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6

Social Networks and Health Care Information Systems

A Structural Approach to Evaluation

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Introduction

Users' attitudes toward information systems have considerable influence on the diffusion and success of such systems (Lucas, 1981). Early expectations may not be met and use of the system may decline over time. Adoption may be uneven across departments and occupations. Physicians and nurses may resist the implementation of a new computer system if it negatively affects their status, autonomy, or traditional staff relations (Anderson, Jay, Schweer, & Anderson, 1986; Brenner & Logan, 1980; Counte, Kjerulff, Salloway, & Campbell, 1987).

Although some changes brought about by the implementation of a new medical information system may be negative, others may be positive. For example, the use of remote terminals may decrease face-to-face communication among users and require new types and distributions of cognitive and technical skills among employees. At the same time, such systems may also allow integration of activities and knowledge across databases, departments, and temporal boundaries. They may

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also provide opportunities for development of new skills and upward job mobility (Hirschheim, 1985; Johnson & Rice, 1987; Markus, 1984; Olson & Lucas, 1982).

Three Structural Aspects of Health Care Organizations

Adoption and utilization of computer-based information systems and attitudes toward them and their effectiveness all involve three underlying structural aspects of organizations: interdependency, interaction, and integration. These organizational characteristics become particularly salient in health care organizations and will be discussed below.

Interdependency

Fundamental tensions exist in health care settings because of differentiation and interdependency. Health care employees belong to different social worlds (medical and nonmedical), occupations (nurses, physicians, administrators, clerical workers, medical technicians), and departments (medical records, women's health), yet their work requires considerable interdependence across these boundaries. Few medical care tasks can be performed without the cooperation of one or more departments (Aydin & Rice, 1992).

At the same time, such boundaries may result in different understandings of overall systems and organizational processes. For example, although physicians in different departments in the same hospital are all likely to be concerned with treating patients, physicians and nurses working in the same department will share common concerns related to the specific tasks, norms, values, and language of that department (Tushman & Scanlan, 1981). Thus, exchange of information and understanding of roles may be asymmetric and insufficient across some departmental boundaries, creating conflict and struggles for power and access to resources (Olson & Lucas, 1982, p. 845).

Interaction

However, interaction within and across boundaries represents opportunities for gaining greater understanding of specialized but interdependent information and sharing of resources, leading to cooperation and coordination (Aydin, 1989; Donnellon, Gray, & Bougon, 1986; Hackman, 1983, p. 1457; Kimberly & Evanisko, 1981; McCann & Galbraith, 1981; Van de Ven, 1986; Van Maanen & Barley, 1985). Further, interpersonal

interaction with patients and other health care workers is often a primary professional motivation for workers in health settings (Mauksch, 1972). Moreover, communications among medical practitioners affect the rate of adoption and diffusion of medical technology. Research has demonstrated that the structure of these communication networks determines which physicians are likely to be early or late adopters of new drugs (Coleman, Katz, & Menzel, 1966; Stross & Harlan, 1979) and a hospital information system (Anderson & Jay, 1985a, 1985b; Anderson, Jay, Schweer, & Anderson, 1987; Anderson, Jay, Schweer, Anderson, & Kassing, 1987).

Integration

By providing geographically dispersed access to common and interrelated medical information, medical information systems can help to create a "virtual office" (Giuliano, 1982), with boundaries related to task and information flow rather than to traditional functional departments, occupations, and spatial proximity (Rice, 1987). Integrated medical information systems that create common databases thus require health care departments to cooperate, altering interdependencies and interactions across departmental and occupational boundaries. For example, how nurses enter drug information into a system will affect how the pharmacy department provides services and manages its billing (Aydin, 1989). These interdependencies necessitate standardized forms, terminology, and policies and procedures, possibly requiring considerable interdepartmental coordination, negotiations, and conflict (Cook, 1985). This integration may reduce dependence on other departments for access to information, possibly reducing conflict (Hage, Aiken, & Marrett, 1971; Olson & Lucas, 1982). Such technological requirements and mediation of interaction can also reinforce these boundaries by isolating workers from interpersonal interactions, by routinizing tasks, and by requiring the development of specialized skills and norms.

Thus there is a complex and subtle interplay of structural differences involving interdependencies and interaction that are affected by the introduction of medical information technology. Kaplan (1986, 1989), for example, noted differences in definitions of the technologists' role in different clinical laboratories in the same medical center. Barley (1986) reported that the first use of body scanners in the radiology departments of two hospitals resulted in new boundaries between the various technological subunits but with different patterns of change in each hospital. Lundsgaarde, Fischer, and Steele (1981) evaluated user acceptance of a computerized problem-oriented medical record system designed to enhance communication among health care professionals on a general medical ward. Nurses and ancillary personnel readily accepted and used the system because it led to an expansion of their professional roles, whereas physicians refused to cooperate in using the system because it was more time-consuming than the manual system and they feared that it would disrupt traditional staff relations.

Basics of Social Network Analysis

Fundamental Concepts

Typically, studies of the implementation of computer-based information systems have focused on their impact on individual's attitudes, work roles, and levels of utilization. However, understanding the effects of introducing a new medical information system into an organization requires an approach that also considers patterns of social relations—such as interaction, interdependence, and integration—rather than focusing solely on individuals. Social network analysis provides both conceptual and analytical tools that can be used in evaluating these other impacts of information systems.

Social network analysis is the study of patterns of relations among a set of people, departments, organizations, and so on. For example, physicians form networks of other physicians with whom they consult in providing patient care. Within these networks some physicians, departments, and such are more extensively connected to other individuals or units than are others. The purpose of social network analysis is to detect the presence of structure or patterns of relations using empirical data; to explain the occurrence of different structures in different types of organizations, settings, or organizational units; and to analyze the effects that network structure or location in the network have on individual members' attitudes, behavior, and performance (Knoke & Kuklinski, 1982).

This methodological approach presumes that individuals are embedded in social networks and structures and thus that their attitudes, norms, and behaviors are influenced through (1) direct and indirect exposure to other network members' behavior, attitudes, and influences; (2) access to resources in those networks; and (3) their position in the network structure (Burt, 1980; Davis, 1966; Hackman, 1983, p. 1455; Laumann & Marsden, 1979; Riley & Riley, 1972; Rogers & Kincaid, 1981; Salancik & Pfeffer, 1978; Wellman, 1983). In general, it is hypothesized that the structure of relations among individuals or units

and their location in the network have important behavioral, perceptual, and attitudinal consequences both for individual members and for the system as a whole (see also Rice, Grant, Schmitz, & Torobin, 1990; Williams, Rice, & Rogers, 1988; and Chapter 11). Such influence may take many forms. For example, innovation diffusion studies have found that individuals who are prominent in these networks are more likely to adopt the innovations sooner and to influence others; whereas those on the periphery are likely to be influenced later in the diffusion process or not at all. Prominent members are those who are extensively involved in the network, thus giving them greater access to the flow of information (Knoke & Burt, 1983).

Relationships

Social network analysis is performed on relational, positional, or spatial data that provide information about the existence or strength of relationships among members of the network (Davis, 1984; Dow, 1988; Erickson, 1988; Johnson, 1988; Rice, 1992). Relational data indicate the extent to which network members interact directly and indirectly with one another (Rogers & Kincaid, 1981). An example is one in which a physician consults another physician about a patient or a new drug or procedure.

Individuals are *positionally* proximate to the extent that they occupy the same roles in a group or organization and thus share the same sets of obligations, status, and expectations. There are various forms of positional proximity. Adherents of the *structural equivalence* form argue that two individuals may have similar attitudes because they have *similar* relationships with the *same* other individuals. These individuals not only share common patterns of interactions with others in the organization but also share common attributes, attitudes, and socialization experiences (Burt, 1980, 1987). For example, two primary care physicians may consult with the same group of specialists but not with one another. *Organizational position* can be conceptualized as similar patterns of information and control relations among horizontally and vertically differentiated jobs (Dow, 1988).

Individuals may be *spatially* proximate, without necessarily being relationally or positionally proximate. Such proximity may occur when individuals with similar tasks are placed together or have common problems or client flow. This spatial proximity in turn produces similar exposure/inaccessibility to others, events, resources, and other aspects of the workplace (Hackman, 1983). For example, a study discussed later in this chapter measured the walking distance between each pair of employees of a student health service. Finally, any or all of the three types of network data may describe relationships among *individuals* or *groups*.

Data Collection

Network analysis depends on the availability of relational, positional, or spatial data—that indicate relations or similarities among members. Once collected, these data are typically organized in a matrix in which rows and columns represent individuals, departments, or organizations that have relations with one another. The simple binary presence or absence of relationships, or scalar measures of the frequency, strength, or value of relationships, are represented by numbers in the appropriate cells of the matrix. This square matrix is generally termed an *adjacency matrix*. Relationships may be symmetric (such as when two physicians report that they each communicate with the other "several times a day") or asymmetric (such as when a generalist physician refers patients to a specialist physician, but not vice versa).

An example of relational data is shown in Figure 6.1. Referrals of patients among 24 physicians who comprise a private group practice are shown. A number in a cell of the matrix indicates the number of different types of professional relations between the two physicians.

Other forms of relational data that are not square matrices can be converted into such matrices and analyzed using social network techniques. For example, a typical table in a report might indicate the number of different modules of a medical information system used by physicians on the medical staff (see Table 6.1a). In this case, the rows represent physicians and the columns represent the modules. This matrix is commonly called an *incidence* or *event matrix*. We can derive two square adjacency matrices from this original table or incidence matrix. In one resulting matrix, the rows and columns represent physicians, and the cell values indicate the number of modules of the medical information system used in common by each pair of physicians (see Table 6.1b), which is one indicator of how similar the physicians are. In the second resulting matrix (see Table 6.1c), the rows and columns represent the modules, and the cell values indicate how many physicians use various combinations of the information system modules. Most techniques used to analyze network data involve the direct manipulation of the square adjacency matrices, although the incidence matrices may also be directly analyzed.

Network data may be collected through various methods, such as by providing respondents with a complete roster of all other members in

Initiating Physician[a]	Responding Physician[b]																						
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
A	–	0	0	1	3	1	3	1	3	1	2	1	0	1	2	0	3	1	0	0	1	1	3	2
B	1	–	0	0	0	1	1	0	2	1	0	1	2	0	0	1	1	0	1	0	0	0	0	1
C	3	0	–	1	0	3	0	3	3	2	0	2	2	1	0	2	1	4	1	1	2	1	0	2
D	3	3	0	–	0	2	0	0	3	2	0	3	3	0	0	0	0	3	1	3	3	2	0	0
E	4	3	1	1	–	3	1	3	3	1	3	1	3	1	1	3	2	1	3	1	1	1	2	1
F	0	0	2	1	1	–	0	0	1	1	1	1	1	1	0	0	1	2	1	2	2	0	0	2
G	2	3	0	0	0	2	–	0	3	0	1	0	1	0	0	1	0	1	1	0	1	0	1	3
H	0	1	1	2	0	0	0	–	2	2	2	1	1	3	0	1	0	0	0	0	1	0	0	0
I	2	0	2	0	0	3	0	1	–	2	2	1	1	1	0	0	2	1	1	2	0	0	1	2
J	3	3	3	1	1	2	1	3	4	–	4	3	3	1	1	3	2	1	3	1	2	1	2	2
K	1	0	0	0	1	1	0	1	2	1	–	1	0	1	0	0	2	2	0	0	0	0	2	0
L	2	3	3	2	2	3	1	3	3	2	1	–	3	3	0	2	2	2	3	3	3	4	0	2
M	1	2	1	1	1	1	2	2	2	2	0	2	–	2	1	2	2	1	2	2	0	3	2	2
N	3	1	3	1	3	3	2	4	4	3	4	3	3	–	0	3	3	1	2	3	3	3	3	2
O	1	0	0	0	1	0	0	0	1	0	0	0	0	0	–	0	1	0	1	1	0	0	1	1
P	0	3	0	0	0	1	2	0	1	1	1	0	1	1	0	–	1	1	1	1	2	1	1	0
Q	3	1	1	1	3	1	1	1	2	1	2	1	1	1	2	2	–	1	2	1	1	1	3	1
R	0	1	2	0	2	3	1	3	3	0	3	1	2	0	0	2	1	–	0	1	2	1	0	2
S	1	2	1	1	1	2	2	1	2	2	2	2	2	2	1	3	2	2	–	1	2	2	2	3
T	0	0	1	1	0	2	1	0	2	0	2	0	2	0	0	2	0	0	0	–	0	0	0	4
U	3	1	2	2	2	3	1	3	3	2	3	4	2	1	1	3	2	2	3	3	–	2	3	3
V	1	1	0	2	0	2	0	0	1	0	1	2	1	0	0	0	1	1	0	0	2	–	1	0
W	2	1	1	0	1	2	0	0	2	0	2	0	2	0	0	2	1	0	2	0	0	0	–	2
X	1	3	1	0	0	2	2	0	1	1	1	1	2	0	1	1	1	1	0	3	1	1	0	–

Figure 6.1. Physician Network—Number of Different Types of Professional Relations Among 24 Physicians Who Are Members of the Group Practice

[a]Initiating Physician: Physician who refers patient or consults with colleagues.
[b]Responding Physician: Physician to whom patient is referred.

the system and asking them to check off the frequency, strength, importance, or ranking of each other member, possibly on several types of

TABLE 6.1 Incidence Matrix and the Two Adjacency Matrices Derived From It

a. Incidence Matrix Indicating Which Medical Information System Modules Are Used by Each Physician

Physician	*Admission Discharge Transfer*	*Order Entry Results Reporting*
A	1	1
B	1	1
C	1	0

b. Adjacency Matrix: The Number of System Modules Used in Common by Each Pair of Physicians

2 = Physician	*A*	*B*	*C*
A	2	2	1
B	2	2	1
C	1	1	1

c. Adjacency Matrix: The Number of Physicians Using Each Combination of System Modules

System Modules	*Admission Discharge Transfer*	*Order Entry Results Reporting*
Admission Discharge Transfer	3	2
Order Entry Results Reporting	2	2

relations, or by asking respondents to list those with whom they interact. Other forms of network data exist, such as snowball samples, nominations, observations, and reports by respondents of perceived relationships among others. An example of snowball sampling is provided in Chapter 9 of this book, in which users of a computerized decision support system were asked to identify other users.

Different forms of network data may also be collected by a system's computer itself, such as the number, length, content, and timing of messages sent among a set of system users (Rice, 1990). System data have been used in studies of medical information systems to identify the attending and consulting physicians for each patient, time elapsed between system implementation and a physician's first use, and varieties of usage, such as obtaining patient lists or laboratory results or entering and retrieving medical orders (regardless of whether entered directly by the physician or indirectly for the physician by other hospital personnel) (Anderson, Jay, Schweer, Anderson, & Kassing, 1987).

Finally, any form of network data can be analyzed with respect to a wide variety of network characteristics, as described next.

Analytic Techniques and Measures

Network analysis can provide descriptive and inferential insights into a wide variety of topics: (1) individual *roles* such as isolates, members of groups such as cliques; (2) the existence and relative positions of those *groupings* in the overall network; (3) *relationships* such as strength, direction, reciprocation, and stability of interactions such as patient referrals; and (4) the overall *structure* of the network such as hierarchies and status rankings. Network indices may be *measured* at the individual or group level and subsequently *analyzed* at the individual or group level. In the "Applications" section below, a number of social network measures and analytical techniques will be illustrated.

Applications

The following sections provide two summary examples of how network approaches have been used to study issues of adoption and use, attitudes, and interdepartmental communication. The first study explored how physicians' positions in the referral and consultation network predicted their adoption and utilization of a medical information system (see Anderson & Jay, 1985a, 1985b; Anderson, Jay, Schweer, & Anderson, 1987; and Anderson, Jay, Schweer, Anderson, & Kassing, 1987, for details). This study also evaluated an experimental program that identified and used physicians who were influential in the referral and consultation networks to increase physicians' use of the medical information system (Anderson, Jay, Perry, & Anderson, 1990). The second study examined the influence of network and occupational groupings on the use of and attitudes toward an integrated medical records system at a student health service and subsequent changes in cross-departmental information exchange (see Aydin & Rice, 1991, 1992, and Rice & Aydin, 1991, for details).

Influence of Physician Networks on System Adoption and Utilization

Study Site and Data

Setting. This study was conducted at Methodist Hospital of Indiana, a private teaching hospital. The hospital had installed the Technicon medical information system that had been upgraded to the TDS HC4000 system, accessible by remote terminals throughout the hospital. At the time that the study was undertaken, the information system supported the following applications: patient registration, admission/discharge/transfer, laboratory, pharmacy, radiology, nursing services, order entry, and results reporting. The system provides communication between hospital services, physicians, and nursing services. During the patient's hospitalization, it serves as a computerized medical record. It collects, organizes, and presents clinical data in order to improve the management of patient care. Physicians with computer codes can retrieve patient information and enter medical orders directly into the system (Anderson, 1992a, 1992b).

In a preliminary study, a questionnaire was used to collect relational data from 24 physicians in a group practice. Physicians were asked to indicate which physicians they referred patients to, consulted with, discussed professional matters with, and took calls for. Self-reported measures of system use were also obtained (see Anderson & Jay, 1985a). In the second phase of the study a questionnaire was used to collect information on physician attitudes toward medical computer applications from 644 physicians on the hospital's medical staff (77% completed the instrument—see Anderson et al., 1986). At three points in time over a 1-year period, the medical information system tapes were accessed to obtain data on physicians' use of the system and relational data indicating the attending and all consulting physicians for each patient (Anderson, Jay, Schweer, Anderson, & Kassing, 1987).

Measures. (a) *Individual attributes.* Individual attributes measured included physician's age, specialty, board certification, number of hospital admissions during the last 6 months, professional activities (0 = no professional or administrative activities, 1 = routine participation on hospital committees, 2 = major activities such as chairman of a hospital committee or officer of a medical society), and medical education (whether or not a physician was involved in training house staff). (b) *Attitudes toward medical computer systems.* This was measured as the degree to which the physician was concerned that computers are likely to reduce professional autonomy (from 1 = little or no concern to 5 = a great deal of concern). (c) *Adoption and use of the system.* Time to adoption was measured as the time that elapsed between the date the hospital information system was implemented and the date the physician voluntarily underwent training to use the system. Two measures of utilization were the proportion of each physician's medical orders that were entered directly by a physician using a terminal over a period of 6 days, and the sum of the frequency of physician use of the system to obtain

patient lists, retrieve and print laboratory results, and enter and retrieve medical orders.

(d) *Network measures.* First, densities were computed to describe relations among subgroups of physicians. *Density* is the number of relations or ties between pairs of network members (e.g., physicians) divided by the total number of possible ties. Values range from 0 to 1.0 if each member (e.g., physician) is directly connected to all other network members. Second, centrality scores (ranging from 0 to 1) were calculated to describe the degree to which information and resources are dispersed throughout the group or centered around a few individuals. In more centralized networks, a few individuals will have high scores while the majority will have low scores. Third, a measure of the physician's predominant role in the network of sending, relaying, or receiving patients and information was computed as the ratio of the number of interactions the physician initiated to those that were initiated by colleagues. Fourth, multiplexity was measured as the proportion of group members with whom a physician had more than one type of relationship. Finally, a measure of prestige was calculated, ranging from 0 (no one consulted the physician) to 1 (all other physicians on the service consulted the physician).

Influence of Physician Network Position

A blockmodel analysis and multidimensional scaling of the relational data among the set of 24 physicians were used to analyze how the physician's position in the referral and consultation network influenced adoption and use of the system (see Anderson & Jay, 1985a). The blockmodel analysis identified groups of physicians who had similar patterns of referrals, consultations, discussions, and on-call coverage with the other physicians in the group practice. Next, relations among these groups of physicians were analyzed. Finally, multidimensional sealing was used to represent the relations among the physicians graphically (Scott, 1991).

CONCOR, a network program that iteratively correlates the rows (and or columns) of an adjacency matrix to identify structurally equivalent positions and hierarchically clusters (Johnson, 1967) the final correlation matrix, was applied to the rows of the four matrices that indicated the professional relations among the physicians. Physicians were considered structurally equivalent, or members of a group, if their pattern of relations with other physicians was similar, as portrayed in Figure 6.2. Figure 6.3 represents the densities of professional relations among the groups. A circle or a line linking two groups indicates that the density of relations among physicians in a group or between two groups of physicians is greater than the density of the total network.

The results suggest a refinement of the center-periphery pattern of relations observed among other groups of professionals. These studies found that professionals are generally informally organized around a central group of influentials who direct and control the flow of information and resources to colleagues (Cole & Cole, 1973; Crane, 1972). Figure 6.3 suggests that two central cohesive groups are linked to the other groups of physicians. The physicians in Group 1 act as gatekeepers in referring patients and consulting with physicians in the other three groups. Physicians in Group 2 appear to initiate discussions on professional matters with all of the other groups.

An examination of the shared attributes and network characteristics of physicians who make up the groups supports this relational structure (see Figure 6.4). Physicians in Group 1 are older and more active in professional activities. They are centrally involved in the professional networks as evidenced by their scores on the indices of centrality, multiplexity, and network role. They initiate almost 1.5 times as many referrals, consultations, and discussions with other physicians as they receive. This may account for their lower number of hospital admissions. Most of the physicians in this group obtained their computer codes and underwent training to use the system at about the same time. They are also the heaviest users of the medical information system: during the 6-day period studied, they directly entered 45% of their own medical orders into the system.

The second group consists of younger physicians with large private practices. They admitted the most patients to the hospital. They too adopted the medical information system into their clinical practice soon after its implementation and used it to enter about 25% of their medical orders during the study period. Physicians in Groups 3 and 4 on the periphery of the network were slow to adopt the system and two physicians never applied for a computer code. These physicians infrequently used the system for order entry.

The network with its groups of structurally equivalent physicians can also be represented spatially through multidimensional scaling, as shown in Figure 6.5. The multidimensional scaling spatially represents the relations among network members in three dimensions. The four major groups that were identified by the CONCOR clustering program emerge as well-determined clusters. The general location of Group 2 between Groups 1 and 3 is consistent with the intermediary role that this group of physicians plays in clinical consultations and discussions.

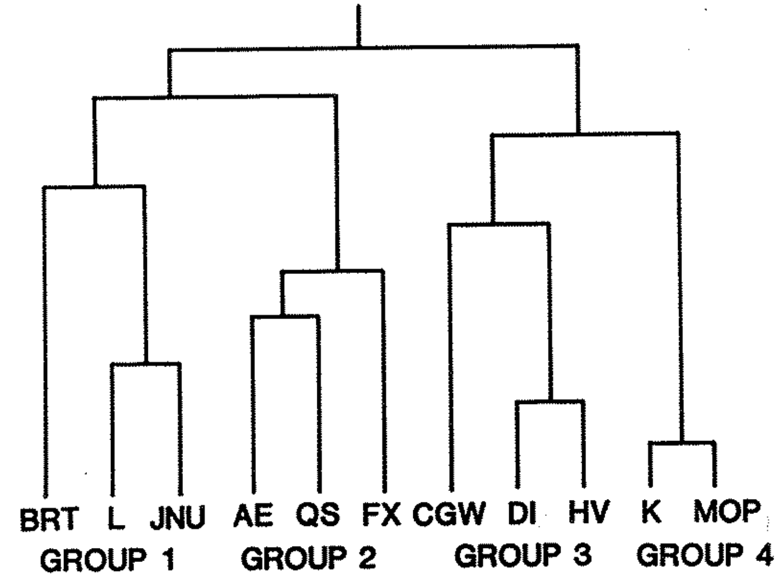

Figure 6.2. Hierarchical Clustering of 24 Physicians Into Four Structurally Equivalent Groups. Physicians in each group have similar patterns of relations with all other physicians in the network. (See Note 1.)

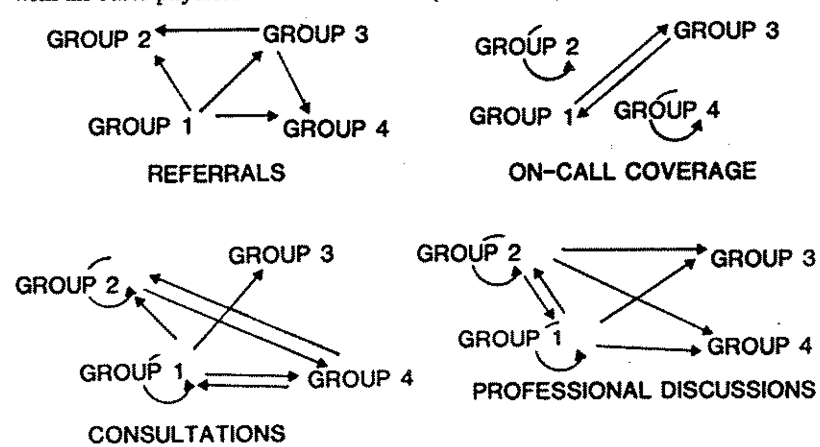

Figure 6.3. Relations Among the Four Structurally Equivalent Groups of Physicians. A circle or a line linking two groups indicates that the density of relations among physicians in a group or between two groups of physicians is greater than the density of the total network. (See Note 1.)

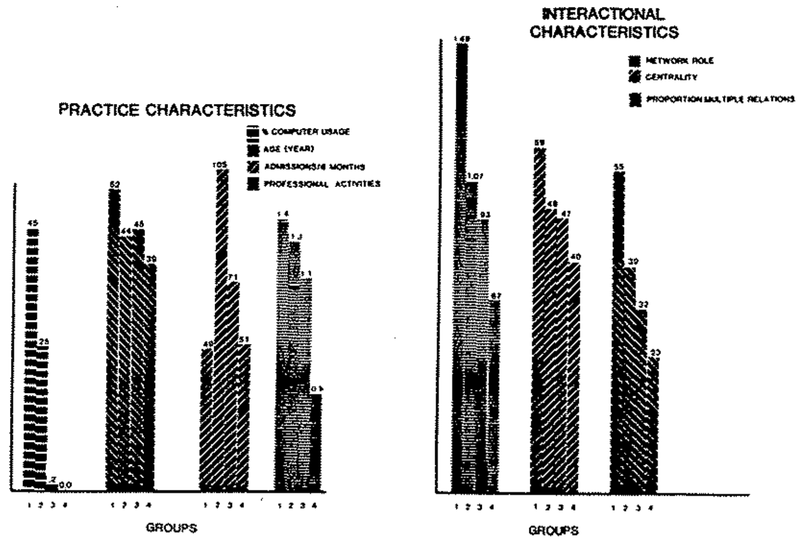

Figure 6.4. Attributes and Network Characteristics of Physicians in the Four Groups (See Note 1.)

Also, the relative position of individual physicians in the three-dimensional space helps to illuminate the role that they play in the network. For example, physician N is located at the center of Group 1. Analysis of his attributes indicates that he plays a central role in referrals and consultations among physicians in the network.

In the second phase of the study, physicians on each hospital service with similar consultation patterns were identified. Figure 6.6 portrays one network that indicates the relationships among groups of the 51 physicians on general surgery. Five of the six groups of physicians are cliques. They frequently consult other group members in providing patient care. The groups also form a hierarchy. Physicians in Group 3 are consulted by members of all other groups. In turn, physicians in Groups 1 and 2 are consulted by those in Groups 4, 5, and 6. Physicians in Group 6 are not consulted at all by their colleagues.

Table 6.2 contains information about attributes, adoption, and utilization of the medical information system by each group of physicians. Physicians in Groups 1, 2, and 3, who are consulted most often, are the youngest and the most involved in the graduate medical education program. Practice patterns also differ significantly among the groups. Physicians in Group 3, who are at the center of the consultation network, admit the most patients to the hospital, were among the earliest to begin

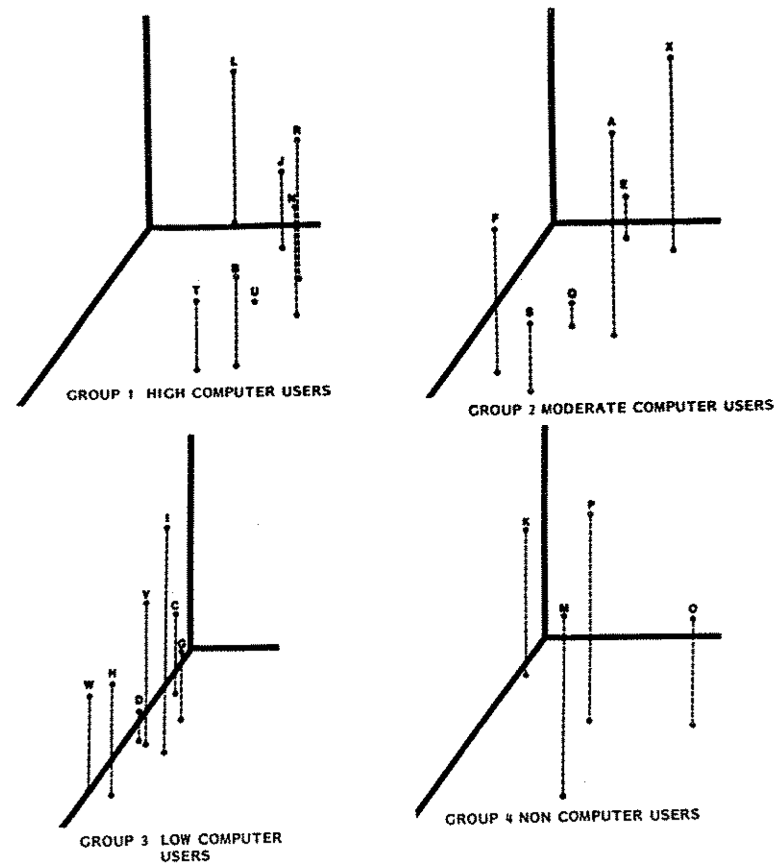

Figure 6.5. Three-Dimensional Representation of the Physician Network Resulting From the KYST Multidimensional Scaling Program. The four groups of physicians identified by the CONCOR clustering program are represented separately in order to illustrate their relative location in three-dimensional space. (See Note 1.)

using the medical information system, and use it most frequently in their clinical practice. They also express the least concern about the potential effect of computer systems on their professional autonomy. In contrast, physicians in Groups 5 and 6 who are more peripherally located in the network admit fewer patients, were the slowest to adopt the medical information system, use it less frequently in their clinical practice, and fear a loss of autonomy as a result of the introduction of computers into medicine.

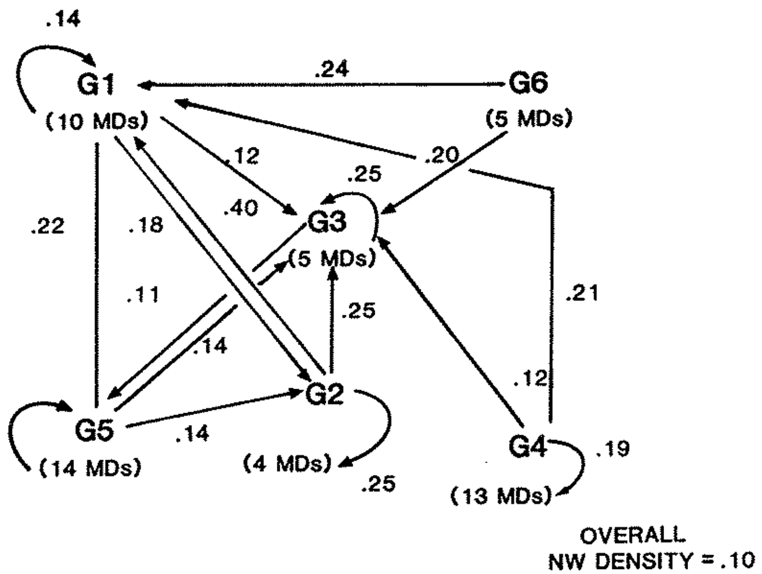

Figure 6.6. Membership of the 51 General Surgery Physicians in Six Groups. Physicians in each group have similar patterns of relations with all the other physicians in the network.

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Influencing Physician Use of the Medical Information System

The final phase of the study implemented and evaluated an experimental program that explicitly used a network-based approach to increase physician use of the medical information system (see Anderson et al., 1990). The study used a quasi-experimental design and appears as Chapter 13 of this book. The results of the study suggest that network approaches are an effective means of influencing physicians' and other medical personnel's use of a medical information system.

Organizational Adaptation to a Medical Information System

Study Site and Data

Setting. The case study summarized here involves the implementation of a vendor's multi-application medical records information system at the student health service (SHS) of a major urban university. A year

TABLE 6.2 Mean Attributes, Adoption, and Utilization for Each Group of Physicians: General Surgery (n = 51)

	Attribute							
Group	*Age*	*Prestige*	*Board Certification*	*Admissions*	*Medical Education*	*Attitude*	*HIS Adoption*	*HIS Use*
1	33	0.23	0.30	2.20	1.00	3.14	0.33	2.46
	(0.33)*	(0.50)	(1.61)	(1.78)	(0)	(0.32)	(1.73)	(0.29)
2	38	0.18	0.50	4.43	1.00	2.83	0	2.73
	(0.38)	(0.51)	(1.15)	(1.54)	(0)	(0.13)	(0)	(0.35)
3	34	0.19	0.20	7.17	1.00	2.75	1.00	3.23
	(0.26)	(0.68)	(2.24)	(1.61)	(0)	(0.20)	(0)	(0.39)
4	41	0.12	0.62	6.79	0.75	3.77	2.25	2.63
	(0.27)	(0.41)	(0.82)	(1.12)	(0.62)	(0.18)	(0.85)	(0.52)
5	43	0.09	0.50	3.95	0.11	3.25	3.89	1.98
	(0.31)	(0.96)	(1.04)	(1.32)	(3.00)	(0.26)	(1.02)	(0.84)
6	46	0.0	0.80	4.0	0.33	4.00	4.00	1.67
	(0.34)	(0)	(0.56)	(1.58)	(1.73)	(0.35)	(0.90)	(0.85)
Total	40	0.13	0.49	4.69	0.56	3.35	2.52	2.46
	(0.31)	(0.81)	(1.03)	(1.41)	(1.09)	(0.26)	(1.19)	(0.52)
F-ratio	1.32	6.65	1.17	0.71	4.96	1.74	1.32	0.75
$p<$	0.27	0.0001	0.34	0.62	0.004	0.15	0.29	0.59

*Coefficient of variation

SOURCE: Reprinted by permission of Springer-Verlag from Anderson & Jay (1987).

after the first system module was implemented, many system functions were operating to: (1) schedule appointments and generate encounter forms (which were printed out by the computer system for each patient's visit and served as "triggers" for most other SHS activities), (2) enter codes for diagnoses and services performed, (3) reconcile written encounter forms with data entered in the computer, and (4) generate reports. Questionnaires, structured interviews, observations, and archival data were collected several months before the system was implemented (Time 1), several months after implementation had begun (Time 2), and approximately 1 year after the second survey (Time 3). Of the approximately 110 full- and part-time employees, 88 were still employed at Time 3; 74 of these employees (84%) completed both the Time 1 and Time 3 questionnaires.

Measures. (a) *Departments and occupations.* Individuals belonged to 1 of 11 departments and 1 of 5 professional occupations, according to organizational records. (b) *Attitude toward the system.* A single-item attitude question asked the extent to which the system was worth the time and effort required to use it (with values from 1 = strongly disagree to 7 = strongly agree). A "combined attitude scale" was also computed by creating factor scores from (1) the residuals of the single item regressed on the same question measured at Time 1 (to control for autocorrelation between Time 1 and Time 3) and (2) two Time 3 questions concerning the extent to which the system changed the ease of doing the department's work and the quality of that work (with values from 1 = significantly decreased to 7 = significantly increased). (c) *Usage of the system.* A 6-point scale ranged from "0" for respondents who never used the system at all, to "1" for those who never used the terminals but did (1) provide information to it, (2) use information from it, or (3) use reports from it, up to "5" for respondents who used the terminals "most of the day." (d) *Archival measures of occupational, organizational and spatial location.* The system trainer, who was also head of SHS's medical records, provided a detailed personnel roster, a formal organizational reporting chart, and a floor plan indicating each employee's location.

Differences Between Departments and Occupations

A traditional analysis testing for differences in the means of various attitudes over time, and between occupations and departments, found that the single-item attitude measure was positive but decreased significantly from 6.02 (agree) to 5.27 (between slightly agree and agree) nearly 2 years later ($p<.01$). Table 6.3 shows that, overall, the mean of

TABLE 6.3 Combined Attitude Scale Toward Computers by Occupation and Department

	N	*Mean*	*SD*
Occupation[a]			
Administrators	6	.77	.37
MDs	5	−1.19	.79
RNs	10	−.34	1.19
Other medical	15	−.14	1.03
Office/clerical	25	.25	.81
F-ratio		4.14**	
Department[b]			
Finance/personnel	8	.29	.80
Primary care	15	−.01	1.12
Women's health	7	−1.08	.92
Specialty clinics	5	−.23	1.47
Medical records	8	.43	.56
Lab	5	−.52	.90
Health education	5	.41	.44
F-ratio		2.28*	

SOURCE: Adapted from Aydin & Rice (1991).
[a] A posteriori Duncan multiple range tests show that (1) MDs differed significantly from Office/Clerical and Administrators and Other Medical, and (2) RNs differed significantly from Administrators.
[b] Includes departments with at least five employees responding to both Time 1 and Time 3 questionnaires. A posteriori Duncan multiple range tests show that Women's Health differed significantly from Primary Care, Finance/Personnel, Health Education, and Medical Records.
*$p<.05$; **$p<.01$.

the Time 3 combined attitude scale differed significantly for the five occupations, with physicians significantly more negative. The mean also differed significantly across departments, with Women's Health employees having significantly less positive attitudes ($p<.05$).

Influence of Network Structure on Attitudes

However, a social network analysis provides different kinds of results.

Network Data. A network roster on the Time 2 questionnaire asked respondents to circle "How frequently, on the average, do you have significant discussions with [each listed] other personnel about how you accomplish your work?" using a scale of 0 = not once in the last year, 1 = once a month or so, 2 = several times a month, 3 = every week, 4 = several times a day, 5 = every day, 6 = several times a day. The final usable adjacency matrix was 62 × 62. The cell values of this matrix were then squared, to approximate the number of times per month person *i* interacted with person *j* (e.g., "every day" is approximately 25 days per month, and $5^2 = 25$). Weak relations (less than 4^2, or "once a week") were dropped. When a symmetric matrix was necessary, the mean of the *(i,j)* and *(j,i)* value was used in each cell. The result was the *relational matrix.* The initial data for the *spatial matrix* was simply the pairwise walking distance between each pair of SHS employees, based on the floor plan.

Although analyzed in the full study, positional proximity and structural equivalence results are not reported here.

Network Influence. For individual-level *overall relational proximity,* frequency of interaction with all those with whom the individual communicated was used. *Relational groups* were identified by the NEGOPY network analysis program. Individual-level *overall spatial proximity* was measured by the squared, then reversed spatial matrix. Hierarchical clustering was used to identify *spatial clusters.*

Figures 6.7 and 6.8, portray, respectively, the relational groupings mapped onto the floor plan and the spatial clusters mapped onto the floor plan, each noting the groupings with highest and lowest mean combined attitudes and usage level. Such visual analyses are useful in locating areas of similar attitudes or usage, as well as boundaries between different attitudes and usage, and showing the relationships among relational and spatial network groupings.

For the individual-level analyses, for each respondent, the combined attitude score of each proximate other (whether relational, positional, or spatial) was multiplied by that other's proximity score (along with the extent to which the respondent felt that the opinion of one's co-workers or one's supervisor was important), then averaged over all proximate others for that respondent. For the group-level analyses, the mean of each member's combined attitude was calculated for each group or cluster.

Individual-Level Results. Based on several regressions, the best individual-level network-based predictors of an individual's combined attitude toward the system were the (1) mean attitude of one's co-workers (each weighted by the frequency of relational interaction with them, but not by importance of co-workers' opinions), and the (2) attitude of one's positional supervisor (weighted by importance of opinion). The variance explained ranged from 17% to 28%.

Group-Level Results. Results from an analysis of variance (ANOVA) show that there was an overall significant difference between the attitude

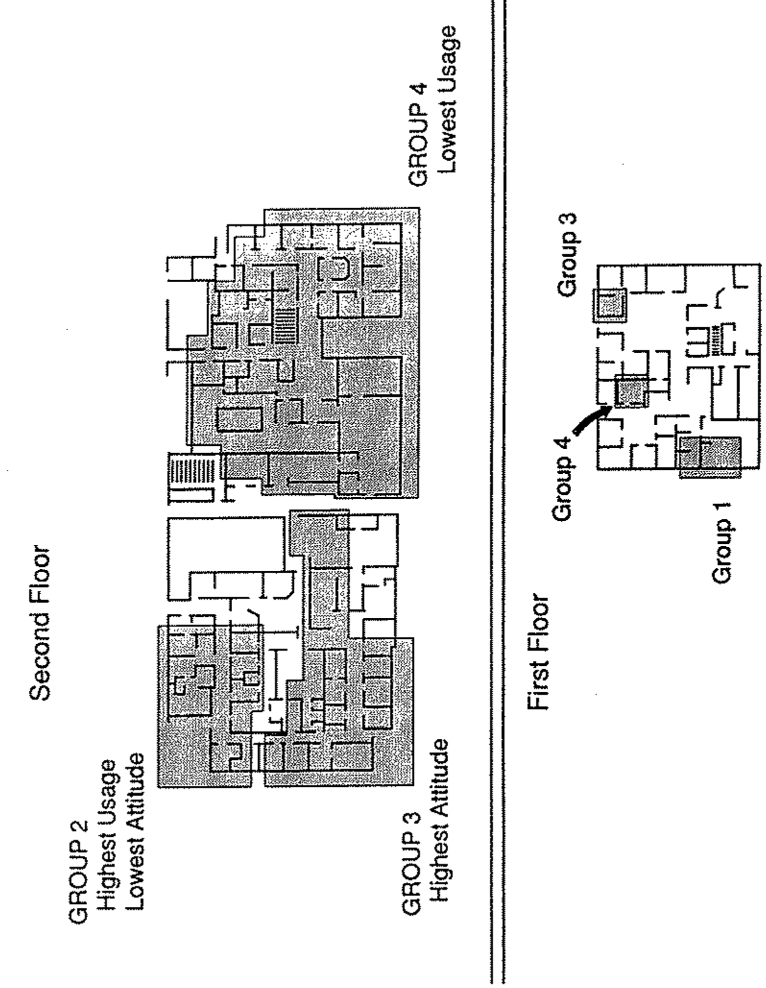

Figure 6.7. Relational Groups Mapped Onto SHS Floor Plan Showing Groups With Highest and Lowest Attitudes and Highest and Lowest Computer Usage.

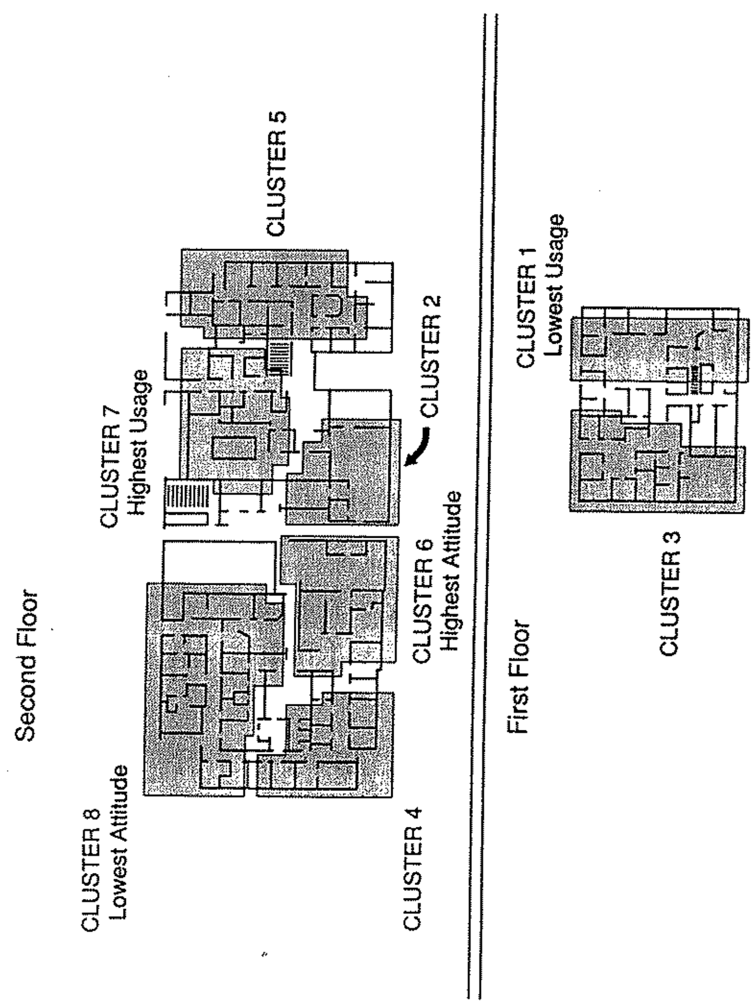

Figure 6.8. Spatial Clusters Mapped Onto SHS Floor Plan Showing Clusters With Highest and Lowest Attitudes, and Highest and Lowest Computer Usage.

means of the *four relational groups*. The group with the most positive attitude toward the system (Group 3) consisted primarily of cashier, billing, and upper-level administrative personnel. The least positive group (Group 2) consisted primarily of finance and personnel em-ployees and some administrators, and it had the highest level of use. As Figure 6.7 shows, these two groups are located next to each other, so spatial proximity cannot be playing a large role in similarity of attitudes.

There was no overall difference in average attitude about the system across the nine *spatially proximate clusters*, though there was an overall difference in system usage. The lowest usage occurred in the spatial subset consisting of radiology (Cluster 1), and the highest usage occurred in the spatial cluster of medical records personnel (Cluster 7), who were part of the relational group showing the lowest overall usage. The two spatial clusters with the highest (Cluster 6) and lowest (Cluster 8) combined attitudes toward the system are also located next to each other.

Influence of Occupational Relations on Attitudes

Although occupational membership plays some role in differences in attitudes toward, and use of, the system, we cannot yet say whether occupational membership represents a form of network influence.

So, to identify within- and cross-occupational relations, a 5 × 5 occupation-by-occupation matrix was aggregated from the 62 × 62 relational matrix. Each occupation's row and column values were then divided by the number of members of that occupation to create the proportional density of within-occupation and cross-occupation communication relations. Then an *image matrix* was created by dichotomizing each cell value into "1" if the value was higher than the overall average density of interaction (3.76) or '0' otherwise. Table 6.4 shows the density matrix and the image matrix.

Compared to the average level of communication interaction at SHS, MDs receive information from RNs but do not otherwise communicate with the rest of SHS or even among themselves. Administrators occupy a central place by communicating reciprocally with RNs and office/clerical staff, all three of whom also communicate within their own occupations. Other medical staff (radiologists, pharmacy) basically communicate only with themselves. The most central occupation in the SHS network, the administrators, has the most positive attitude.

From a *relational* perspective, the density matrix indicates that only the physicians talk with themselves more than they do with any other occupation (although this is still less than the average level of interaction). The other medical workers, nurses, and administration all talk

TABLE 6.4 Density Matrix, Image Matrix, and Mean Combined Attitude Score for the Five Occupational Categories at SHS

		Density Matrix					Image Matrix				
Occupation	*N*	*MD*	*OM*	*RN*	*AD*	*CL*	*MD*	*OM*	*RN*	*AD*	*CL*
Physicians	6	**2.77**	1.94	2.45	2.28	.47	0	0	0	0	0
Other medical	15	3.50	**3.93**	1.92	5.08	2.04	0	1	0	0	0
Nurses	12	4.85	3.60	**8.19**	12.83	3.42	1	0	1	1	0
Administration	6	3.28	3.11	5.41	**3.33**	7.12	0	0	1	0	1
Clerical	29	1.24	1.20	2.26	4.13	**3.99**	0	0	0	1	1
Mean combined Attitude Score	−1.19	−.14	−.34	77	.25						
F-ratio = 4.14, $p<.01$											

SOURCE: Adapted from Aydin & Rice (1991).

with at least one other occupation proportionally more frequently than they do with their own occupation (though they each talk with themselves more than the average overall interaction level). Although 78% (48) of all the individuals did interact within their own occupation at a level at least equal to their average interaction with *all* other individuals (a rather minimal criterion), the communication density within each occupation (the diagonal value) is less than 50% of the total communication density for the respective row. These results indicate that we cannot consider occupations as *relational* groups.

Conclusion

This chapter demonstrates how social network analysis can be used in evaluating responses to and the impact of medical information systems. Both are influenced by characteristics of the organization's structure and by relationships—whether relational, positional, or spatial—among individuals and organizational units. The distinguishing characteristic of this approach to evaluation is that it uses information about the professional's location in organizational and professional networks and his or her relations with other professionals as well as individual attributes to understand adoption, diffusion, use, and attitudes toward a medical information system.

Additional Reading

Network Analysis

A wide variety of network analysis methods, computer packages, and measures exist (Alba, 1982; Berkowitz, 1982; Burt, 1980; Burt & Minor, 1983; Fombrun, 1982; Freeman, 1979; Marsden & Lin, 1982; Monge & Contractor, 1988; Rice & Richards, 1985; Richards & Rice, 1981; Rogers & Kincaid, 1981; Tichy, 1981; Wellman & Berkowitz, 1988).

Knoke and Kuklinski (1982) and Scott (1991) provide excellent readable introductions to social network analysis.

Network Analysis Programs

In the United States, the three most-used network analysis packages are these:

1. UCINET IV (a wide-ranging suite of menu-driven programs and functions), obtainable from Dr. Stephen Borgatti, Analytic Technologies, 306 S. Walker St., Columbia, SC 29205; Bitnet: NO40016@UNIVSCVM.
2. STRUCTURE (a suite of programs emphasizing structural equivalence), obtainable from Dr. Ronald S. Burt, Center for the Social Sciences, 420 West 118th St., 8th floor, Columbia University, New York, NY 10027.
3. NEGOPY (a single program using a relational, graph-theory approach), obtainable from Dr. William Richards, Department of Communication, Simon Fraser University, Burnaby, British Columbia, CANADA, V5A 1S6; Bitnet: WRICHARD@WHISTLER.SFU.CA.
4. Also available is a companion program called FATCAT (Fat Categorical data) for cross-comparing network/relational data with attribute/categorical data. Also well known in Europe is Gradap (Graph Definition and Analysis Package), a suite of programs more similar to the familiar SPSS package than the other network analysis programs. It is available for about $500 from iec ProGAMMA, Kraneweg 8, 9718 JP, Groningen, The Netherlands.

Note

1. Figures 6.2 to 6.5 are reprinted by permission of JAI Press, Inc. (publishers of *The Sociological Quarterly*) and by permission from Pergamon Press Ltd (publishers of *Social Science & Medicine*) from Anderson & Jay (1985c, 1985a).

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