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Some Recent Developments in Organizational Communication: Network Analysis – A Systemic Representation of Communication Relationships

Communication per se is a relatively complex social process with many dimensions. Essential functions in any social system are accomplished through processes of communication. These essential functions have been divided into three basic categories by *Barnard* (1938): (1) production, (2) maintenance, and (3) innovation. Although other scholars developed different schemes into which the functions of social systems can be categorized, members of all social systems engage in activities that resemble *Barnard's* thinking. These functions, however, can only be carried out through various forms of communication. If the researcher studies the forms of communication in which the three functions of production, maintenance, and innovation are inherent, it can then be said – within limitations – that the social system has been analyzed with regard to communication. Each time the researcher focuses on one of these three activities, as they are reflected within the realms of communication, he specifies a particular communication network. If one would superimpose all existing communication networks within a system, this overall network could be considered to reflect the communication behavior of a social system.

One area in particular that provides insight into methods for describing large, complex systems is systems theory. *Buckley* (1967), for example, considers the notions of wholes, parts, structure, interdependence, etc. of primary importance. Similar emphasis can be found with *von Bertalanffy* (1940), *Rapaport* (1970), and others. The problem is, however, that a specification of how to find parts or units of formative process' has not been adequately established and constitutes today one of the major issues in systems theory (*Krippendorff,* 1971). Network analysis attempts precisely to overcome some of these inadequacies and takes into account some of the notions that are central to systems theory.

The paper focuses on the techniques and methods underlying the generation and analysis of communication networks in large, complex social systems. Communication networks consist of the detected patterns of communication contacts among individuals within a social system. These contacts can be 'arrested' for analysis purposes by assessing the attributes of face-to-face communication, communication by memoranda, by telephone, by letters, etc. *Pool* (1973) has described networks as the *thread* that holds social systems together. The analysis of networks can thus provide descriptions and characterizations of the system's structure. It should be noted that the applications of the network analysis technique are appropriate to many forms of social systems such as organizations, villages, class rooms, entire industries, interorganizational analysis, and others.

Relational Analysis

The basic unit of analysis in network analysis is a relationship between two system elements within the same system. The term relationship deserves some specific attention before presenting further concepts. Generally, in network analysis one is interested in dynamic, functional relationships, i. e., active interaction between the related elements. This kind of relationship, obviously, is of prime importance if one is to construct a network composed of relationships. Conceptually, the existence of a relationship between two elements is constituted by the recognition of some constraint which restricts the behavior, at least minimally, of one or both of the elements. Such a constraint suggests one other characteristic of a relationship, namely that of interdependence between the elements.

Social scientists frequently have urged the need for relational analysis by emphasizing the importance to turn away from monadic and aggregate data (Cf., e. g., *Coleman,* 1972; *Rosenberg,* 1972). The proponents of this approach to view 'reality' argue that the researcher not only manages to arrest data of two elements, A and B, as in the monadic analysis, but that additional information is added to the recognition of constraints or, generally, a relationship between A and B.

Four major properties of relational constraints can be identified: symmetricality, strength, specificity and transitivity. A relationship *r* is said to be *symmetrical* if ArB ("A is related to B") implies BrA. This relationship is asymmetrical if ArB does not imply BrA. Since it is usually assumed that communication is a two-way process, communication would be a symmetrical relationship between two people by definition. An asymmetrical relationship would merely indicate a one-way flow of influence or information.

Strength, as a second property of a relationship, is understood as the extent to which B is influenced by A (or A is influenced by B) in the relationship *r* in ArB. Other conceptualizations for strength can be operationalized as importance, intensity, influence, etc.

The *specificity* of a relationship expresses the extent to which the relationship is not able to be replaced by another relationship that would allow for the occurrence of the same behavior of the relational system as before. In relational expressions, if the *r* in ArB cannot be replaced by some other *r*, e. g., ArC, the original *r* is defined as being specific to A and B. In terms of organizational settings, it is easy to conceive of situations in which there is only one person that has specific information and where this person could not be replaced by another person in order to achieve the same, initially intended goal.

Transitivity, the last property to be presented for the purposes of this paper, of a relationship *r* is then existent when ArB and BrC together imply ArC. Consequently, *r* is said to be intransitive if the first two relationships do not imply the third relationship. In terms of a communication situation, a transitive communication relationship suggests that A influences B and B influences C, and that at least in part the behavior of C is influenced by A via B. Transitivity is one of the key features of most balance-theoretic conceptualizations of social relationships (Cf., *Heider,* 1958; *Newcomb,* 1953; *Bales,* 1950; *Harary, Norman & Cartwright,* 1965).

With regard to network analytic purposes, a system is viewed as a set of elements imbedded in a network of relationships. So far, the units of analysis, i.e., relationships, have been described and specified. Next, a collection of relationships constituting a network as well as the manner in which these relationships can be analyzed and described will be viewed.

Measurement and Data Representation

Network analysis allows the researcher to identify the communication structure of a social system (e.g., company, school, classroom, village, 'invisible colleges'). The analysis is started by building the existing structure with the smallest units of analysis that constitute the input data. The smallest units of analysis are relationships or interactions or links. It is essential that these relationships within a social system are found and recorded. These relationships can take on various forms of interaction such as in face-to-face communication, telephone calls, communication via memoranda, letters, etc. The more interaction exists between two members of a social system, the stronger is their communication link. The overall communication structure of the system is determined by the recognized patterns of these communication links and their relative strengths.

The detected properties of each network give certain insight into the way in which communication flows within a social system. In order to find the communication links from these properties, a network analysis data gathering instrument is administered to all or a representative (Cf., *Coleman,* 1972) set of members of the social system to be analyzed. This instrument is used to determine, among other areas of interest to the researcher, the existence and strength of links (and, consequently, the lack thereof) between members of a social system. Each instrument anticipates minimally five basic requirements:

(1) a definition of the social system,
(2) a definition of the network type to be investigated.
(3) the identification of the respondent,
(4) the identification of the respondent's contact(s) or contactee(s),
(5) determining the strength of the link between the respondent and his or her contact(s).

A sample data gathering instrument is attached in the appendix from which all information can be transferred onto computer cards. Generally, the data are sequenced as follows: respondent identification (ID) number, the ID number of the respondent's first contact, the value for the frequency of that communication link, the value for the communication strength of that link, the ID number of the respondent's second contact, etc. continuing until all of the respondent's contacts have been recorded. Typically, the following format is used:

Columns:

1–2	Project identification code
3–5	Respondent's ID number
6–8	First contact ID number
9	Link value (frequency) for first network
10	Link value (importance) for first network
11	Link value (frequency) for second network (if needed)
12	Link value (importance) for second network (if needed)
n_1–n_3	Second contact ID number
n_4	Link value (frequency) for first network
n_5	Link value (importance) for first network

There are a few considerations that need to be kept in mind when considering data that become input for network analysis. First, it should be noted that a link is not necessarily to be understood like a relationship with all its characteristics. A link is merely an indicator of the existence of a relationship, obtained through the process of measurement. Secondly, the properties of the type of relationship under consideration should be mirrored in the data: the data themselves do not constitute the properties or relationships. Thirdly, the data can only be isomorphic to the real world to the extent to which the measurement process is precise, accurate and representative.

From Relationships to Networks

Although a general description of relationships has been presented, it is useful to view in some detail the historical development of relationships to networks before considering the configuration of a multitude of relationships as networks. Most concepts and methods related to communication networks have been developed by sociometricians as well as social psychologists. The literature dealing with sociometry is rather extensive and becomes quickly evident when familiarizing oneself with the review presented by *Lindzey* and *Berne* (1969). Not too many of these studies deal specifically with communication relationships and communication networks per se. One way of representing a communication network is through the use of a sociogram (*Moreno,* 1934), in some way a form of graph theory (*König,* 1936; *Harary, Norman & Cartwright,* 1965). *Moreno* uses points or nodes that represent members in the network and connecting lines between these points express certain relationships. All nodes and all lines within a sociogram represent the structure of a system in terms of the recognized relationships. There are a number of rather severe limitations to the use of sociograms for a rigorous social scientist (*Wigand,* 1974b):

(1) The data input for sociograms does not allow for a multidimensional representation of the relationships among system members.
(2) The strength of a relationship is difficult to express and as N becomes larger, nearly impossible.
(3) Sociograms may be of some use for the representation of the system that is relatively small. As N becomes 50 or larger, there are severe spatial limitations to represent the system two-dimensionally. Consequently, it becomes increasingly difficult to produce and interpret a large sociogram.
(4) Few criteria, if any, exist that specify the length of a link or relationship, i. e., it is to be decided by the researcher whether the length of a link is to express the amount, frequency, duration of communication or a combination thereof.
(5) It is unclear how the analyst can specify the angles constituted by the incoming and outgoing links at a given focal node.
(6) With the availability of computers, the sociometric representation compares to being tedious, cumbersome and inefficient.

Conjointly with the development of sociometric and graph-theoretic representations of networks, one approach that overcomes in part some of the above mentioned limitations of sociograms is the use of matrix methods. *Katz* (1947), *Festinger* (1949), *Chabot* (1950), *Luce* (1950), *Jacobson and Seashore* (1951), *Weiss and Jacobson* (1955), and *Weiss* (1956) have utilized matrices to represent relationships in networks in which various techniques allow for the detection of groups or cliques as well as certain characteristics thereof. The analysis of networks through matrix methods are of utility as long as N remains small. Even the use of computerized techniques becomes prohibitively expensive when N becomes larger, if not impossible, when N equals, e. g., 100. With a N of 100, each of the 100 could communicate with 99 others. Consequently, 9900 possible connections would exist. If N would be 5 000, nearly 25 000 000 possible links exist.

Another area that has contributed to the development of network analysis is that of small group research typically conducted in laboratory settings. This research is said to have started with *Bavelas* in 1948 and has led to numerous studies. Reviews of these studies and some criticism are presented by *Glanzer and Glaser* (1959, 1961), *Shaw* (1971), and *Collins and Raven* (1969). Some of the key concepts that emerge from small group research deal with task complexity, centralization and decentralization of networks, as well as various communication network configurations (e.g., wheel, circle, all channel, etc.). Some of the main criticism of small group research is that the research is artifically conducted in the laboratory and that the analysis may allow for generalizations within a specific group, but not for generalizations for the higher-level behavior of several groups or an entire social system or organization.

Social networks have been investigated with regard to rumor diffusion, diffusion of innovations, information flow and other communication aspects (Cf., e.g., *Barnes,* 1954, 1969a, 1969b; *Bott,* 1957; *Coleman, Katz & Menzel,* 1957; *Mitchell,* 1969; *Rogers,* 1973). Most of these studies were conducted in urban or national settings as opposed to strictly organizational settings.

An analysis technique of social systems that largely overcomes the above mèntioned shortcomings is network analysis. It is directly complementary to the key notions of systems theory. Network analysis provides a specific method of handling the relationships in large, complex systems. The technique is described in the following section.

Network Analysis: The Technique

The unique characteristic of network analysis is the method by which communication groups are formed. The method considers first the entire pattern of relationships among individuals before a decision is made what constitutes a communication group (or clique or cluster). This implies, if persons in the network leave or if studies of the same network are conducted over several points in time, different communication groups are likely to be detected. The network analysis technique, then, divides the system into parts only after descriptive data are obtained such that this method of analysis can be regarded as reflecting more adequately emergent properties of a system than methods which merely impose a structure before the analysis begins. A priori decisions with regard to the partitioning of a system is inappropriate. It becomes quickly apparent that in the case of communication, all communication relationships in the system to be analyzed must be considered before a division into parts can be taken into account that is appropriate to that system. All individuals that interact in a system must be considered in order to describe – and definitely not to prescribe – the communication structure which is present. The suggested procedure has been translated into the form of a computerized algorithm (*Richards*, 1971) using many concepts drawn from matrix analysis (*Jacobson & Seashore*, 1951; *Weiss*, 1956), graph theory (*Festinger*, 1949; *Flament*, 1963; *Harary, Norman & Cartwright*, 1965) as well as set theory (*Wigand*, 1973). The present program entitled NEGOPY is capable of the efficient analysis of the relationships within systems of up to 4,096 members. NEGOPY has two primary goals: (1) to produce the typological description of the network under investigation (more specifically, a list of the groups within the system and a description of the roles of all the individual members within the system), and (2) to calculate a number of statistics descriptive of several parts of the system at various levels of analysis.

With regard to the desired structural aspects to be detected from the system, the following set of definitions and criteria emerged:

I. *Non-participant nodes* are either not connected to the rest of the network or are only minimally connected. They include:
1. *Isolates Type One* are nodes that have no links and are truly isolated within the network.
2. *Isolates Type Two* are nodes which have merely one link.
3. *Isolated Dyads* are nodes with a single link between themselves.
4. *Treenodes* are nodes that have a single link to a participant and have some number of other isolates attached to themselves.

II. *Participants* are nodes that have two or more links to other participant nodes. Usually, this type of node makes up the majority of network elements and thus allows for the development of communication structure. They include:
1. *Group members* are nodes with more than some percentage of their linkage with other members of the same group. This percentage is hereafter referred to as α-criterion.
2. *Liaison nodes* fail to meet the α-criterion with members of any group within the network and they have the majority of interactions with members of groups, but not with members of any single group.
3. *Type other* are nodes which fail to meet the α-criterion as well as the classification of the liaison and group member role.

III. For the *recognition of a group* the following five criteria must be met:
1. There must be at least three members.
2. Each must meet the α-criterion with the other members of this group.
3. There must be some path lying entirely within the group, from each member to each other member (connectiveness criterion).
4. There mey be no single node (or arbitrarily small set of nodes) which, when removed from the group, causes the rest of the group to fail to meet any of the above criteria (the critical node criterion).
5. There must be no single link (or subset of links) which, if cut, causes the group to fail to meet any of the above criteria (the critical link criterion).

The classification of the members of the system in terms of these specifications is achieved through two major steps. First, an approximate solution is generated through the use of a pattern-recognition algorithm to the results of an iterative operation. This operation treats each link or relationship existing between two nodes similar to a vector. Vectors have two basic attributes: direction and magnitude. The *direction* of each vector is understood as a nominal variable specifying to whom the link goes. The *magnitude*, however, is operationalized as the strength of the relationship, i.e., the extent to which the behavior of the two nodes is influenced due to this relationship. Other measures of *magnitude* can be operationalized as frequency, importance, intensity, etc. Under consideration of these additional characteristics of a relationship or link, a *relationship* is defined as: "the mode or process in which members of a social system are connected or associated interdependently among or between each other; i.e., a partial unification of members which when considered irrespective of such a relation, would be incapable of being conceived together" (*Wigand*, 1974b). The tentative solution that is generated through the above described algorithm is only an approximate description of the system's structure. An exact solution is generated after the above specified criteria are applied to approximate solution. Similar to the process described in the first stage, several heuristic devices are applied such that the efficiency of the algorithm can be maximized.

Once communication networks have been analyzed according to the above described criteria (see fig. 1), it is then possible to represent this network with a focal emphasis on groups (see fig. 2), on liaisons (see fig. 3), and other network roles. In addition, these detected network roles can be utilized in the form of an overlay onto the formally designed, hierarchical structure of a system, e.g., a company (Cf., fig. 1 with fig. 4). This comparison between the actual communication structure and the designed hierarchical structure may then be utilized as a rather powerful and heuristic method in redesigning a social system, in this case, a company (Cf., *Monge & Lindzey*, 1974; also *Wigand*, 1974a; *Farace & Wigand*, 1975; *Wigand*, 1976). This method, generally, relies on more precise data than most other known techniques in the many and highly popular, but frequently dubious forms of organizational development. Many of these popular techniques have not been tested for their effectiveness, there is a lack of longitudinal studies, and some of them take not into account the multidimensionality of social behavior.

In addition to the classification of communication patterns into various network roles, network analysis provides a number of statistics or metrics that provide additional information about the network which is described next.

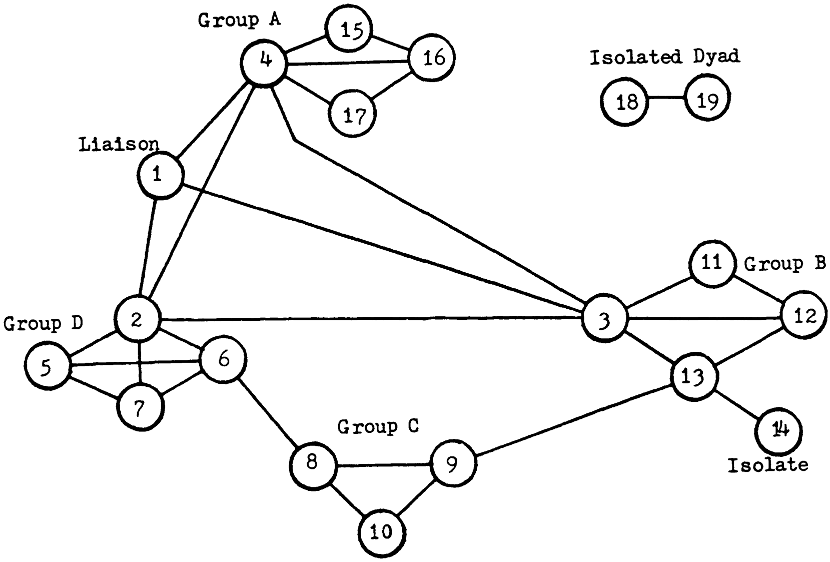


Fig. 1: Communication network among the members of company X

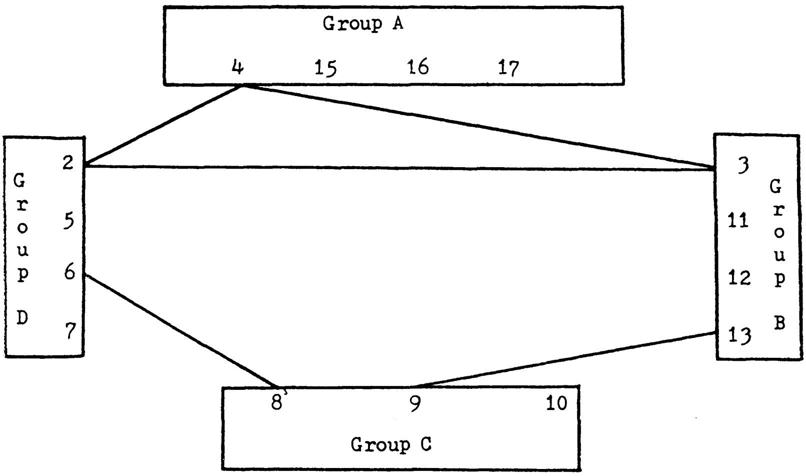


Fig. 2: Communication links between the four communication groups in the network of company X

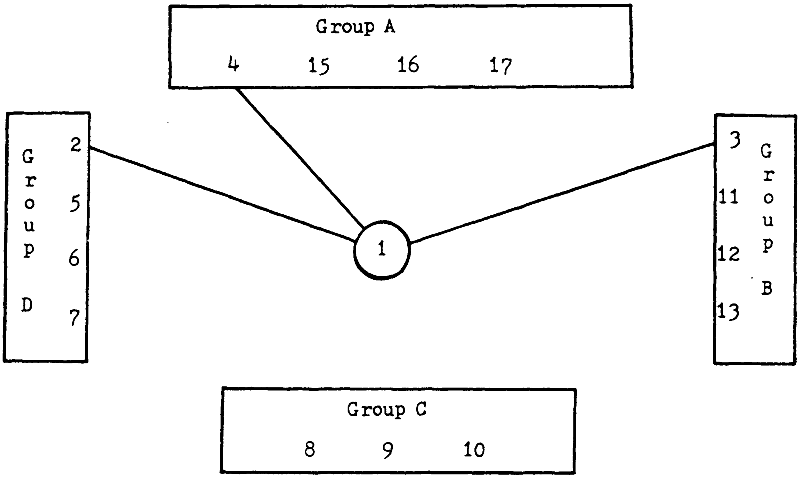


Fig. 3: Liaison linkages between the four communication groups in the network for company X

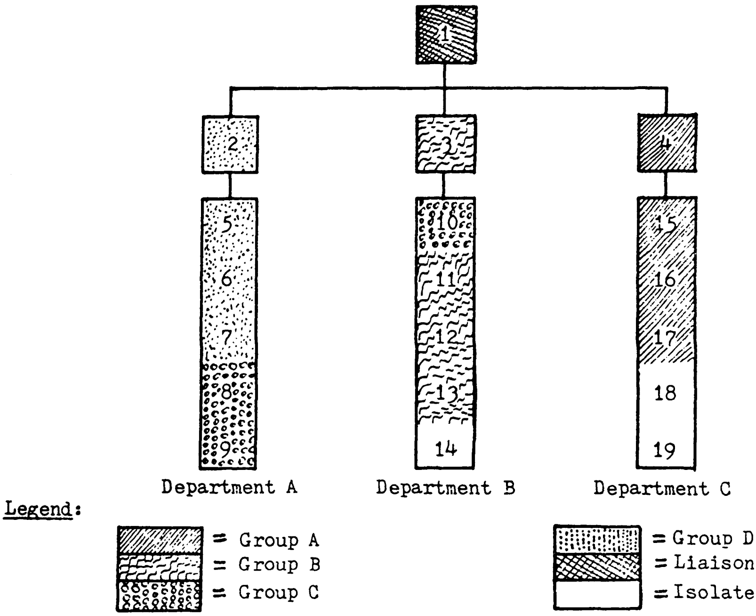


Fig. 4: The four communication groups of the network of company X within its organizational hierarchy

Statistical Analysis of the Network Structure

Various aspects of the detected communication structure and its breakdown into network roles can be analyzed, i.e., quantified as ratios, indices, and percentages that allow for further insight into the network. Furthermore, this quantification of network characteristics allows for greater precision when describing network roles and allows the researcher to study communication networks in relation to numerous other system dimensions (e.g., satisfaction, control, climate). There are two types of statistics or metrics that describe the network structure at two system levels: there are metrics that describe characteristics of *groups* and there are those that describe the characteristics of *individuals.* Below, a few of these are presented:

Group connectedness. A measure that indicates the number of connections or density among the members of a group is labeled *connectedness.* If a group has a large number of within-group links, it is said to be highly connected; if it has only a few within-group links, it is said to be loosely connected. If every node within a group would be connected with each other, then the group connectedness would be 100 percent. Obviously, this measure is dependent on the group size since members of large groups have to communicate an unusually high amount in order to communicate with everyone else. One must, therefore, use this measure with care such that it does not loose its meaningfulness. As already suggested, this measure can be expressed as a percentage; it is also possible to derive a ratio measure through the use of graph-theoretic applications:

$$C_i = \frac{2\,(L)}{Nd\,(Nd - 1)}$$

where, C_i stands for connectedness of group i, L stands for the number of actual within-group links, Nd stands for the number of nodes existent in the network.

The magnitude of C_i may range from 0.0 to 1.0.

Individual integrativeness. This measure is conceptualized as the extent to which a focal node is linked to others; in addition, one must consider the degree to which these other nodes are connected among each other. A particular node's integrativeness is thus determined by examining the links that connect this node to other nodes. Next, one specifies the links that exist among these other nodes. If they are all linked to each other, one may state that the integrativeness of the focal node is maximally high. If they happen to be isolated from each other and their only connection is through this focal node, then, it may be stated that this focal node has a low integrativeness. Derived from graph-theoretic measures, individual integrativeness is expressed in the following formula:

$$I_i = \frac{2(L_o)}{l_i(l_i - 1)}$$

where, I_i stands for the integrativeness of individual i, L_o stands for the number of actual within-group links among those other individuals with which i is connected (excluding i's linkages directly connecting with those other individuals), l_i stands for the number of actual linkages to and from individual i.

Communication flexibility index. In terms of flexibility, one easily will conceive that the most restrictive network structure is the cyclic network. Consequently, it follows that the highly decentralized network is the least restrictive structure with respect to flexibility. These two extremes can then be designated as being either 1-flexible for the decentralized network or 0-flexible for the cyclical network.

A communication network (N) with n nodes (nd_n) is defined as having a minimum of links (L_{min}) when

L_{min} = nd, where nd > 1,

and a maximum of links (L_{max}) when

$$L_{max} = \frac{\sum_{k=1}^{n} nd_i (\sum_{k=1}^{n} nd_i - 1)}{2}, \text{ where nd} > 1.$$

Obviously, by definition access must be provided to each node and each node must be accessable to any other node within the network. The following index has been developed to show the degree of *flexibility* (*f*) of communication networks with n nodes (nd_n) and with n links (L) from nd_i to nd_j

$$\underline{f}\text{-flexibility} = \frac{\sum_{k=1}^{n} L_{ij} - \sum_{k=1}^{n}}{\sum_{k=1}^{n} nd_i \ (\sum_{k=1}^{n} nd_i - 2)},$$

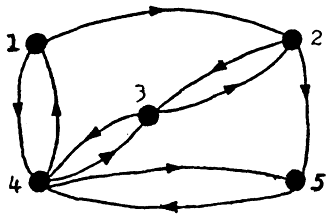
where, $\sum_{k=1}^{n} L_{ij}$ represents the sum of all links*) (bi-directionality counts as two links), and where

$\sum_{k=1}^{n}$ represents the sum of all nodes in the network.

The above formula for flexibility should meet the initial considerations of determining the cyclic network as 0-flexible, and determining the decentralized network as 1-flexible. Two examples presented in fig. 5 shall explicate the above formula for the respective network structures A and B.

*) The term link (L) is defined here as being merely unidirectional, thus only existing in the direction of nd_1 to nd_2 or nd_2 to nd_1, but not both or constituting a reciprocal relationship. If a reciprocal relationship exists between two nodes, the value for L is 2.

Example A:

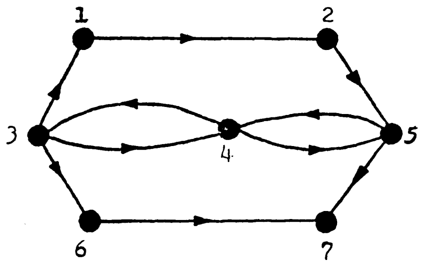


$$\underline{f} = \frac{\sum_{k=1}^{n} L_{ij} - \sum_{k=1}^{n} nd_i}{\sum_{k=1}^{n} nd_i \left(\sum_{k=1}^{n} nd_i - 2\right)}$$

$$= \frac{10 - 5}{5(5-2)} = \frac{5}{15}$$

$=$ .33-flexible with five nodes

Example B:



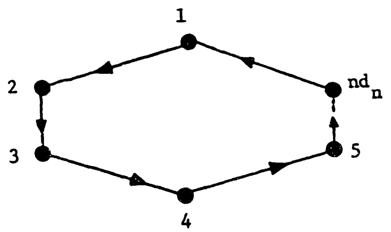
$$\underline{f} = \frac{10 - 7}{7(7-2)}$$

$$= \frac{3}{35}$$

$=$ .086-flexible with seven nodes

Fig. 5: An application of the flexibility index

It is obvious that when calculating the flexibility-index, *f*, the difficulty of computing the value for L by merely examining the network in graph format increases as Σnd becomes large. The value for L, however, can easily be specified by developing the corresponding n $\times$ n adjacency matrix, M_N, for the network (see fig. 6).



Network N

$$M_N = \begin{bmatrix} 0 & 1 & 0 & 0 & \dots & 0 \\ 0 & 0 & 1 & 0 & \dots & 0 \\ 0 & 0 & 0 & 1 & \dots & 0 \\ & & \cdot & & & \\ & & \cdot & & & \\ & & \cdot & & & \\ 1 & 0 & 0 & 0 & \dots & 0 \end{bmatrix}$$

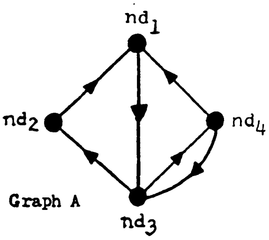
Adjacency matrix M_N of network N

Fig. 6: A network and its adjacency matrix

It should be noted that the adjacency matrix can only then be developed as long as Σnd is reasonably small. If Σnd is not too large, subsets (groups, etc.) of the network can be analyzed for their flexibility. Each entry or value,

$m_{N_{ij}}$, in matrix M_N of fig. 6 is defined as 1 if a unidirectional link is present from nd_i to nd_j, whereas nd_i and nd_j ε N. Particularly with regard to the flexibility index, it should be pointed out that no node is represented in the adjacency matrix that communicates with itself. Therefore, the matrix diagonal consists of zero (0) entries only.

Communication accessibility index. A communication network is defined as being *a*-accessible where *a* indicates the minimum number of referrals necessary to enable complete accessibility, i.e., every node has access to every other node. The index for accessibility is developed from the graph A and the adjacency matrix M_A in figure 7.



$$M_A = \begin{pmatrix} 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 \end{pmatrix}$$

M_A is the adjacency matrix of graph A

Fig. 7: Graph A with its adjacency matrix M_A from which the notion of accessibility is developed

Matrix M_A can then be squared (M_A^2) and cubed (M_A^3):

$$M_A^2 = \begin{pmatrix} 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 2 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 \end{pmatrix}$$

With regard to accessibility, the value $(m_{A31})^2 = 2$ indicates that there are 2 sequences of length 2 in graph A from nd_3 to nd_1, namely, nd_3, nd_2, nd_1, and nd_3, nd_4, nd_1.

$$M_A^3 = \begin{pmatrix} 2 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 1 & 2 & 1 \\ 2 & 1 & 1 & 1 \end{pmatrix}$$

$\vdots$

M_A^n

In the case of the cubed matrix M_A, i.e., M_A^3, the entry $(m_{A13})^3 = 1$ suggests that there is 1 sequence of length 3 in graph A from nd_1 to nd_3, namely nd_1, nd_3, nd_4, nd_3.

Generally, accessibility is, therefore, determined by the entry $(m_{ij})^n$ which gives the number of mutual choices for access involving person nd_i:

$$a\text{-accessible}_{min} = \sum_{j=1}^{n} M_j$$

where, M_j has elements $(m_{ij})^n$ from the adjacency matrix M and $(m_{ij})^n$ specifies the number of cycles or referrals in M from nd_i to nd_j.

Other measures. Various other measures with regard to distance, dominance, centrality, etc. are available, but are not presented here due to space limitations.

A set of dispersion metrics has been developed that demonstrates the extent to which units vary in the degree to which they show some property: the variance in the number of links each node has, the variance in the entries of a given row or column of a distance matrix for a subset of the network, etc. Among the dispersion metrics also included are information-theoretic measures since they refer to the extent to which relative frequencies of occurrence vary from event to event within the set of all possible events (e.g., uncertainty measures, etc.).

Much of the above discussed measures can be readily represented by the analyst in 'communicator's profiles' for each individual network member. Typically, such a 'communicator's profile' gives information about the individual's network type, his network role, membership in a specific group, information about his links (e.g., total number, within-group, to or from group bridges and liaisons, reciprocated and unreciprocated), the percentage of individual connectedness, his percentage contribution to group liaison linkage, as well as his percentage contribution to between-group linkage, and others.

Conclusion

This paper has described a way in which the communication behavior of social systems can be represented through the use of the network analysis technique. Communication networks are generated by the analysis and subsequent representation of detected patterns of communication contacts among individuals within a social system. Several network roles (group member, liaison, isolate, and others) have been identified which can be further described through various statistical measures. It was pointed out that systems analysts typically encounter difficulties in assessing system

Appendix

Network Analysis Sample Data Gathering Instrument

Your ID Number

Below are the names of persons in this organization. First, please circle your *own* name and then record the number next to your name in the blank space provided for *'Your ID Number'* at the top of this page. Using the Communication Frequency Scale below, indicate how often you communicate with each person about *Production* issues. Then, evaluate this communication with regard to the importance of that communication frequency by using the Communication Importance Scale below. Lastly, repeat this procedure for *Maintenance* and *Innovation* related communication. Then continue with the next person, etc.

Communication Frequency Scale:

6 – Several times a day or more
5 – Once or twice a day
4 – Several times a week
3 – Once a week
2 – Several times a month
1 – Once a month

Communication Importance Scale:

0 5 10

low IMPORTANCE high

How often do you communicate with these persons?
How important do you judge this communication?

	Production Issues		*Maintenance Issues*		*Innovation Issues*	
	Fre-quency	Im-portance	Fre-quency	Im-portance	Fre-quency	Im-portance
001 Don Adams						
002 Jackie Black						
003 Bob Calder						
004 Fred Dawsey						
005 Phil Erickson						
006 Sid Fulton						
. . . . etc. etc. etc.						

parts such that this assessment is relevant to the overall, integrated system. Network analysis was designed to overcome in part some of these inadequacies. In addition, this technique emphasizes a systemic, specific and precise set of criteria that are applicable to all types of social systems.

Collins and Raven (1969) point out that an unfortunate state of affairs is prevalent throughout the entire network literature, "It is almost impossible to make a simple generalization about any variable without finding at least one study to contradict the generalization (p. 147)." It is the contention of this author as well as the group of individuals engaged in the development of the network analysis technique that the methods described in this paper may considerably improve ways for the description and analysis of as well as eventually lead toward the explanation and prediction of the communication behavior existent in social systems.

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Zusammenfassung – Summary – Résumé

Kommunikationsnetze bestehen aus regelmäßigen Mustern von Kontakten zwischen den Mitgliedern eines sozialen Systems. Kommunikationskontakte entstehen, wenn diese Systemmitglieder diverse Kommunikationsformen (Unterhaltungen, Aktennotizen, Telefongespräche usw.) benutzen, um gewisse Aufgaben und Tätigkeiten auszuführen. Das Wissen über das Funktionieren der verschiedenen Typen menschlicher Kommunikationsnetze ist wichtig und kann auch dazu dienen, den Informationsfluß innerhalb des Systems sowie seine Effektivität und Leistungsfähigkeit zu erkennen. Ein formaler Algorhythmus für die Analyse von Kommunikationsnetzwerken ist in der Form eines erweiterten FORTRAN-Programms für den CDC 6500 Computer entwickelt worden. Dieser Algorhythmus kann auf jedem größeren gebräuchlichen Computer verwendet werden und übertrifft jede andere, dem Verfasser bekannte analytische Technik in bezug auf Nutzbarkeit, Kapazität und Leistungsfähigkeit. Ziel der Netzanalyse ist es, jede Struktur auf der Dyaden-, Gruppen- oder Systemebene des Netzes (1) zu erkennen und (2) zu beschreiben. Das FORTRAN-Programm bietet auch zusätzliche Informationen über solche Indizes wie den Grad der Konnexion, der Integriertheit usw. von individuellen Knotenpunkten sowie auch von gesamten Gruppen für Netzwerke von fast 5000 Personen. Der Artikel beschreibt eine Reihe von Verfahren zur Analyse solcher Kommunikationsnetze in großen sozialen Systemen.

Communication networks consist of the regular pattern of communication contacts which develop among people within a social system as they use various forms of communication (face-to-face conversations, memoranda, telephone calls, etc.) to accomplish certain tasks and activities. Information regarding the functioning of the various types of human communication networks is important and can be used to understand the system's process flow of information and to assess its effectiveness and efficiency. A formal algorithm for analyzing communication networks has been implemented in an extended FORTRAN program for the CDC 6500 computer. This algorithm can be realized on any large, general purpose machine, and it far surpasses any other similar analytic technique, that the author is aware of, in terms of utility, capacity, and efficiency. The goals of network analysis are, (1) to detect and (2) to describe any structure at the dyadic, group or systems level of the network. The FORTRAN program provides additional information with regard to indices such as connectedness, integrativeness, etc. of individual nodes as well as entire groups for networks of up to nearly 5 000 people. The paper describes a set of procedures for analyzing such communication networks in large systems.

Des réseaux de communication se composent des modèles réguliers des contacts communicatifs qui se développent entre les membres d'un système social en utilisant diverses formes communicatives (conversations face à face, mémoranda etc.) pour réaliser certaines tâches et activités. L'information concernant le fonctionnement des divers types de réseaux de communication humains est importante et peut servir à comprendre le flux d'information à l'intérieur du système et pour en évaluer l'efficacité et l'efficience. Un algorythme formal pour l'analyse des réseaux communicatifs a été développé sous forme d'un programme élargi (FORTRAN) pour l'ordinateur CDC 6500. On peut réaliser cet algorythme avec chaque grand ordinateur usuel. Il surpasse autres techniques analytiques semblables – selon la connaissance de l'auteur – en ce qui concerne l'utilité, la capacité et l'efficacité. Les objectifs de l'analyse des réseaux sont (1) la découverte et (2) la description des structures au niveau des dyades, des groupes ou des systèmes du réseaux. Le programme FORTRAN offre de l'information additionnelle sur des indices tels que le degré de connexion, d'intégration etc. des réseaux individuels et des groupes entiers pour des réseaux d'une capacité de presque 5000 personnes. L'article décrit une série de procédés pour l'analyse de tels réseaux communicatifs en grands systèmes.