own, internal drum. The latter are often less successful in the workplace. In this study, high self-monitoring correlated positively with another measurement of socio-emotional sensitivity, Level IV accuracy (see Table 1 for descriptions of the different levels of analysis of networks). Contradictorily, self-monitoring did not correlate with classic network centrality, the term referring to the most commonly used measures of an individual's place in a network (Wasserman & Faust, 1994).

It is possible that an instrument that accurately measures socio-emotional sensitivity in the setting of a corporation cannot be applied successfully to teams of graduate electrical

and computer engineering students working together in small groups. This could be a reason for other anomalies found in the study that were described in the results chapter. A possible reason is that the self-monitoring test does not scale. The limited size of the sample should not affect one's ability to correctly monitor and respond to emotions and social situations.

There were also no significant correlations between self-monitoring and either the structural balance index or task performance. The lack of a relationship with the structural balance index is understandable, not just for self-monitoring, but with the other variables as well. The structural balance index was not linearly distributed among the teams. The distribution was "lumpy" (see Table 6), and four of the eight teams had a balance index of zero. And, of course, seven teams is a very small sample. (Only seven of the eight teams were included in the task performance score.) It is possible that a study using a well distributed balance index that covered the full range of possible indices, which was not the case here, would result in reliable and more significant findings.

There is no reason to believe that balance does not have an effect on small group performance. The lack of correlation between self-monitoring with task performance would be interesting to study further. The dynamics of the groups as they worked on the task was not analyzed, although the data to do so was available in the chat logs. Those chat logs documented the only interaction team members had with each other during the task session. Two analysis techniques drawn from the study of linguistics were applied to the chat logs on a very small and experimental scale. The analyses did show some results, but the findings were only cursorily analyzed. (Oberoi, Finger, and Rose, 2013).

Another confound that could have affected the results is the fact that the social network from which the team balance was determined was of the subjects' familiarity with

each other at the beginning of the semester. The balance of a group could well have changed by the time the task was undertaken. Working from a network determined closer to task time should yield data that are more reliable.

I mention the confounds here because they refer generally to the methods and assumptions of the study. Two major questions are: 1) Can the assumptions and theory behind the instruments be used with small groups? And, 2) Was it appropriate to use the centrality and balance variables?

The most interesting findings to come out of study were the measures of accuracy of perceptions that were determined through the analysis of the results of the second questionnaire given to the class. That questionnaire asked respondents about Levels II, III and IV of Krackhardt's "levels of analysis." Level III and Level IV accuracies are of individuals' *perceptions* of the affective dynamics among people, regardless of how the other individuals actually feel. (The latter is a Level II perception.).

Just prior to the conclusion of this study, there were additional findings regarding the constructs of Level III and, especially, Level IV. These findings are preliminary and will provide the basis for further investigation into Levels III and IV of the levels of analysis of social networks.

Another potential topic for study is the question of whether accuracy or balance has more of an impact on the outcome of collaborative groups. It would be useful to know if either should be a consideration in the selection of group members. My initial hypothesis was that balance was more important. Upon reflection, it would seem that accuracy would act as a more reliable indicator. The reason for this is that an individual who has accurate emotional perceptions would be better able to achieve actual *versus* perceived balance in a

group. The question then is, is there a correlation between accurate emotional perception and group performance.

Network level of analysis III entails the use of the cognitive social structure (CSS) to examine aspects of a network that are not apparent without parsing the CSS's 3-dimensional matrix (Krackhardt, 1987). There are "[T]hree basic kinds of reductions, each with its own set of rules and motivated by its own set of questions it tries to answer. These three aggregations [are] referred to [...] as Slices, Locally Aggregated Structures [...], and Consensus Structures. (P. 115)

No such reductions have been found for the 4-dimensional ($N \times N \times N \times N$) matrix of Level IV, yet. However, while looking for a way to calculate the accuracy of a respondent's "perception of perception of a relationship," Krackhardt found a tractable means of indexing the $N \times N \times N \times N$ cells in the matrix containing the data from the study.²⁰ The subjects responded to the questions: 1) How do you feel about each of your teammates (Level II)? 2) How do each of your teammates perceive the feelings that each of the other teammates have about each other (Level III)? And 3) How do you perceive your teammates' perceptions of the feelings each of the other teammates have about each another (Level IV)?

Within a team each relationship, perception of a relationship, and perception of a perception of a relationship can be indexed as $M_{(n1, n2, n3, n4)}$ (Table 11) with the greatest value of an index digit being 4 (team size). There are $4 \times 4 \times 4 \times 4 = 256$ permutations. Interpreting the string of subscripts requires explanation. Using the notation $n1, n2, n3, n4$, a

²⁰ It is possible to manipulate the data by hand to a certain extent using a spreadsheet, but the method is not only extremely tedious it is highly error prone.

string is read as, “ $n4$ perceives that $n3$ perceives that $n1$ likes $n2$ ²¹ (refer to Table .11).

Therefore, indices having the sequence of, say, 4, 2, 3, 1, are equivalent to, “Teammate 1 perceives that teammate 3 perceives that teammate 4 likes teammate 2.

Table 11. Meaning of index digits

Index Digit	Meaning
n4	Responder to a Level IV question
n3	Perceiver in a Level IV question, Responder to a Level III question
n2	Sender (source of tie)
n1	Receiver (recipient of tie)

These patterns represent all of the 256 unique subscripts allowable for a four-person team. However, the full set collapses into just eight “equivalence classes.” An equivalence class is represented by the combination of the subscript’s digits shown in Table 12.

Put another way, a “sophisticate” class is one of which all digits are unique, not just the sequence 1, 2, 3, 4. This class also includes, for instance, 4, 2, 3, 1, and 3, 4, 1, 2. A “narcissist” is represented by the pattern of subscripts shown in the table under that class name. For example, the sequence of 3, 2, 4, 2 has a pattern of $n2$ being the same as $n4$, and $n1$, and $n3$ being unique, making that the set of subscripts to retrieve a “narcissist’s” data. A “game theorist” has the pattern of the first and last digits being the same, while the middle two are unique, and so forth.

Far from being an exercise in numerology, each equivalence class represents a unique type of question, and each class has a unique character in at least one respect, which is the degree of accuracy it carries with it. Each respondent’s accuracy score can be broken down

²¹ “Likes,” in this case, implies “likes, dislikes, or is indifferent to”

by equivalence class, showing how accurate that individual was when answering that type of question. Table 13 shows the accuracy scores derived from the total data set taken from questionnaire II.

Table 12. Equivalence Classes

Digit Combination	Name	Pattern
1211	Level II	$n1 = n3 = n4; n1 \neq n2$. “ $n1$ likes $n2$ ”)
1221	“Game Player	$n1 = n4; n1 \neq n2$ and $n3; n2 = n3$. “ $n1$ believes ²² $n2$ believes $n1$ likes $n2$. ”
1222	Level III	$n1 \neq n2, n3$, and $n4; n2 = n3, n4$. “ $n2$ believes $n1$ likes $n2$. ”
1223	“Matchmaker”	$n1 \neq n2, n3$ and $n4; n2 = n3$. “ $n3$ believes $n2$ believes $n1$ likes $n2$ ”
1231	“Game Theorist”	$n1 \neq n2$ and $n3; n1 = n4; n2 \neq n3$ and $n4$. “ $n1$ believes $n3$ believes $n1$ likes $n2$. ”
1232	“Narcissist”	$n1 \neq n2, n3$, and $n4; n2 \neq n3; n2 = n4$. “ $n2$ believes $n3$ believes $n1$ likes $n2$. ”
1233	Level III	$n1 \neq n2, n3$ and $n4; n2 \neq n3; n3 = n4$. “ $n3$ believes $n1$ likes $n2$ ”
1234	“Sophisticate”	All digits are unique. “ $n4$ believes $n3$ believes $n1$ likes $n2$. ”

The unnamed class “1211” is the Level II truth and is correct by definition. The two least accurate scores are the unnamed classes that collapse to Level III accuracies. The highest score is “1232,” the “narcissist.”

²² “Believe” means perceive.

The full significance of equivalence classes has yet to be explored, and the question of whether they have attributes other than accuracy has not been answered. There is the possibility, too, that there are other “classes” of classes to be discovered while examining the Level IV 4-dimensional data structure. Also to be answered is the question of the type of slice(s) that might be extracted in addition to those already known for the 3-dimensional cognitive data structure.

I see these as logical lines of potential future research on Level IV analysis.

Table 13. Summary of equivalence classes’ accuracy scores for all subjects.

Class Pattern	Accuracy score	Levels
1211	1.000	Level II “Truth”
1221	0.271	Level IV
1222	0.000	Level III
1223	0.208	Level IV
1231	0.292	Level IV
1232	0.427	Level IV
1233	0.010	Level III
1234	0.302	Level IV

Notes. N=8, M = 0.314, SD = 0.313. Range of index = -1 to 1. 0.0 indicates as many correct as wrong answers -1.0 indicates all wrong answers, 1.0 indicates all correct answers.

Probably the major confounds of the study were the attitudes the team members had towards performing the design exercise, and what skills, technical and social, they brought to the group. Any of these could have had a more of an impact on doing the task than the constructs examined.

A second confound that could have been significant, was the fact that the structural balance of the group was determined at the beginning of the semester, when the subjects were not as well acquainted with each other. The balance would have been decidedly

different than when the task was undertaken, six weeks later. At that point, subjects had had a chance to get to know each other, as well as work together.

A third confound might be that a factor in the results was that several assumptions made about the variables might not scale from company sized networks to teams of four individuals. An example would be that betweenness has no meaning in such a small group.

A fourth confound is that while much that is known about small groups has been studied using face to face encounters, the design task used in this study allowed contact only via a computer “chat” window. In a task of this sort, reading of body language, facial expression, and tone of voice is not possible. The applicability of various theories in this kind of “virtual” group may not be applicable.

One determination that was not attempted was to see if balance or accuracy was more important in team performance. If an experiment can be conducted with a sufficiently large number of subjects making up a significant number of teams, several other of variables used in this study can be compared with each other, to test the relative size of their effect.

The most interesting findings of the study originally had nothing to do with what might affect performance, but were added to take advantage of the subject pool. These were the measurements of the accuracy of what Krackhardt calls levels III and IV of network analysis. While individuals’ level III perceptions of their networks has been studied, level IV, the perception of perceptions, has not. In addition, the three dimensional matrix used to store level III data, and the four-dimensional matrix used to store level IV data, allow a very fine parsing of the level data not achievable before this.

One of the discoveries by Krackhardt using these data structures was that of “equivalence classes,” a matrix indexing scheme that at first glance resembles numerology,

but in fact shows that different types and levels of perception yield very different degrees of accuracy.

7. CONCLUSION

While not breaking startling new ground, the study discussed in this dissertation raises some interesting questions about what affect certain social science constructs have on small group performance. Centrality, structural balance, and the accuracy of individuals' perceptions of the relationships within their social networks were examined, as were both ability and trait emotional intelligences to determine which if any of them could be used as predictors of how well a small team of engineering students would work together to solve a design problem.

A number of fruitful future research paths have been suggested above. Using a more refined methodology and with larger Ns, I believe much can be learned about groups and networks by working with the variables used in this study.

It would be particularly interesting to pursue the implications of Level IV of the network levels of analysis. The significance of the different accuracies of perception of the equivalence classes is interesting in itself.

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Appendix A – Social Network Questionnaire I

The following three questions were asked within the first two weeks of the semester. The online questionnaire presented the subjects with the name and picture of each of the other subjects in turn. In addition to the name, the target person's picture was shown to the respondent.

1. How well do you know [name]?

- A. I do not know [name]
- B. I know [name] by reputation only
- C. I am acquainted with [name]
- D. I know [name]
- E. I know [name] well

2. How much do you like [name]?

- A. I greatly dislike [name]
- B. I dislike [name] somewhat
- C. I neither like nor dislike [name]
- D. I like [name] somewhat
- E. I greatly like [name]

3. How much do you trust [name] with respect to technical information you get from them?

- A. I greatly distrust [name]
- B. I distrust [name] somewhat
- C. I neither trust nor distrust [name]
- D. I trust [name] somewhat
- E. I greatly trust [name]

Appendix B – Social Network Questionnaire II

Section I

People working together in groups usually have opinions about each other. We are interested in your sense of how the people in your Delta Design team think of each other. That is, we would like to know your impression of whom your teammates like, dislike or neither like nor dislike.

Please remember that your answers are strictly anonymous. Neither your fellow students nor your instructors will have access to this information.

The first question we would like **you** to consider is which teammates do **you** like, dislike, or neither like nor dislike?

Marcia Smith ☐ Dislike ☐ Neither like nor dislike ☐ Like

Section II

Now we would like to know what your teammates think about each other. Please answer the questions without asking your teammates what they think.

Who does Marcia like, dislike or neither like nor dislike?

Peter Simon ☐ Dislike ☐ Neither like nor dislike ☐ Like

Section III

Now we are going to ask you something that may be difficult. We know that people develop friendships. We also know that people watch who develops friendships with whom. In addition, we know that people pay attention to what other people think about their social surroundings. In this section we would like you to give us a sense what you think your teammates think about each other. We want you to put yourselves in the shoes of your teammates and answer the questions as if you were they.

Please answer the questions without asking your teammates what they think.

Whom do **you** think **Marcia Smith** would say **you** like, dislike or neither like nor dislike?

Marcia Smith ☐ Dislike ☐ Neither like nor dislike ☐ Like

Appendix C1 – Perceiver Types, Level III

Percentage of each Level III Type for each subject.

		Correct		Incorrect		Neg.
		Neut. Emp.	Pos. Emp.	Oblivious	Pollyanna	
Team	subj.	0/0	1/1	0/1	1/0	-1.
1	a	67%				33%
	b	100%				
	c	44%				56%
	d	67%				33%
2	e	22%		78%		56%
	f	22%		78%		
	g	22%		22%		
	h	44%		56%		
3	i		33%	67%		
	j		67%	33%		
	k		67%	33%		
	l		100%			
4	m	44%		33%	11%	11%
	n	44%		56%		
	o	33%	22%		44%	
	p	44%		56%		
5	q		67%		33%	
	r		44%	44%	11%	
	s	22%	33%	33%	11%	
	t		44%	33%	22%	
6	u	33%		67%		
	v	33%		67%		
	w		56%		44%	
	x	11%	11%	67%	11%	
7	A	33%		67%		
	B	33%		67%		
	C			100%		
	D	33%		67%		
8	E	44%	11%	44%		
	F	44%	11%	44%		
	G	44%		56%		
	H	67%	11%	22%		

Appendix C2 – Perceiver Types, Level IV

Percentage of each Level IV Type for each subject.

		Correct		Incorrect		
		Neut. Ment.	Pos. Ment.	Pessimist	Optimist	Neg.
Team	Subj.	0/0	1/1	0/1	1/0	-1
1	a	81%				19%
	b	81%				19%
	c	89%				11%
	d	81%				19%
2	e	78%			4%	19%
	f	78%			15%	7%
	g				100%	
	h				81%	19%
3	i	7%	37%	44%	11%	
	j		67%		33%	
	k	15%	33%	33%	19%	
	l	15%	52%	4%	30%	
4	m	59%	7%	15%	19%	
	n	70%		26%		4%
	o		7%		93%	
	p	59%	11%	26%		4%
5	q		56%		44%	
	r	19%	26%	56%		
	s	7%	52%	22%	19%	
	t	15%	63%	4%	19%	
6	u	59%		41%		
	v	59%		41%		
	w	26%	7%		67%	
	x	15%	33%		52%	
7	A	100%				
	B	100%				
	C	100%				
	D	100%				
8	E	96%		4%		
	F	89%		7%	4%	
	G	89%		11%		
	H	93%	4%	4%		

Appendix D – Situational Test of Emotional Management

Instructions

In this test, you will be presented with a few brief details about an emotional situation, and asked to choose from your responses the most effective course of action to manage the emotions that the person is feeling and the problems they face in that situation.

Although more than one course of action might be acceptable, you are asked to choose what you think is the most effective response for that person in that situation would be.

Remember, you are not necessarily choosing what you would do, but choosing the most effective response for that situation.

1. Pete has specific skills that his workmates do not and he feels that his workload is higher because of it. What action would be the most effective for Pete?
 - ☐ Speak to his boss about this.
 - ☐ Start looking for a new job.
 - ☐ Be very proud of his unique skills.
 - ☐ Speak to his workmates about this.

2. Wai-Hin and Connie have shared an office for years, but Wai-Hin gets a new job and Connie loses contact with her. What action would be the most effective for Connie?
 - ☐ Just accept that she is gone and the friendship is over.
 - ☐ Ring Wai-Hin and ask her out for lunch or coffee to catch up.
 - ☐ Contact Wai-Hin and arrange to catch up but also make friends with her replacement.
 - ☐ Spend time getting to know the other people in the office, and strike up new friendships.

3. Shurbhi starts a new job where he doesn't know anybody and finds that nobody is particularly friendly. What action would be the most effective for Shurbhi?
 - ☐ Have fun with friends outside of work hours.
 - ☐ Concentrate on doing his work well at the new job.
 - ☐ Make an effort to talk to people and be friendly himself.
 - ☐ Leave the job and find one with a better environment.

4. Andre moves away from the city his friends and family are in. He finds that his friends make less effort to keep in contact than he thought they would. What action would be most effective for Andre?
- ☐ Try to adjust to life in the new city by joining clubs and activities there.
 - ☐ He should make the effort to contact them, but also try to meet people in his new city.
 - ☐ Let go of his old friends, who have shown themselves to be unreliable.
 - ☐ Tell his friends he is disappointed in them for not contacting him.
5. Clayton has been overseas for a long time and returns to visit his family. So much has changed that Clayton feels left out. What action would be most effective for Clayton?
- ☐ Nothing—it will sort itself out soon enough.
 - ☐ Tell his family he feels left out.
 - ☐ Spend time listening and getting involved again.
 - ☐ Reflect that relationships can change with time.
6. Daniel has been accepted for a prestigious position in a different country from his family, who he is close to. He and his wife have decided it is worth relocating. What action would be the most effective for Daniel?
- ☐ Realize he shouldn't have applied for the job if he didn't want to leave.
 - ☐ Set up a system for staying in touch, like weekly phone calls or emails.
 - ☐ Think about the great opportunities this change offers.
 - ☐ Don't take the position.
7. Mei Ling answers the phone and hears that close relatives are in the hospital, critically ill. What action would be the most effective for Mei Ling?
- ☐ Let herself cry and express emotion for as long as she feels like.
 - ☐ Speak to other family to calm herself and find out what is happening, then visit the hospital.
 - ☐ There is nothing she can do.
 - ☐ Visit hospital and ask staff about their condition.

8. Upon entering full-time study, Vincent cannot afford the time or money he used to spend on water-polo training, which he is quite good at. Although he enjoys his full-time study, he misses training. What action would be the most effective for Vincent?
- ☐ Concentrate on studying hard, to pass his course.
 - ☐ See if there is a local league or a less expensive and less time-consuming sport.
 - ☐ Think about whether sport or study is more important to him.
 - ☐ Find out about sporting scholarships or bursaries.
9. Greg has gone back to university after a lapse of several years. He is surrounded by younger students who seem very confident about their ability and he is unsure he can compete with them. What action would be the most effective for Greg?
- ☐ Focus on his life outside the university.
 - ☐ Study hard and attend all lectures.
 - ☐ Talk to others in his situation.
 - ☐ Realize that he is better than the younger students as he has more life experience.
10. Shona has not spoken to her nephew in months, whereas when he was younger, they were very close. She rings him, but he can only talk for five minutes. What action would be the most effective for Shona?
- ☐ Realize that he is growing up and might not want to spend so much time with his family any more.
 - ☐ Make plans to drop by and visit him in person and have a good chat.
 - ☐ Understand that relationships change, but keep calling him from time to time.
 - ☐ Be upset about it, but realize there is nothing she can do.
11. Joel has always dealt with one particular client, but on a very complex job, his boss gave the job to a co-worker instead. Joel wonders if the boss thinks he can't handle the important jobs. What action would be the most effective for Joel?
- ☐ Believe he is performing well and will be given the complex tasks in the future.
 - ☐ Do good work so that he will be given the complex tasks in the future.
 - ☐ Ask his boss why the co-worker was given the job.
 - ☐ Not worry about this unless it happens again.

12. Hasina is overseas when she finds out that her father has passed away from an illness he has had for a year. What action would be the most effective for Hasina?
- ☐ Contact her close relatives for information and support.
 - ☐ Try not to think about it, going on with her daily life as best she can.
 - ☐ Feel terrible that she left the country at such a time.
 - ☐ Think deeply about the more profound meaning of this loss.
13. Mina and her sister-in-law normally get along quite well, and the sister-in-law regularly baby-sits for a small fee. Lately she has also been cleaning away cobwebs, commenting on the mess, which Mina finds insulting. What action would be the most effective for Mina?
- ☐ Tell her sister-in-law these comments upset her.
 - ☐ Get a new baby sitter.
 - ☐ Be grateful her house is being cleaned for free.
 - ☐ Tell her only to baby sit, not to clean.
14. Juno is fairly certain his company is going down and his job is under threat. It is a large company and nothing official has been said. What action would be the most effective for Juno?
- ☐ Find out what is happening and discuss his concerns with his family.
 - ☐ Try to keep the company afloat by working harder.
 - ☐ Start applying for other jobs.
 - ☐ Think of these events as an opportunity for a new start.
15. Mallory moves from a small company to a very large one, where there is little personal contact, which she misses. What action would be the most effective for Mallory?
- ☐ Talk to her workmates, try to create new social contacts and make friends.
 - ☐ Start looking for a new job so she can leave the environment.
 - ☐ Just give it time, and things will be okay.
 - ☐ Concentrate on her outside-work friends and colleagues from previous jobs.

16. Blair and Flynn usually go to a café after the working week and chat about what's going on in the company. After Blair's job is moved to a different section of the company, he stops coming to the café. Flynn misses these Friday talks. What action would be effective for Flynn?
- ☐ Go to the café or socialize with other workers.
 - ☐ Don't worry about it, ignore the changes and let Blair be.
 - ☐ Not talk to Blair again.
 - ☐ Invite Blair again, maybe rescheduling for another time.
17. Michelle's friend Dara is moving overseas to live with her partner. They have been good friends for many years, and Dara is unlikely to come back. What action would be most effective for Michelle?
- ☐ Forget about Dara.
 - ☐ Spend time with other friends, keeping herself busy.
 - ☐ Think that Dara and her partner will return soon.
 - ☐ Make sure she keeps in contact through email, phone or letter writing.
18. Hanna's access to essential resources has been delayed and her work is way behind schedule. Her progress report makes no mention of lack of resources. What action would be most effective for Hanna?
- ☐ Explain the lack of resources to her boss or to management.
 - ☐ Learn that she should plan ahead for next time.
 - ☐ Document the lack of resources in her progress report.
 - ☐ Don't worry about it.
19. Jacob is having a large family gathering to celebrate him moving into his new home. He wants the day to go smoothly and is a little nervous about it. What action is most effective for Jacob?
- ☐ Talk to friends or relatives to ease his worries.
 - ☐ Try to calm down, perhaps go for a short walk, or meditate.
 - ☐ Prepare ahead of time so he has everything he needs available.
 - ☐ Accept that things are not going to be perfect but that the family will understand.

20. Julie has not seen Ka for ages and looks forward to their weekend trip away. However, Ka has changed a lot, and Julie finds that she is no longer an interesting companion. What action is most effective for Julie?

☐ Cancel the trip and go home.

☐ Realize that it is time to give up the friendship and move on.

☐ Understand that people change, so move on, but remember the good times.

☐ Concentrate on her other, more rewarding friendships.

Appendix E – Self-Monitoring Scale

DIRECTIONS: The statements below concern your personal reactions to a number of different situations. No two statements are exactly alike, so consider each statement carefully before answering. If a statement is TRUE or MOSTLY TRUE as applied to you, check “True.” If a statement is FALSE or NOT USUALLY TRUE as applies to you, check “False.”

1. It is hard to imitate the behavior of other people.
☐ True ☐ False
2. My behavior is usually an expression of my true inner feelings, attitudes, and beliefs.
☐ True ☐ False
3. At parties and social gatherings, I do not attempt to do or say things that others will like.
☐ True ☐ False
4. I can only argue for ideas which I already believe.
☐ True ☐ False
5. I can make impromptu speeches even on topics about which I have almost no information.
☐ True ☐ False
6. I guess I put on a show to impress or entertain people.
☐ True ☐ False
7. When I am uncertain how to act in a social situation, I look to the behavior of others for cues.
☐ True ☐ False
8. I would probably make a good actor.
☐ True ☐ False
9. I rarely seek the advice of my friends to choose movies, books, or music.
☐ True ☐ False
10. I sometimes appear to others to be experiencing deeper emotions than I actually am.
☐ True ☐ False
11. I laugh more when I watch comedy with others than when alone.
☐ True ☐ False
12. In groups of people, I am rarely the center of attention.
☐ True ☐ False
13. In different situations and with different people, I often act like very different persons.
☐ True ☐ False
14. I am not very good at making people like me.
☐ True ☐ False

15. Even if I am not enjoying myself, I often pretend to be having a good time.
☐ True ☐ False
16. I am not always the person I appear to be.
☐ True ☐ False
17. I would not change my opinions (or the way I do things) in order to please someone else or win their favor.
☐ True ☐ False
18. I have considered being an entertainer.
☐ True ☐ False
19. In order to get along and be liked, I tend to be what people expect me to be rather than anything else.
☐ True ☐ False
20. I have never been good at games like charades or improvisational acting.
☐ True ☐ False
21. I have trouble changing my behavior to suit different people and different situations.
☐ True ☐ False
22. At a party, I let others keep the jokes and stories going.
☐ True ☐ False
23. I feel awkward in company and do not show up quite as well as I should.
☐ True ☐ False
24. I can look anyone in the eye and tell a lie with a straight face (if for a right end).
☐ True ☐ False
25. I may deceive people by being friendly when I really dislike them.
☐ True ☐ False

APPENDIX F—Worked example of Level IV calculation (S_9)

		Truth		
		-1	0	1
Perception	-1	<i>a</i>	<i>b</i>	<i>c</i>
	0	<i>d</i>	<i>e</i>	<i>f</i>
	1	<i>g</i>	<i>h</i>	<i>i</i>

Results tabulation table

$$S_9 = \frac{(a + e + i) - (b + c + d + f + g + h)}{a + b + c + d + e + f + g + h + i}$$

		Truth		
		-1	0	1
Perception	-1	0	0	0
	0	0	24	2
	1	0	1	0

Tabulated results

$$S_9 = ((0+24+0)-(0+0+0+2+0+1))/(0+0+0+0+24+2+0+1+0)$$

Level IV accuracy index: $S_9 = 0.77778$

Each respondent perceives the perceptions of 3 teammates. Each teammate perceives 12 relationships. Of those 12, 3 are irrelevant (e.g., $D \rightarrow C \rightarrow C$ likes A) leaving 27 perceptions.

27 perceptions of perceptions. 26 were “indifferent,” 1 was “like.” The “Truth” was 25 “indifferent,” 1 “like” Respondent perceived 24 of the perceptions of “indifferent” correctly.

Respondent perceived 1 of the perceptions of “indifferent” as “like.”

Respondent perceived the 2 “like” perceptions as “indifferent.”

Respondent perceives 12 perceptions of each of 3 teammates = 36 perceptions times 32 respondents = 1152 items in data base.

APPENDIX G—Delta Design description, roles, and specifications

THE DESIGN TASK²³

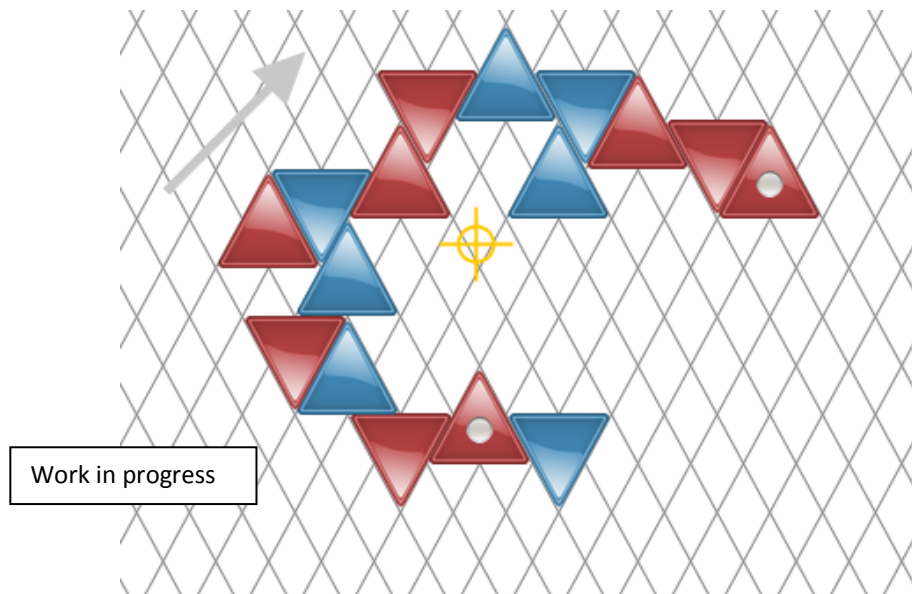
Introduction

Congratulations! You are now a member of an expert design team. Your collective task will be to design a new residence suitable for inhabitants of the imaginary Deltoid plane. These written materials, provided to help you prepare for this task, are organized in four sections.

The next section provides an overview of life on the Deltoid plane, DeltaP, as it is known to the natives. The following section describes your team, and the final, your design task. A second handout, different for each team member, provides the specific information you will need to perform the role you have been assigned within your team. Each team member will contribute different expertise to the project, and each has different design responsibilities to fulfill. All must work together for your team to create a first-rate design.

Life on DeltaP

Life on DeltaP, residential and otherwise, is quite different from what you have grown accustomed to here on Earth. First off, DeltaP is a plane, not a planet, so your team will be designing in two-dimensional rather than three-dimensional space. If your design "meets spec" and is considered attractive and functional by your Deltan clients, one view on a single sheet of paper will convey to those responsible for constructing it all the information they need to do so.

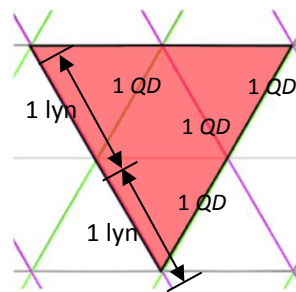
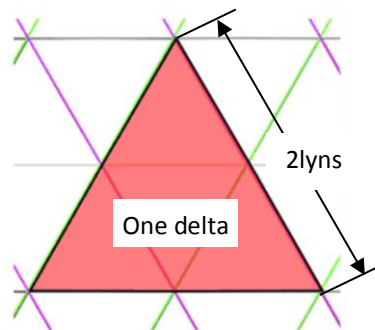


²³ Copyright 1991 MIT; All rights reserved

APPENDIX G—Delta Design description, roles, and specifications (cont.)

The view on this single sheet may not be quite what you expect, however, because in addition to lacking a z-axis, Deltoid space has unfamiliar relations between the x and y axes as well. What we think of as "perpendicular" is hopelessly skewed to a Deltan, and vice-versa. In our units, a right angle on DeltaP measures 60° or $\pi/3$ radians. Thus, all sides of an equilateral triangle form lines considered perpendicular to all others. If there were such a thing as a "circle" on DeltaP, it would be composed of only $4\pi/3$ radians.

But there is no such thing as a "circle" on DeltaP, nor even the concept of continuity embodied therein. In this flat though angular world, residents construct their artifacts strictly with discrete triangular forms. Of these, the equilateral triangle --with its three perpendicular sides (!)-- is considered the most pleasing. Accordingly, your team will design the residence by assembling into a cluster the most prized building materials on DeltaP, equilateral triangular components called "deltas." Deltas come in red and blue versions and always measure 21yns per side. Four "quarter-deltas", ODs, triangular units of area measure with sides of 1lyn, fit within a delta.



1 QD = 1 quarter delta

Lyns? QDs? Not surprisingly, Deltan systems of measurement are as unfamiliar as that for spatial coordinates. Table 1 summarizes the measurement schemes on DeltaP that you will need to know to carry out your design task.

All of DeltaP's units of measure share the divisibility and extensibility conventions of the metric system; in the measure of time, for example, there are both microwex (μwx) and megawex (Mwx). In relation to the attention-and life-spans of Deltans, these units are roughly equivalent to seconds and years, respectively, here on earth.

PROJECT MANAGER PRIMER

As project manager, your main concerns are cost and schedule, the interpretation and reconciliation of performance specifications, and negotiations with contractor and client. You want to keep costs and time-to-build at a minimum, but not at the expense of quality. When your team submits its final design, you must report the cost and time that

APPENDIX G—Delta Design description, roles, and specifications (cont.)

you estimate will be required to build it. These estimates will be in zwigs (!) and wex, respectively.

As an experienced project manager, you know that all specifications are prone to slip during the conceptual design phase, and that budget and schedule, your specific responsibilities, are the

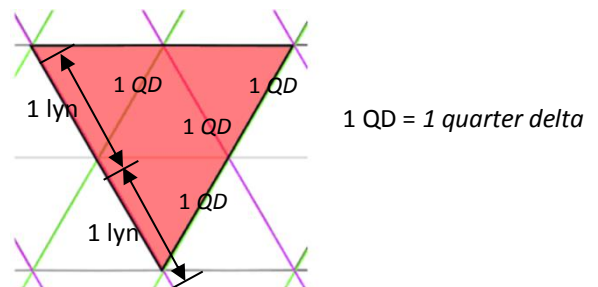
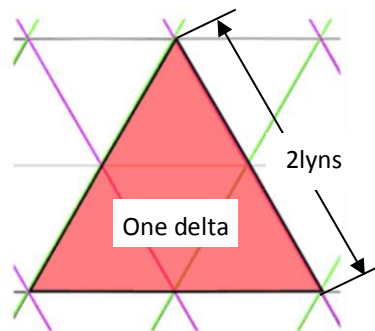
most vulnerable. You have already realized that both are likely to be binding constraints, and further, that the Deltans are tight with a zwig and anxious to move in. Like clients everywhere, they desire a better residence than they can comfortably afford

.ARCHITECT PRIMER

As architect, your concern is with the intrinsic form and function of your team's design, as well as how it relates to the site. When your team submits its final design, you should be prepared to discuss how and why the Deltans will find the residence attractive and functional. You will also be asked to report some more quantitative architectural measures discussed below.

Function Follows Form

As simple as the fundamental building elements appear, quite complex, intricate and angular form can be composed out of deltas. As architect, it is your responsibility to create design that not only meets the clients' physical needs but in some way stands as an expression of their vision of themselves and their community.



You read this vision as a vision of progress and innovation. You imagine a form that, while rooted in tradition, suggests a reaching out toward the unknown. Tradition has valued the angular exterior facade. You want to experiment with the smooth. Perhaps a rhythmic alternation of a smooth facade over a finite number of lyns with the traditional angular exterior will prove interesting.

APPENDIX G—Delta Design description, roles, and specifications (cont.)

Coming more into vogue is the angular interior. There is some kind of reversal going on here. The interior traditionally has been made smooth, to maximize interaction and communication. Nowadays privacy has become a common word in architectural discourse. While an argument can be made that the use of deltas to shape interior nooks and crannies is an inefficient use of this one resource, you think that this is a short-sighted view even though it is a view "rationally" argued by your engineering colleagues.

Your clients want to go even further, They seem to want some kind of "fractal" interior --not just one space with nooks and crannies but sub-spaces which themselves suggest nooks and crannies. This is all very fuzzy in your mind but you are keen to experiment and have started sketching.

At the same time, you are keen to economize on space designated for circulation within the interior. You want, in other words, to maximize functional space. Note that a quarter-delta is an area within which three inhabitants could stand and talk comfortably, one to another. Several lynes are then required for circulation cross-section, not only within the interior but also at the entrance.

The single entrance/exit is conventionally aligned with the force field and "upstream" as viewed from outside; that is, one enters the cluster moving forward, in the direction of gravitational pull. This is so because Deltans are themselves subject to gravity. They have evolved over the many *gigawex* of their existence to the point where they now are able to maneuver in any direction without conscious attention to the force field. However, the entrance to most clusters is located so that the residents would fall into rather than out of the cluster if they were to *lose* this sense. This orientation is essential during passage of a gravity wave.

As noted in the description of the design task, your client is blue sensitive. While the allowable dosage of blue deltas in the environs is no set number, you conjecture that the blues ought not to constitute more than 60% of the elements, Dispersion of the blues is preferred as well, so that residents are not confronted with seemingly endless blue vistas when viewing the interior.

STRUCTURAL ENGINEER

As structural engineer, you are responsible for the physical integrity and robustness of your team's design. You must insure that the residence you propose will hold together under prescribed loading conditions. You should see to it that the two points at which your structure is anchored to the plane are appropriately chosen, that all joints are sufficiently strong, and that the overall shape of the cluster does not violate sound structural engineering practice. You should also strive for an elegant and efficient design, one that provides the requisite strength and durability with minimum costs and materials.

APPENDIX G—Delta Design description, roles, and specifications (cont.)

When your team submits its final design, you will be asked to attest to its quality by explaining the location of the anchors, identifying the strongest and weakest joints, and estimating, as a measure of robustness, the average load on all joints expressed as a percentage of failure loads. You may be asked to predict what will happen to your design during the next gravity wave. This primer will give you the tools, essentially the methods of static equilibrium analysis, with which to do your work. It assumes you have read the introduction to the Delta design exercise.

THERMAL ENGINEER PRIMER

As thermal engineer, you are responsible for the comfort and thermal stability of your team's design. This primer will review some basics of heat transfer on DeltaP, then cover methods you may use to estimate the average temperature and extreme values for individual deltas. It assumes you have read the introduction to the exercise.

To insure the comfort of prospective residents, you want the average temperature of all deltas in the cluster, a good proxy for interior temperature, to fall between 55 and 65 degrees Nn . For stability, you want the temperature of each delta to stay above 20° Nn and below 85° Nn , as they melt at 85° Nn and begin to grow at 20° Nn . Either event would have catastrophic consequences, with your clients tumbling down the plane amidst the wreckage of their dwelling. When your team submits its final design, therefore, you will be asked to estimate internal temperature and the location and temperature of the hottest and coldest deltas.

APPENDIX G—Delta Design description, roles, specifications (cont.)

TABLE 1. **Measurement Units on DeltaP**

MEASUREMENT	UNIT OF MEASUREMENT	SYMBOL
Time	Wex	wx
Distance	Lyn	ln
Area	Quarter-Delta	qd
Heat	Deltan Thermal Unit	DTU
Temperature	Degrees Nin	°Nn
Force	Din	Dn
Moment	Lyn-Din	LD
Currency	Zwig	!

TABLE 2. **Summary of Design Specifications**

FUNCTIONAL INTERNAL AREA	100 QD
Maximum Cool Deltas (% Total)	60-70 %
Average Internal Temperature Range	55-65 °Nn
Individual Delta Temperature Range	20-85 °Nn
Maximum Load at Anchor Points	20 Dn
Maximum Internal Moment	40 LD
Overhead Factor –K	(varies)
Total Budget	! 1400.00

APPENDIX H—Existing Knowledge vs. Contributions

Existing Knowledge

- Social Network Theory
 - Balance (Heider, 1946, Cartwright & Harary, 1956)
 - Study on balance and group problem solving using NASA's "moon problem" (Civettini, 2007)
 - Centrality Measures (Leavitt, 1949)
- Theory of Ability Emotional Intelligence
 - Situational Test of Emotion Management (STEM)
- Theory of Trait Emotional Intelligence
 - Self-Monitoring (SM)
 - Self-Monitoring Scale
- Playground Design Task
- City Planning Task
- Delta Design
- Collaborative Learning
- Levels of Analysis (Krackhardt)
 - Levels 0-IV

My Contributions

- Adapted Gower and Legendre's (1986) equation S_9 for use with a 3 x 3 matrix to determine Level III and Level IV accuracy.
- Only studies on balance and group problem solving using Playground Design Task, City Planning Task, and Delta Design (2009).
- Conceived and executed four subsequent studies on balance and group problem solving using Delta Design (2009-2012).
- Developed original Level II questionnaire for use in the above studies.
- Assisted in testing computerized Delta Design exercise.
- Assisted in developing protocol for administering Delta Design.
- Developed rubric for scoring Delta Design (Prior to this, Delta Design was used strictly as a learning tool and did not have a quantifiable outcome.)
- Conceived and administered pilot study for Level IV questionnaire.
- Work with David Krackhardt
 - Assisted in development of questionnaire for Level IV study
 - Expanded level of analysis Level IV
 - Correlated equivalence and responder classes with Level III and Level IV accuracy.
 - Co-conceived, conducted, and analyzed first ever Level IV study. Study used unique combination of Level II questionnaire, Level IV questionnaire, and STEM and SM instruments.
 - Developed means of calculating and analyzing Level III and Level IV accuracy using spreadsheet.

APPENDIX H—Existing Knowledge vs. Contributions (cont.)

Existing Knowledge			
		Levels of Analysis	
		Level III	Level IV
Centrality 1			
	Degree	N/A	N/A
	In degree	N/A	N/A
	Out degree	N/A	N/A
	Betweenness	N/A	N/A
	Closeness	N/A	N/A
Emotional Intelligence (EI)			
	Ability EI 3	N/A	N/A
	Trait EI 4	N/A	N/A
Balance		N/A	N/A
Group performance ⁵		N/A	N/A

New Knowledge			
		Levels of Analysis	
		Level III	Level IV
Centrality			
	Degree		
	In degree	0	0
	Out degree	0	0
	Betweenness	-	-
	Closeness	-	-
Emotional Intelligence (EI)			
	Ability EI	0	0
	Trait EI	+	+
Balance		-	-
Group performance		0	0

Note. – = negative correlation
0 = no correlation
+ = positive correlation