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NETWORK ANALYSIS AS AN INVESTIGATIVE TOOL FOR ORGANIZATIONAL COMMUNICATION

By

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specifies distances between points according to the reciprocal pattern of relationships found in the data.[5] According to the Proctor and Loomis scheme, What the study proves is for a group (A and B would be located closest together when both A chooses B, and B chooses A; A and B would be somewhat less close together if A chooses B, and B does not choose A; A and B would be even less close if neither A or B choose each other; and, in turn, A and B would be furthest apart if A rejects B, and B rejects A.)

A similar attempt at standardizing the sociogram has been made by Northway.[6] The Northway technique results in a "target sociogram" where those persons mentioned most often, as contacts, are located in the center of several concentric circles. As one moves away from this center, individuals are placed on the appropriate circle according to how frequently they are mentioned as contacts, with Isolates (those with no contacts) located on the outermost circle.

Standardizing the sociogram usually involves attempts at formalizing the distances between points on the graph according to some rule. However, in the standardization techniques mentioned (Proctor and Loomis and Northway), the distances between the points do not emerge from the data, but are arbitrarily specified by the investigator. The techniques mentioned do not establish a metric space, but instead several ordinal points (determined by the number of reciprocal relationship types or concentric circles) and the intervals between these points are left to the discretion of the investigator. In order for there to be a one to one correspondence between a given set of sociometric choices and a given sociogram (in the absence of distances specified according to convention or fiat); it would be necessary to transfer the lists of respondent choices into a distance or spacial model. If one chooses to do a spacial analysis of the sociometric choices, attention must be directed toward the dimensionality of the space, finding and naming the principal dimensions, and determining the configuration of points in the space.[7] If however, one chooses to do a network analysis of the sociometric choices, attention must be directed toward an a priori set of criteria which when satisfied constitute a link, and the primitive units in the analysis are those people who are connected by a link, and those people who are not. The problem being considered -- the infinite number of sociograms which can emerge from any single set of sociometric choices -- seems to lead to at least two possible responses: 1) transform the set of sociometric choices into a spacial configuration (spacial analysis) or 2) treat each of the points, or respondents, as either linked or not linked according to some previously specified criteria, (network analysis).

Before proceeding with an examination of the two types of analysis (spacial and network) several key theoretic distinctions need to be specified.[8]

The Meaning of a Zero

In a metric space (a metric space being one which permits a measurement of distance) a zero distance between two points means that they are the same point. While in a network analysis, (a zero merely implies the lack of a link between the respective points and does not entail an identity.

The Symmetry of Measurement

In a metric space, the distance from A to B must equal the distance from B to A. A network analysis, however does not always assume that a link from A to B necessarily implies a link from B to A. For example, the case where B can receive messages from A, but does not have the ability to send messages in return.

The Rule of Triangular Inequality

In a metric space, some rule for triangular inequality must be held such that the distance from A to B plus the distance from B to C must be greater than or equal to the distance from A to C. In addition, if the sociometric choice list is to be represented in a Euclidean space, the distances must conform to the more stringent rule that the distance from A to C = $(A^2 + B^2)^{\frac{1}{2}}$. Network analysis also carries with it an assumption that if A is connected to B, and B is connected to C; A is connected to C by a two-step linkage. This assumption becomes of central importance when the topic of matrix exponentiation as a tool for group structure investigation is discussed.

The Role of Motion

In a metric space, the motion that interests the investigators is that of the points located in the space. Motion, in this metric space, should conform to some general rules such as if a single point in the space is moved, the distance between that point and all other points in the space should change; while the distance between any unmoved points should remain constant.[9] On the other hand, in a network analysis, the investigator may be most interested not in the movements of points or linkages, but in the movement of a third variable along the linkage between two points. What is dynamic in a network model is not the movement of points or linkages (which would have no meaning in this nonspacial analysis), but the movement of messages along the respective linkages.

The discussion above is intended to explicate some of the basic assumptions which may distinguish two types of analysis performed on a sociometric choice list. It is now necessary to look at the procedures involved in both the network and spacial analysis.

In a network analysis, the most primary item of information is whether or not two individuals are linked. This information may be parsimoniously stated in a matrix representation of the data. When a sociometric choice list is converted into matrix form, the matrix is usually:

1) square; a matrix of order NxN, where N equals the number of respondents,

2) binary; the elements of the matrix are made up of zeros and ones, where zero signifies no link, and one signifies a link,

3) conditional; the matrix N is conditional meaning that the element in the i*th* row, j*th* column, n(i,j) does not necessarily equal the element in the j*th* row, i*th* column, n(j,i). If this condition were true the matrix would be symmetric, n(i,j) = n(j,i).

One approach to exposing the subgroup formation within this matrix was developed by Forsyth and Katz.[10] A matrix was constructed so that each respondent had a number (1 to N) which was listed across the top of the matrix (designating columns) and along the side of the matrix (designating rows). If, for example, respondent 16 reported a linkage with respondent 24, a one would be placed in the matrix cell located in the 16th row, 24th column. By moving pairs of rows and columns (the order of columns must always remain identical to that of the rows) it is possible to get the ones in the matrix to cluster around the diagonal. It can be easily shown, for example, that if respondents 13, 14, 15, and 16, of matrix N, all report linkages with each other, ones will tend to cluster around the cells n(13,13), n (14,14), n(15,15), n(16,16) or along the diagonal. By moving people who report similar linkages close to each other (in terms of rows and columns) ones will cluster along the diagonal and subgroups can be extracted. Weiss and Jacobson further identified the structural components which can be specified once the clusters are formed. Weiss and Jacobson identified a:[11]

1) Work Group (later to be called just a group) as members who have linkages more with each other and not with members of other groups.

2) Liaison, as an individual who had links with at least two other individuals who were members of groups other than his own; and,

3) Contact between groups (later referred to as a bridge) as a single linkage between members of work groups who would otherwise be classified as totally separate groups.

One the rows and columns of the matrix have been sufficiently manipulated that the "ones" (reports of contact) cluster around the diagonal, the extraction of structural components, subgroups, liaisons, and bridges may begin. However, the manipulation of matrix rows and columns may be an extremely time-consuming and difficult task, and as a result, numerous algorithms have been developed to facilitate the process. Two least squares techniques will be discussed here, one developed by Katz and one by Beum and Brundage.

It should be remembered that any simultaneous reordering of rows and columns does not change the meaning of the matrix, (only element positions) and thus the desired state of the matrix (position of rows and columns) is one of maximized concentration of contacts around the diagonal. Katz has developed a least squares equation which, when minimized, designates this optimum ordering of rows and columns. Assuming that the distance between any adjacent row or column is one, the square of the distance of the element in the i<u>th</u> row and j<u>th</u> column from the main diagonal is equal to $\frac{1}{2}(i-j)^2$. In order then to get the binary matrix into a form where contacts are concentrated along the diagonal, it only becomes necessary to minimize $e_{i,j}\ (i-j)^2$, where $e_{i,j}$ is the element (one or zero) in the i<u>th</u> row and j<u>th</u> column, and the constant factor ($\frac{1}{2}$) is dropped.[12] It can be easily seen that the least squares equation will minimize as the $(i-j)^2$ terms become smaller for each whole number entry. In turn, the $(i-j)^2$ terms will become smallest when the whole numbered elements locate themselves around the diagonal. It should be noted however, that while the least squares equation above serves as an indicator of preferred form, it does not provide much insight on the most efficient method for achieving this form. The technique developed by Beum and Brundage not only results with contacts being clustered around the diagonal, but contains, within its procedures, suggestions for the next possible re-ordering of rows and columns to achieve this form.[13]

The rules for the Beum and Brundage technique are given below:

1) column sums are obtained:
2) beginning with the bottom row, weights are assigned to the rows of the matrix;
3) each column element is multiplied by its respective weight and then summed;
4) the weighted sums are divided by column sums;
5) divided sums are ranked (one for the largest to N for the smallest);
6) the column then with the highest rank (1) is moved to the extreme left, and then corresponding row to the top. The next ranking column and row are then placed next to the first and so on for the N rows and columns.

An example matrix can be shown below:

Original Matrix

Wts.		A	B	C	D	E
5	A	0	1	1	1	0
4	B	1	0	1	1	1
3	C	0	0	0	0	0
2	D	0	0	1	0	0
1	E	1	0	1	0	0
col. sums		2	1	4	2	1
prod. sums		5	5	12	9	4
div. of sums		2.5	5	3	4.5	4
rank		5	1	4	2	3

Revised Matrix
(rows and columns re-ordered)

	B	D	E	C	A
B	0	1	1	1	1
D	0	0	0	1	0
E	0	0	0	1	1
C	0	0	0	0	0
A	1	1	0	1	0

The Beum and Brundage algorithm needs to be successively repeated on the matrix until 1) further iterations do not cause a change in row or column position or 2) further iterations result in an alternating pattern of row and column orderings. When either of these conditions are met, the squared distance of the contacts away from the diagonal will be minimized.

Once the contacts become clustered around the diagonal, it becomes necessary to locate the structural components. This location of structural components can be accomplished by visual inspection or computation according to some criteria. Regardless of which technique is used, initial subgroup formation is usually tentative and subject to further tests of "groupness."

One common test of groupness in the sociometric literature involves the percent of ingroup communication. This percentage is found by dividing the number of ingroup links (links to other tentative group members) by the total number of links for that respondent times 100. The investigator may then require that each legitimate group member have at least a certain percentage of his total communication with other group members. Sociometricians have frequently set this percentage criterion to 51.0% because 1) this figure requires a substantial portion of one's communication to be with other group members, and 2) this figure does not allow any individual to be in more than one subgroup.

A second standard frequently used as a test of group-ness is a maximum step linkage between members. It is possible to represent, in matrix form, the minimum number of links between any two group members. An entry of three, for example, in the second row, fourth column, of the group linkage matrix, would designate that group member number two was three links away from group member number four, or in other words, a message sent from group member two to group member four would have to be transmitted through two other members. Determination of these linkage distances by inspection of a sociogram would be an extremely time consuming task; as an alternative, Festinger has developed a matrix multiplication procedure which significantly simplifies this task.

Festinger noticed that raising the binary matrix to successive powers reveals the number of links between members, that is, squaring the matrix reveals two step links, cubing the matrix reveals three step links, etc.[14] If group member A lists B as a contact, and B lists D as a contact, A has a two step link connection with D. An example of a two-step link exposed by matrix exponentiation is illustrated below.

Matrix of Contacts

	A	B	C	D	E
A	0	1	0	0	0
B	0	0	0	1	0
C	0	0	0	0	0
D	0	0	0	0	0
E	0	0	0	0	0

Squared Matrix of Contacts

	A	B	C	D	E
A	0	0	0	1	0
B	0	0	0	0	0
C	0	0	0	0	0
D	0	0	0	0	0
E	0	0	0	0	0

The one in the (A,D) cell of the squared matrix indicates A and D are connected by a two-step link. It can be easily shown that the entry in the squared matrix (a,d) or (row 1, column4) cell is the sum of products of the elements in the A row times the corresponding elements in the D column. The A row, in turn, can be interpreted as the people A reports as contacts, and the D row as the people who report contacts with D; as a result, when an entry in the A row (people who A contacts) corresponds with an entry in the D row (people who contact D) a two-step link is exposed. The squared matrix is also capable of reporting the number of two-step linkages between two members. For example, in the matrix below, A and D are connected by two two-step links, one through B and one through C.

Matrix of Contacts

	A	B	C	D
A	0	1	1	0
B	0	0	0	1
C	0	0	0	1
D	0	0	0	0

Squared Matrix of Contacts

	A	B	C	D
A	0	0	0	2
B	0	0	0	0
C	0	0	0	0
D	0	0	0	0

It was also noticed by Festinger, that the diagonal elements in the squared matrix represented a two-step link between a person and himself, or in network terminology, a reciprocated contact (A reports a contact with B, and B reports a contact with A). As a result, the squared matrix of contacts is extremely rich in information as the following interpretation will attempt to show.

Matrix of Contacts

	A	B	C	D
A	0	1	0	0
B	1	0	1	0
C	0	1	0	0
D	1	0	0	0

Squared Matrix of Contacts

	A	B	C	D
A	1	0	1	0
B	0	2	0	0
C	1	0	1	0
D	0	1	0	0

Interpretation of Squared Matrix

1) A has one reciprocated link
   A has one two-step link with C

2) B has two reciprocated links

3) C has one two-step link with A
   C has one reciprocated link

4) D has one two-step link with B
   D has no reciprocated links

Raising the matrix to a third power (postmultiplication of the original matrix by the squared matrix) in turn, reveals the number of three-step links between any two members; with the diagonal elements indicating the number of three-step links between a person and himself, or in diagram form, the number of triangles.

A B

C

Th~~is~~e diagonal element in the cubed matrix can be extremely important because it does indicate this number of triangular group membership formations. Triangles, in turn, are indicative of how highly structured the subgroup is; a triangle (as opposed to a square or some other configuration) is a multi-step linkage (namely three) where all members of the linkage also communicate directly with each other. As a result, in a triangular structure, the inter-connectivity of the subgroup members is at a maximum. By adding together the diagonal elements of the cubed matrix of contacts for a tentative subgroup, an inter-connectivity score for subgroup members can be obtained. A possible test for a tentative group structure might then be the sum of the cubed matrix diagonal elements (number of triangles in the group) corrected for the number of individuals in the group. A possible interpretation for the cubed matrix of contacts could then be as follows.

Matrix of Contacts

	A	B	C	D
A	0	1	0	0
B	0	0	1	1
C	1	1	0	0
D	1	0	1	0

Squared Matrix of Contacts

	A	B	C	D
A	0	0	1	1
B	2	1	1	0
C	0	1	1	1
D	1	2	0	0

Cubed Matrix of Contacts

	A	B	C	D
A	2	1	1	0
B	1	3	1	1
C	2	1	2	1
D	0	1	2	2

Examples of Interpretation of Cubed Matrix

1) B has one three-step link with A
(B-D, D-C, C-A)

2) A is involved in two triangles
(A-B, B-C, C-A)
(A-B, B-D, D-A)

3) the total number of triangles for this subgroup is 9.

Luce and Perry explain that raising the matrix to additional powers (4th, 5th, 6th, etc.) will show respective linkage distance between group members (number of 4-step links, 5-step links, 6-step links, etc.).[15] However, raising the matrix past the third power introduces the problem of repetitive linkage patterns. For example, a 6-step link could actually be composed of A to B, B to C, C to D, D to B, B to C, C to C, and D to A, where several of the links are actually being duplicated. The mathematical problem here is also paralleled by a theoretical one which asks: Of what meaning is it to have two group members who are six links apart, or members who can only communicate with each other via five other individuals? As a result, a common criteria for subgroup formation is that no two group members be greater than three links apart from each other.

Thus far, the analysis discussed as been based on linkage or network assumptions where the primary variable is a dichotomous one: are two individuals connected? It is now possible to shift our analysis to a spacial paradigm, where the primary variable is a continuous one involving distances.

Before looking at the sociometric choice matrix under spacial assumptions, it will be necessary to transform the matrix from a conditional state to a symmetric one (the element in row i, column j, equals the element in row j, column i). This revision is necessary so that the distance from A to B equals the distance from B to A; and can be accomplished by: 1) dropping unreciprocated links or 2) forcing reciprocation. Either technique may be used as long as the elements are mirrored along the diagonal; or a one in row i, column j, corresponds with a one in row j, column i.

Once the matrix has been expressed in symmetrical form, it is possible to think of each row as specifying the coordinates of a point in N dimensional space, where N equals the number of respondents.[16] This matrix (or set of N row vectors in N dimensional space) may be post-multiplied by its transpose yielding a scalar product matrix where 2) the diagonal elements equal the squared length of the respective row vector (length of first row vector equals (1,1) ; and 2) off-diagonal elements equal the product of vector lengths times the cosine of the angle between them. In turn, dividing the scalar product matrix by N (the number of rows or columns) results in a variance-covariance matrix where diagonal elements indicate the variance of reported contacts for each respondent and the off-diagonal elements indicate the covariance of reported contacts for any two respondents.

By working with standardized score, (dividing the deviations from the mean of each column, by the standard deviation for the same column), the variance-covariance matrix reveals correlation coefficients with unity on the diagonal elements and correlations between respondent choices on the off-diagonal elements. From this correlation matrix, it becomes possible to factor analyze the choice patterns among respondents under the assumption that individuals will cluster together in the space, when they make similar sets of choices.[17] When the matrix is factor analyzed, each factor should represent a whole subgroup, with the dimensionality of the space determined by the number of subgroups. And in turn, an individual's membership among the subgroups can be interpreted through his set of respective factor loadings.

In review, it can be seen that the original sociometric choice list left too much variance as to the number and type of sociograms which could be constructed from a single data set. As a result, attention was turned toward representing the choice list in matrix form, and decomposing this matrix into subgroups using assumptions of a linkage (network) analysis or a spacial (distance) analysis.

PROCEDURES AND METHODS

OF NETWORK INVESTIGATION

In this section, attention will be given to the sample, testing procedures, questionaire, and data analysis method used in gathering and analyzing the data.

Sample

The sample used in this investigation was the Lansing Junior League of Women, of Lansing, Michigan. Membership in this organization is divided into three sections: 1) provisionals, first-year tentative membership in the league; 2) actives, normal functioning members; and 3) sustainers, members who only pay dues to maintain formal membership. The following characteristics are descriptive of the League membership:

1) all participants live in the mid-Michigan area;
2) ninety-eight percent of the members are married;
3) ninety percent of the members have children;
4) thirty percent indicate part-time or full-time jobs;
5) total league membership is 393 women composed of: 22 provisionals, 144 actives, 217 sustainers, and 11 of no known status.

Procedure

The network analysis being reported here was part of an lar~~ger and more comprehensive~~ investigation of ~~total League~~ operations.[18] Between January and May ~~of 1975, four ques~~t-ionai~~res were distributed~~ in the League assessing the correspondence between multi-dimensional attitude configurations and reports of overt behavior. On May 20, 1975, the network questionaire was mailed to 22 provisionals, 144 actives, and 65 sustainers. After one week, actives and provisionals who had not returned their questionaire were called by telephone and asked to do so. After ~~four~~ weeks, the return rate was as follows:

1) ~~27~~% return of "actives" questionaires

2) 80% return of "sustainers" questionaires

3) ~~91~~% return of unknown status

4) ~~91~~% return of provisionals

It should be noticed, however, that ~~only~~ 65 of the 217 sustainers (30%) were actually sent questionaires. Given the limited role which these sustainers play in the League, it was not felt that obtaining data from the entire population of sustainers was worth the ~~expense~~. As a result, the 65 questionaires sent to sustainers were selected from a random number table, and the 52 questionaires received represent 80% of the questionaires sent, but only 24% of the total number of sustainers.

Questionaire

The design for the questionaire was primarily adopted ~~from a~~ Jacobson and Seashore questionaire developed for an early organizational network study.[19]

The cover page of the questionaire informed each respondent, that the communication research ~~team~~ was performing an "Information Flow Study" of their organization. Each respondent was then asked to 1) place their name at the top of the questionaire, 2) complete the questionaire, and 3) return the questionaire to the Department of Communication, Michigan

Two comments about questionaire design are in order. The first is that the respondent categories under the "Subject Matter" scale ~~were given~~ more precise definitions at ~~the top of the page, as follows~~:

> Personal Issues: "Conversations where your own personal feelings about League activities are discussed."
>
> Social Issues: "Conversations where others' expectations, family friends, neighbors, about your League activities are discussed."
>
> Situational Issues: "Conversations where the requirements of League activities are discussed (e.g., difficulty of activity, time spent working, effort, responsibility, etc.)"

Results

The second comment is that the dichotomous choice used to designate initiator of contact proved unsuccessful. Respondents consistently indicated that over the range of contacts with another individual initiation could only be reported as a proportion or percent and not as a yes or no. As a result, this question was dropped from the data analysis.

Data Analysis

The primary method of data analysis used in this study is a network analysis program written by William D. Richards Jr., and stored in a CDC 6500 computer at Michigan State University.[20] In abbreviated form, the network analysis algorithm is one which lists the respondents 1 to N along a continuum, and then computes a mean contactee score for each respondent. The mean contactee score is derived from the sum of all contactee numbers divided by the total number of contactees. The respondents are then re-ordered along the continuum according to their mean contactee score. When this iterative procedure is performed a number of times, the resultant continuum contains clusters of respondents who have made similar contact choices. Then, in a somewhat metaphorical sense, a scanning radius measures the distance between consecutive respondents to determine whether the clusters are close enough to each other to constitute a subgroup. In a more precise sense, the scanning radius (whose diameter may be determined by the investigator) centers on each respondent and records the number of other respondents to the left and right of the centered respondent which still fall within the radius. Once this has been accomplished for each respondent, it is possible to establish a ratio of non-overlapping to overlapping structures. For example, the scanning radius centered on respondent ~~20~~ 19 reveals 3 respondents to the left and 2 respondents to the right; while when centered on respondent 20 reveals 3 respondents to the left and 5 respondents to the right, the non-overlapping to overlapping ratio does not experience much change, while group boundaries will be indicated by relatively large shifts in the ratios between respondents. ~~The difference in ratios needed to form a subgroup or a boundary can be controlled by the investigator.~~

It should be noted that the procedure discussed above is used only in the formation of tentative group structure, and that further requirements (e.g., 51% ingroup communication) are usually specified by the examiner.

FINDINGS

This section will analyze the data at two hierarchic levels of abstraction: 1) the structure of the network as a whole, and 2) the decomposition of this network into structural components.

what ~~It~~ is assumed ~~here~~ that the network as a whole should exhibit some kind of structure, such that some individuals have a large chance of being linked, while for others, this chance is somewhat smaller. In other words, the assumption of a structured network is an assumption of deviance between the network structure revealed in the data, and the network structure expected from a totally random network. For the purposes of this analysis, a highly structured communication network is one which contains high variance of linkages between members, or where differential position in the organization requires differential use and number of communication linkages. On the other hand, a random communication network makes the assumption that any two organizational members have an equal chance of a communication linkage. Looking at the deviation in the variances of these networks is in many ways a test of our obtained network under the assumption of a structured communication organization.

Before proceeding, it is necessary to define what is meant by a link. A link is normally indicated when a respondent reports a communication contact with another organization member; a reciprocated link is where the contactee also reports this link. Of the ~~494~~ 25 links reported by respondents, ~~101~~ or 20% were reciprocated (A reports B, and B reports A). Two options are left open to the investigator, 1) to drop 393 unreciprocated links or 2) add 393 links to force reciprocation. Different procedures are listed and used ~~at~~ different times in this analysis and will be ~~so~~ designated beforehand.

In order to ascertain whether a significant difference exists between the obtained network structure and a random network, an F test of linkage variance needs to be performed.

The variance of forced reciprocated links in the obtained network can be derived from the following equation.

$$s_o^2 = \frac{\overset{n}{\underset{i=1}{}} \quad (l_i - \bar{l})^2}{N}$$

where,

s_o^2 = variance of obtained network

l_i = number of links per respondent

$\bar{l}$ = mean number of links across all respondents

N = number of respondents

The mean number of links was, in turn, found by dividing the total number of links (the links reported plus the links added for reciprocation) and dividing by N or 394 respondents Substituting values in the variance equation yields:

$$s_o^2 = 273.46$$

According to the binomial expansion, the variance in the number of links for the expected random network can be expressed as:[21]

n p q, where:

n = the number of chances for a link for each respondent or (n-1)

p = the probability of any given pair of respondents being linked or $\frac{L}{N\ (N-1)}$ (total number of links)

q = the probability of any two respondents not being linked or 1-p or:

$$\frac{N\ (N-1)\ -\ L}{N\ (N-1)}$$

Therefore, the equation looks as follows:

$$npq = \frac{(N-1)}{1} \cdot \frac{L}{N(N-1)} \cdot \frac{N\ (N-1)\ -\ L}{N\ (N-1)}$$

or,

$$npq = 2.20$$

and,

$$S^2_{exp} = 2.20$$

An F test with degrees of freedom 393 and 393 shows a significant difference between the networks at .001 significance level, and thus supports the assumption that the network revealed in the data significantly differs from what would be expected of a randomly structured network.

A further test of significance needs to be applied to this data, however, due to the particular nature of this organization. Within the League are a large number of sustainers, who perform few functions in the League, and thus are involved in little or no League communicative acts. Inclusion of these sustainers into the previous analysis greatly inflated the squared deviations from the mean and resultantly, the variance. It should be advisable to compute the F-test again, excluding these marginal members from the analysis. The F ratio of variances obtained in this manner is somewhat smaller than the initial one, but still shows a significant difference between the obtained network and random networks at the .001 significance level. It can thus be determined that the distribution of links found in the data significantly differs from that which would be expected in a random model.

The preceding discussion was directed at the wholistic properties of the network; this portion on the other hand, focuses on the structural components which may be detected by the network program. These structural components include:

1) Group Members: Individuals whose communication links are more with other group members than non-members.

2) Bridge: A person who is a member of a communication group and has a link to a person who is a member of a different group.

3) Isolate: An individual in the network who has fewer than two communication links.

4) Liaison: A person within a network who has links with two or more communication groups, but does not have a majority of links with any one group.

II C

The most fundamental component in this network analysis is the link, or that which indicates the communication relationship between people. The study being reported here used two variables (weights) to characterize each communication link. Respondents were asked not only to identify the other participant in their communicative interaction (the link), but to characterize this relationship according to its frequency and importance. These frequency and importance ratings were then used to assess the strength of each link according to the equation:

$$\text{Strength of a link} = (X + Y) + (X \cdot Y)$$

where,

Strength	=	the strength of the link from one person to another,
X	=	the frequency rating given to the link (1 to 5, where 5 is greatest frequency)
Y	=	the importance rating given to the link (1 to 5, where 5 is greatest importance)

This link weighting procedure serves two special functions in the decomposition of the entire network into structural components. First, by directing the program to only look at links of some minimum strength, it is possible to eliminate those links from the analysis which are relatively infrequent and lacking in importance. Second, the group percentage criterion (what percent of one's communication must be with other group members in order to be in the group) looks at the percent of strengths and not the number of links per se.

Before revealing the structural components of this network, a cautionary comment is in order. The network program used in this study offers the investigator considerable flexibility in the determination of program parameters, and thus similar influence in the decomposition routines of the program. Changes in the following parameters, for example, result in considerably different determinations of group membership, isolates liaisons, etc.

Parameter 3 - whether unreciprocated links are dropped, or links added to force reciprocation,

Parameter 10 - the minimum strength which a link must have to be included in the analysis

Parameter 14 - the width of the scanning radius,

Parameter 15 - the maximum path length (number of links) which may separate any two group members,

Parameter 36 - percentage criterion for group membership.

The point to be made here is that an experienced user of this program can so specify the parameters to control the decomposition of the network. Whether the network breaks down into a few groups with high connectivity amongst its members, or many groups with few inter-group links can frequently be directed or controlled by the experimenter. As a result, it seems advisable to specify the parameters involving network decomposition into structural components prior to actually running the data.

The initial value of the parameters used, and the structural components found in this network are recorded in Table I. With the parameter values so specified (using forced reciprocated links) the program could find only one large group (N=112) in this network. Three reasons suggest that this might be an accurate representation of the communication structure in this organization. First, the organization is a volunteer one, and an attempt to force a strict hierarchical communication structure (such as an organizational chart) might meet with resistance or desertion. Second, the communication structure of the organization seems to be not that of a multi-leveled organizational chart, but of a circle with several active (in the communicative sense) individuals in the center and numerous isolates around the fringe. Third, an inspection of the deviation scores used in computing the variance of links in the obtained network revealed two groups, those who had many links (and therefore high deviation scores) and those that had one or no links (and therefore high deviation scores). As would be expected, an inspection of the subgroup with high deviation scores due to many links, tended to have these links between each other. In conclusion, the analysis discussed here seems to suggest that the organization can be characterized as having one central group (29% of the members) which engages in a large amount of inner-group communication, and a large number of individuals who have fewer than two links.

The question may now be rephrased however to ask, what group or linkage criterion are necessary to break up this large central group? This question calls for an after-the-fact alteration of program parameters to facilitate the decomposition of this network.

The parameters values used for the structural components found are recorded in Table II. In this case, the network was decomposed into three groups (N=35, N=3, N=56). The primary changes in parameters which may account for this structuring are:

Parameter 11 - minimum weight for a link
Parameter 14 - width of scanning radius
Parameter 36 - group percentage communication criterion

The primary effect of these parameter changes was to 1) drop linkages from the analysis which were relatively infrequent or unimportant (this took the greatest proportion of links away from the "active" communicators, for while these isolates had few links they tended to use them frequently and see them as having high importance); 2) to decrease the potential size of group boundaries by decreasing the scanning radius and 3) to generally make it easier to be in a group (with a percentage criterion of 40% it was even possible to be in two subgroups. This, however, did not occur.) If the program is instructed to look only at high frequency, high importance links with decreased potential group boundaries and eased percent of necessary in-group communication, three groups can be found in the network.

In summary, this section has attempted to look at the network in wholistic terms, as a contrasted unity with a random network, and in structural terms as the different components which make up the network.

FOOTNOTES

1. For a discussion of the various definitions of sociometry see: Bjerstedt, A. (1956) Interpretations of Sociometric Choice Status. Copenhagen: Muskgaard.

2. Network analysis has been done on some variables not directly related to communication. For a more thorough discussion see: Wigand, R. T., and Larkin, T. J., "Interorganizational Communication, Information Flow and Service Delivery Among Social Service Organizations;" a paper presented to the International Communication Association, 1975 Convention.

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4. Borgatta, E. F., (1951). A Diagnostic Note on the Construction of Sociograms and Action Diagrams. *Groups*, p. 3, 300-308.

5. Proctor, C. H. and Loomis, (1951) Analysis of Sociometric Data. In Marie Jahoda, M. Deutsch, and S. W. Cook (Eds) *Research Methods in Social Relations: With Special Reference to Prejudice*. Part 2, New York: Dryden. p. 561-585.

6. Northway, Mary L. (1940) A Method for Depicting Social Relationships Obtained by Sociometric Testing. *Sociometry*, 3, p. 144-150.

7. For a detailed discussion of spacial and linkage analysis see, Roistacher, Richard C., " A Review of Mathematical Models in Sociometry" *Sociological Methods and Research*, Vol. 3, No. 2, November 1974.

8. Roistacher, Ibid., pg. 151.

9. For a more complete discussion of the assumptions involved in spacial and network models see: Craig, Robert T. "Models of Cognition, Models of Messages and Theories of Communication Effects: Spacial and Network Paradigms." Paper presented at the International Communication Association, Chicago, Illinois, 1975.

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16. Van de Geer, John P., Introduction to Multivariate Analysis for the Social Sciences (W. H. Freeman and Co., San Francisco, 1971) p. 18.

17. An example of factor analysis used on a sociometric choice matrix is: Bock, R. D., and S. Z. Husain, An Adaption of Holzingers B-Coefficients for the Analysis of Sociometric Data. Sociometry (1950) 13, 146-153.

18. Seibold, David R., A Complex Model of Multidimensional Attitude and Overt Behavior Relationships: The Mediating Effects of Certainty and Locus of Control. Ph.D. Thesis at Michigan State University, 1975.

19. Jacobson, E., and Seashore, S., Communication Practice in Complex Organizations, Journal of Social Issues, 1951, Vol. 7, #3, 28-40.

20. For more information about the technique see: Richards, William D. Jr., Network Analysis in Large Complex Systems: Technique and Methods-Tools. Paper presented to 1974 International Communication Association, April 16-21, 1974.

21. Richards, William D., Jr., Network Analysis in Large Complex System: Metrics. Paper presented to 1974 International Communication Association, April 16-21, 1974.

22. Monge, P. and Lindsay, G. N., The Study of Communication Networks and Communication Structure in Large Organizations. Unpublished paper at Michigan State University, Department of Communication.

TABLE I

GROUP MEMBERSHIP AT INITIAL PARAMETER VALUES

Network Analysis Porgram Version 4.0 Sept. 1974

CONTROL PARAMETERS

PARAMETER	NO. 1	(N OF NODES)	VALUE=	349	**USER**
PARAMETER	NO. 2	(N OF LINKS)	VALUE=	700	**USER**
PARAMETER	NO. 3	(RECIPROCAT)	VALUE=	1	**USER**
PARAMETER	NO. 4	(DIRECTION)	VALUE=	0	**USER**
PARAMETER	NO. 5	(N OF ITERS)	VALUE=	4	**USER**
PARAMETER	NO. 6	(N RAW PRNT)	VALUE=	3	**USER**
PARAMETER	NO. 7	(DATA UNIT)	VALUE=	60	**USER**
PARAMETER	NO. 8	(OBSV/CARD)	VALUE=	7	**USER**
PARAMETER	NO. 9	(NAME-WIDTH)	VALUE=	9	**USER**
PARAMETER	NO. 10	(LOW HEIGHT)	VALUE=	1	**USER**
PARAMETER	NO. 11	(HI WEIGHT)	VALUE=	35	**USER**
PARAMETER	NO. 12	(EXPONENT)	VALUE=	1	**USER**
PARAMETER	NO. 13	(DNSTY HIST)	VALUE=	1	**USER**
PARAMETER	NO. 14	(SCAN RDIUS)	VALUE=	200	**USER**
PARAMETER	NO. 15	(MAX PATH L)	VALUE=	10	**USER**
PARAMETER	NO. 16	(LOW S. NO.)	VALUE=	1	**USER**
PARAMETER	NO. 17	(FILE OJTPT)	VALUE=	0	**USER**
PARAMETER	NO. 18	(PRINTO SUP)	VALUE=	0	**USER**
PARAMETER	NO. 19	(GRID SUP)	VALUE=	0	**USER**
PARAMETER	NO. 20	(GROUP SUP)	VALUE=	0	**USER**
PARAMETER	NO. 21	(MAX OUTPUT)	VALUE=	15	**USER**
PARAMETER	NO. 22	(MIN SPLIT)	VALUE=	12	**USER**
PARAMETER	NO. 23	(GRP-SNSVTY)	VALUE=	100	**USER**
PARAMETER	NO. 24	(SPLITDEV)	VALUE=	30	**USER**
PARAMETER	NO. 25	(UNUSED)	VALUE=	0	DEFAULT
PARAMETER	NO. 26	(UNUSED)	VALUE=	0	DEFAULT
PARAMETER	NO. 27	(UNUSED)	VALUE=	0	DEFAULT
PARAMETER	NO. 28	(UNUSED)	VALUE=	0	DEFAULT
PARAMETER	NO. 29	(UNUSED)	VALUE=	0	DEFAULT
PARAMETER	NO. 30	(UNUSED)	VALUE=	0	DEFAULT
PARAMETER	NO. 31	(UNUSED)	VALUE=	0	DEFAULT
PARAMETER	NO. 32	(UNUSED)	VALUE=	0	DEFAULT
PARAMETER	NO. 33	(DETAILS)	VALUE=	0	DEFAULT
PARAMETER	NO. 34	(MEAN STRST)	VALUE=	0	DEFAULT
PARAMETER	NO. 35	(PUNCH DECK)	VALUE=	0	DEFAULT
PARAMETER	NO. 36	(PERW)	VALUE=	51.000	**USER**
PARAMETER	NO. 37	(CONS)	VALUE=	.000	**USER**
PARAMETER	NO. 38	(MX)	VALUE=	1.000	**USER**
PARAMETER	NO. 39	(MY)	VALUE=	1.000	**USER**
PARAMETER	NO. 40	(CCX)	VALUE=	.000	**USER**
PARAMETER	NO. 41	(CCY)	VALUE=	.000	**USER**
PARAMETER	NO. 42	(MCPK)	VALUE=	1.000	**USER**
PARAMETER	NO. 43	(DROP-SPLIT)	VALUE=	.100	**USER**
PARAMETER	NO. 44	(2-STEP WI)	VALUE=	1.000	DEFAULT
PARAMETER	NO. 45	(UNUSED)	VALUE=	.000	DEFAULT

GROUP NUMBER 1 HAS 112 MEMBERS

56.	85	1.	1
57.	86	2.	2
58.	88	3.	3
59.	89	4.	4
60.	90	5.	5
61.	91	6.	11
62.	92	7.	12
63.	95	8.	13
64.	96	9.	14
65.	97	10.	15
66.	98	11.	16
67.	100	12.	17
68.	102	13.	18
69.	104	14.	19
70.	105	15.	20
71.	106	16.	21
72.	107	17.	22
73.	108	18.	23
74.	109	19.	24
75.	112	20.	27
76.	113	21.	28
77.	114	22.	29
78.	117	23.	30
79.	124	24.	31
80.	125	25.	35
81.	126	26.	37
82.	127	27.	38
83.	128	28.	39
84.	130	29.	40
85.	131	30.	42
86.	132	31.	43
87.	135	32.	44
88.	136	33.	45
89.	137	34.	49
90.	138	35.	51
91.	139	36.	52
92.	140	37.	53
93.	141	38.	54
94.	142	39.	56
95.	143	40.	57
96.	145	41	58
97.	146	42.	61
98.	147	43.	62
99.	158	44.	64
100.	151	45.	65
101.	152	46.	66
102.	153	47.	67
103.	170	48.	74
104.	174	49.	75
105.	187	50.	76
106.	197	51.	78
107.	243	52.	80
108.	266	53.	81

109.	282	54.	83
110.	289	55.	84
111.	292		
112.	326		

TABLE II

GROUP MEMBERSHIP AT REVISED PARAMETER VALUES

Network Analysis Program Version 4.0 Sept. '74
Copyright 1974. William D. Richards, Jr.

CONTROL PARAMETERS

```
PARAMETER NO. 1     (N OF NODES) VALUE=      394 **USER**
PARAMETER NO. 2     (N OF LINKS) VALUE-      900 **USER**
PARAMETER NO. 3     (RECIPROCAT) VALUE=        1 **USER**
PARAMETER NO. 4     (DIRECTION ) VALUE=        0 **USER**
PARAMETER NO. 5     (N OF ITERS) VALUE=        4 **USER**
PARAMETER NO. 6     (N RAW PRNT) VALUE=       15 **USER**
PARAMETER NO. 7     (DATA UNIT ) VALUE=       60 **USER**
PARAMETER NO. 8     (OBSV/CARD ) VALUE=        7 **USER**
PARAMETER NO. 9     (NAME-WIDTH) VALUE=        0 **USER**
PARAMETER NO. 10    (LOW WEIGHT) VALUE=        8 **USER**
PARAMETER NO. 11    (HI WEIGHT ) VALUE=       35 **USER**
PARAMETER NO. 12    (EXPONENT  ) VALUE=        1 **USER**
PARAMETER NO. 13    (DNSTY HIST) VALUE=        1 **USER**
PARAMETER NO. 14    (SCAN RDIUS) VALUE=      150 **USER**
PARAMETER NO. 15    (MAX PATH L) VALUE=        3 **USER**
PARAMETER NO. 16    (LOW S. NO.) VALUE=        1 **USER**
PARAMETER NO. 17    (FILE OUPT ) VALUE=        0 **USER**
PARAMETER NO. 18    (PRINTO SUP) VALUE=        1 **USER**
PARAMETER NO. 19    (GRID SUP  ) VALUE=        0 **USER**
PARAMETER NO. 20    (GROUP SUP ) VALUE=        0 **USER**
PARAMETER NO. 21    (MAX OUTPUT) VALUE=       15 **USER**
PARAMETER NO. 22    (MIN SPLIT)  VALUE=       12 **USER**
PARAMETER NO. 23    (GRP-SNSVTY) VALUE=      120 **USER**
PARAMETER NO. 24    (SPLITDEV  ) VALUE=       30 **USER**
PARAMETER NO. 25    (UNUSED    ) VALUE=        0 DEFAULT

PARAMETER NO. 26    (UNUSED    ) VALUE=        0 DEFAULT
PARAMETER NO. 27    (UNUSED    ) VALUE=        0 DEFAULT
PARAMETER NO. 28    (UNUSED    ) VALUE=        0 DEFAULT
PARAMETER NO. 29    (UNUSED    ) VALUE=        0 DEFAULT
PARAMETER NO. 30    (UNUSED    ) VALUE=        0 DEFAULT
PARAMETER NO. 31    (UNUSED    ) VALUE=        0 DEFAULT
PARAMETER NO. 32    (UNUSED    ) VALUE=        0 DEFAULT
PARAMETER NO. 33    (DETAILS   ) VALUE=        0 DEFAULT
PARAMETER NO. 34    (MEAN STRST) VALUE=        0 DEFAULT
PARAMETER NO. 35    (PUNCH DECK) VALUE=        0 DEFAULT

PARAMETER NO. 36    (PERW      ) VALUE=   45.000 **USER**
PARAMETER NO. 37    (CONS      ) VALUE=     .000 **USER**
PARAMETER NO. 38    (MX        ) VALUE=    1.000 **USER**
PARAMETER NO. 39    (MY        ) VALUE=    1.000 **USER**
PARAMETER NO. 40    (CCX       ) VALUE=     .000 **USER**
PARAMETER NO. 41    (CCY       ) VALUE=     .000 **USER**
PARAMETER NO. 42    (MCPK      ) VALUE=    1.000 **USER**
PARAMETER NO. 43    (DROP-SPLIT) VALUE=     .100 **USER**
PARAMETER NO. 44    (2-STEP WT ) VALUE=    1.000 DEFAULT
PARAMETER NO. 45    (UNUSED    ) VALUE=     .000 DEFAULT
```

GROUP NUMBER 1 HAS 35 MEMBERS

1.	1
2.	2
3.	3
4.	16
5.	19
6.	20
7.	23
8.	27
9.	28
10.	29
11.	30
12.	38
13.	39
14.	40
15.	42
16.	43
17.	44
18.	45
19.	51
20.	96
21.	62
22.	66
23.	74
24.	81
25.	84
26.	85
27.	91
28.	92
29.	100
30.	104
31.	105
32.	108
33.	128
34.	145
35.	151

GROUP NUMBER 2 HAS 3 MEMBERS

1.	31
2.	130
3.	357

GROUP NUMBER 3 HAS 56 MEMBERS

1.	5
2.	12
3.	13
4.	14
5.	17
6.	18
7.	21
8.	22
9.	24
10.	35
11.	37
12.	49
13.	52
14.	93
15.	54
16.	57
17.	61
18.	64
19.	76
20.	78
21.	80
22.	83
23.	86
24.	88
25.	89
26.	90
27.	96
28.	97
29.	102
30.	106
31.	107
32.	112
33.	113
34.	114
35.	124
36.	125
37.	126
38.	127
39.	135
40.	136
41.	137
42.	138
43.	139
44.	141
45.	142
46.	146
47.	150
48.	152
49.	153
50.	170
51.	187
52.	243
53.	282
54.	289
55.	292
56.	326

4) The average importance of the communication.

Answering these questions will allow us to discover the networks or routes which interpersonal messages take as they flow through the League's organizational structure.

****

Please write in the names of those people in the League with whom you have most contact and answer the questions to the right.

	FREQUENCY OF CONTACT					Do you usually initiate this contact?	
Names of board members or other officers	Several times daily 5	Daily 4	2 or 3 times weekly 3	Several times monthly 2	Several times per year 1	YES	NO
example: Mary Doe			✓				✓

Names of other actives whom you contact.

Names of other provisionals, transfers or sustainers whom you contact.

*Conversations where your own personal feelings about league activities are discussed (e.g., enjoyment, satisfaction, disappointment, etc.)

**Conversations where others' expectations, family, friend, neighbors, about your league activities are discussed.

***Conversations where the requirements of league activities are discussed (e.g., difficulty of activity, time spent working, effort, responsibility, etc.)

SUBJECT MATTER				IMPORTANCE OF CONVERSATIONS				
Personal Issues*	Social Issues**	Situational Issues***	Other	Utmost 5	Great 4	Some 3	Little 2	None 1
___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___