Social Network Analysis

David J. Dekker
Radboud University Nijmegen, The Netherlands

Paul H.J. Hendriks
Radboud University Nijmegen, The Netherlands

INTRODUCTION

In knowledge management (KM), one perspective is that knowledge resides in individuals who interact in groups. Concepts as communities-of-practice, knowledge networks, and "encultured knowledge" as the outcome of shared sense-making (Blackler, 1995) are built upon this perspective. Social network analysis focuses on the patterns of people's interactions. This adds to KM theory a dimension that considers the effects of social structure on for example, knowledge creation, retention and dissemination. This article provides a short overview of consequences of social network structure on knowledge processes and explores how the insights generated by social network analysis are valuable to KM as diagnostic elements for drafting KM interventions. Relevance is apparent for management areas such as R&D alliances, product development, project management, and so forth.

BACKGROUND

Social network analysis (SNA) offers a combination of concepts, formal (mathematical) language, statistical, and other methods of analysis for unraveling properties of social networks. Social networks have two building blocks: nodes and ties among the nodes. Nodes may represent people, groups, organizations, and so forth, while the ties represent different types of relationships for example communication flows, collaboration, friendships, and/or trust. As illustration, Figures 1a and 1b represent graphs of the business and marriage network of Florentine families in 15th century (see Padgett & Ansell, 1993). The graphs are created with Netdraw (Borgatti, 2002).

SNA has its origins in the early decades of the 20th century. It draws on insights from a variety of disciplines, most notably social psychology, structural anthropology, sociology, and particularly the sociometric

Figure 1a. Florentine families business network

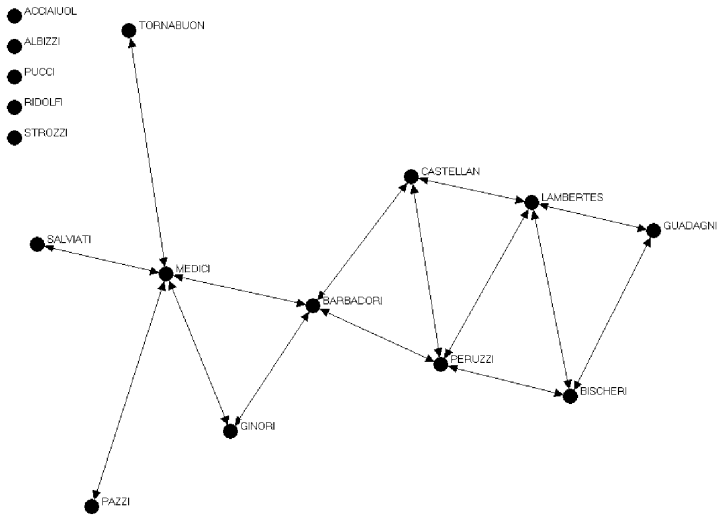
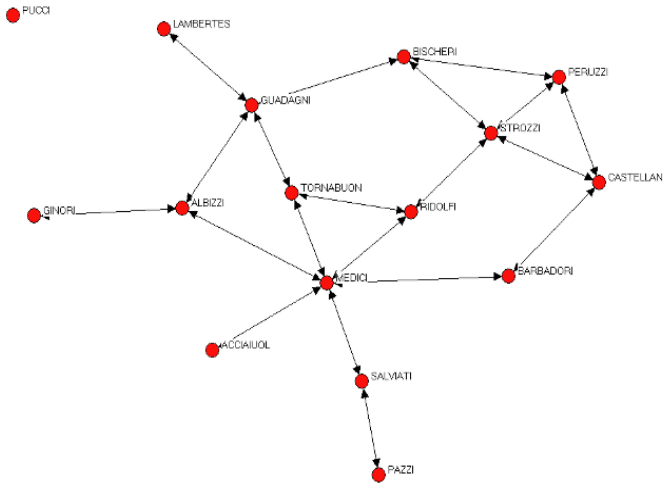


Figure 1b. Florentine families marriage network



traditions (Scott, 2000). The formal language of SNA is based in the mathematical branch of graph-theory (e.g., Harary, Norman, & Cartwright, 1965).

Network statistics describe characteristics of a network and include network size, density, centrality, and so forth. Social network thinking has produced many such statistics (see Wasserman & Faust, 1994). However, only a limited number have been studied and have known consequences for knowledge management. To analyze and characterize networks, SNA provides statistics of the whole network, groups within the network, individuals, and relationships. The substantive meaning of these statistics often depends on the contents of the ties in the network.

Granovetter's (1973) seminal paper, titled "The Strength of Weak Ties," heralds the central place of social networks in knowledge management and shows the importance of relationship characteristics for knowledge transfer. Others show that social relationships and structures also are important for other knowledge processes, such as creation and retention (e.g., Burt, 2004; Hansen, 2002; Hargadon & Sutton, 1997; Reagans & McEvily, 2003). Granovetter's (1973) title may be a bit misleading. It suggests that "weak ties" will help individuals to get unique beneficial information. However, the paper demonstrates that it is the quality of "bridging ties" that brings this advantage. Bridging ties are relationships in a network that, when they would be removed, would leave the network in two unconnected components. These relationships are often weak in the sense that contacts are less frequent and affect is low. However, as Burt (1992) points out, this is a mere correlation. "Strong bridging ties" would offer the same or even more advantages than weak bridging ties. The advantage of bridging ties Granovetter refers to lies in the structure of all relationships, not the strength of the relationship.

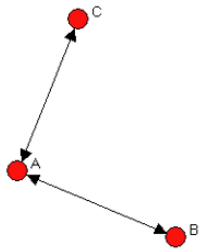
This leads us to focus here on the structural characteristics of networks and their impact on KM goals. This allows tapping into accumulating insights in the KM domain generated by SNA applications. Several recent studies in network literature focus on the (contingent) effects of such dyadic qualities as tie strength, level of trust, and power on knowledge transfer and retention (e.g., Hansen, 1999; McEvily, Perrone, & Zaheer, 2003; Uzzi, 1997).

SNA AND KM GOALS

Many SNA concepts bear relevance for KM research. Recent studies show that four SNA concepts in particular affect KM. These are:

1. **Brokerage:** Affects creativity, the generation of ideas and knowledge exploration
2. **Centrality:** Shapes knowledge transfer
3. **Cohesion:** Influences both knowledge transfer and retention

Figure 2. Node 'A' is a broker between nodes 'B' and 'C'



4. **Equivalence:** Reflects knowledge retention through common knowledge

Elaborating how the inspection of organizations through the lens of these four concepts is relevant for KM debates presumes an understanding of KM. KM is about an organization selecting appropriate goals with regard to knowledge, selecting a management model, and executing interventions, also called KM practices. Commonly, three KM domains and sets of KM goals are discerned:

1. The domain of knowledge processes that constitute valuable knowledge for an organization, most notably knowledge exploration, knowledge exploitation, knowledge sharing or transfer, and knowledge retention (see Alavi & Leidner, 2001; Argote, McEvily, & Reagans, 2003; Hendriks & Vriens, 1999)
2. The domain of a knowledge infrastructure as the organization setting in which knowledge processes evolve
3. The domain of a knowledge strategy as the set of goals that refer to how knowledge may give an organization its specific competitive position

These three KM domains and the goals they involve are interconnected. The domain of a knowledge infrastructure concerns setting the appropriate conditions for knowledge processes to evolve in such a way that they fit strategic KM goals. Focusing on aspects of social network structure, as this article does, involves paying special attention to the KM domain of knowledge infrastructure and its link to the first domain, that of knowledge processes.

Knowledge managers may benefit from insights in the four SNA concepts that will be presented in more detail in the remainder of this article. As elaborated next, insights into the domain of knowledge infrastructure and knowledge processes may form the basis for an informed selection of interventions for reaching KM goals. These interventions may target individuals (nodes) and/or their ties. Such KM interventions directly change the way knowledge processes develop. As such, the efforts of KM target the level of the individual knowledge worker. For example, SNA may prove useful:

1. in helping these individuals review their personal networks
2. in showing the necessity for them to develop their networking skills (e.g., Baker, 2000)
3. for their career planning

Furthermore, the insights that SNA generates also may allow KM to facilitate conditions for establishing network relationships and affect the resources used in networks. Note that both concern KM at the level of the knowledge infrastructure.

BROKERAGE

The first concept discussed here is that of knowledge brokerage. A broker is defined as someone who holds a position in a network that connects two or more unconnected parts of that network (see Figure 2). It is closely related to the idea of bridging ties because bridging ties imply brokerage. To emphasize that it is not the bridge itself, but the gap it closes that reflects value, Burt coined the term "Structural Hole" (Burt, 1992). A structural holes reflects the opportunity to connect two or more unconnected others.

Several authors suggest the value of brokerage for the creation of innovative ideas (Burt, 2004; Dekker, 2001; Hargadon & Sutton, 1997). Burt (2004) shows that there is strong evidence that brokerage generates good ideas. He states: "People with connections across structural holes have early access to diverse, often contradictory information and interpretations which gives them a competitive advantage in seeing and developing good ideas." They derive their value by enabling the flow of resources between otherwise unconnected subgroups within a larger network. This induces innovation (Hargadon & Sutton, 1997). Hansen (2002) shows that brokers work best when they use their own contacts and do not depend on other intermediaries. Dealing with fewer intermediaries who serve as boundary spanners provides search advantages, which leads to better knowledge acquisition.

The result that brokers may hold value is not without controversy. It has been shown that the value of brokers depends very much on the content of relationships (Podolny & Baron, 1997). Some relationship contents such as trust or tacit knowledge flow better through

nonbridging relationships (Dekker, 2001; Gargiulo & Benassi, 2000).

In short, SNA identifies brokers and shows the conditions under which broker positions become valuable.

KM Interventions

The insights from knowledge brokerage analyses inspire, for example, the following KM interventions:

- Retention of key knowledge brokers in the organization. This could be done by aligning the reward systems with the recognition that informal reputation is central. Formal peer reviews should tap into those mechanisms
- Knowledge brokers need to be managed (or manage themselves) in such a way that they need as little other intermediaries as possible to acquire knowledge. Ideally, every team needs to organize its own "intelligence"
- The structure of work should confront some members of the workforce with a continuous flow of new problems, discourage them to overspecialize, and rotate them between projects on a regular basis. Only then is an "organic emergence of brokerage skills" conceivable
- Management style and the basic management model should reflect norms for collaboration. This could be implemented by avoiding management through normative control and by teaching newcomers the "attitude of wisdom" through brainstorming routines and regular meetings (e.g., Monday Morning meetings as described by Hargadon & Sutton, 1997)
- Recruitment and employee selection policies should respect the work and management styles and practices described. Peers should play a key role in those policies. Hargadon and Sutton (1997) describe how the product design firm IDEO only hires new personnel when at least 10 peers support these

Another KM intervention would be to find potential brokers to fill structural holes as starting points for idea generation. Other possible interventions include:

- The introduction of programs for team building and the development of networking skills and collaborative exercises may increase the chances that structural holes disappear
- Individuals' motivation to become knowledge brokers may be stimulated, through the reward system, career management, the selection of topics addressed in their development interviews, and personal commitment statements.
- Exit interviews and outplacement procedures may be considered for individuals who prove unfit for any boundary spanning activities

CENTRALITY

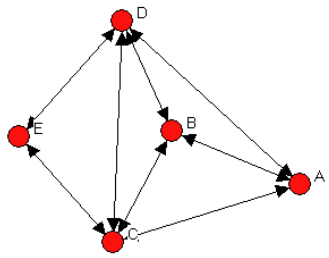
Centrality is a network structural characteristic of an individual or a whole network (for an overview, see Wasserman & Faust, 1994). The definition of various forms of centrality we will give focuses on individual centrality or point centrality. On a network level, similar measures have been developed (see Freeman, 1979). Several different types of centrality have been defined. Three well-known measures defined by Freeman (1979) are degree centrality, betweenness centrality, and closeness centrality. Degree centrality is measured as the number of ties an individual has in a network. This measure indicates the potential for communication activity that individual has. Betweenness centrality is based on the number of times that an individual stands between two others. Standing between two others here means being on the shortest path (geodesic) that connects two others. The more often an individual is on the shortest paths between any two others in the network, the higher that individual's "betweenness centrality." This form of centrality says something about control of communication within the network. Closeness centrality measures how close an individual is to the others in a network. Having relationships with everybody implies being closest, while having to depend on others to reach someone implies a greater distance toward that individual. Closeness centrality indicates independence. The higher the closeness centrality the more an individual can avoid the potential control of others (Freeman, 1979).

Centrality of networks has a close relationship to coordination in teams and particularly has an impact on knowledge transfer. For instance, Rulke and Galaskiewicz (2000) show that generalist teams do better than specialist teams in centralized networks. In decentralized networks, generalist and specialist teams perform equally well. Tsai (2002) shows that hierarchy has a negative impact on knowledge sharing, particularly in situations of inter-unit competition for market share. In such situations, informal lateral relations show a positive impact on knowledge sharing. Furthermore, Tsai (2002) shows that the drawbacks of hierarchy for knowledge transfer are less severe when competition among teams concerns usage of internal resources.

KM Interventions

Insights in the centrality of networks provide specific guidance for drafting control structures within project-

Figure 3. The group of nodes 'A,' 'B,' 'C,' and 'D' form a clique. In the group of nodes 'A,' 'B,' and 'C,' a fourth node 'D' can be added that has ties with all three others. Node 'E' doesn't belong to the clique because 'E' does not have ties with all clique members.



based or team-based organizations:

- Especially among specialists, if knowledge sharing is important, centralized, hierarchical control structures as coordination mechanisms in teams should be avoided
- Particularly in situations of inter-unit competition for market share, it may be wise to reexamine the degree of hierarchy in the prevailing control structures
- SNA research also has implications for staffing policies of teams: developing generalist teams puts less pressure on adequacy of existing control structures

COHESIVENESS

Cohesiveness in a network implies that all individuals or subgroups of individuals in that network have strong, direct, intense, frequent, and positive ties (Wasserman & Faust, 1994, p. 249). Several measures to detect cohesiveness have been developed. Probably the most well-known is the clique. Cliques are formally defined as maximal complete subgraphs of three or more nodes (Luce & Perry, 1949). This means a group is a clique if no individual in the network can be added to that group such that all those in the group have a direct tie with each other (see Figure 3). Ties in cliques are sometimes referred to as "Simmelian ties" after the renowned German sociologist Georg Simmel (Krackhardt & Kilduff, 1999). Simmel was the first to discuss the properties of triads, which are the smallest possible cliques. Simmelian ties are super strong, according to Krackhardt (1998), because they create opportunity for norms to arise and the means to enforce these norms (see also Coleman, 1990).

For knowledge management, this means that cohesiveness in networks allows the development, transfer, and retention of routines. Reagens and McEvily (2003) show that cohesion improves knowledge transfers. Hansen (2002) shows that cohesiveness between units may prove counterproductive under circumstances. He argues that the direct relations that produce cohesiveness are most effective for the transfer of complex knowledge. His research shows that the higher the number of direct relations, the longer the completion time of projects that employ codified knowledge. As to the cost involved in maintaining strong ties, research by Borgatti and Cross (2003) shows that its negative impact on knowledge transfer cannot be substantiated. They do show that awareness of competent knowledge transfer partners and easy access to their knowledge furthers knowledge transfer.

KM Interventions

SNA research shows that stimulating cohesiveness within teams is crucial for the broad spectrum of knowledge processes. If there is a lack of cohesiveness in parts of the organizational network, concrete interventions to help achieve such objectives include:

- The introduction of programs for developing networking capabilities not just for team members but particularly for managers (Baker, 2000). Other research has shown that heavyweight project leaders are needed for successful projects. SNA research shows that networking capabilities skills are crucial in addition to other managerial competencies
- As research suggests that successful teams have both weak and strong ties with other units, recruitment and selection procedures for team composition should ensure an adequate balance between both types of ties
- The introduction of programs for team building including collaborative exercises
- SNA may identify those nodes in the network, for example, team members that contribute most to low cohesiveness scores. These insights may inspire exit interviews with such team members and starting outplacement procedures for them
- The identification and adoption of key tasks and deliverables of teams and subgroups, as these may provide a focus for cohesion
- The introduction of elements of networking by team members in personal commitment statements, career management, and development interviews

- All aforementioned KM interventions should not just focus on intra-unit communication, but also address inter-unit communication. However, it should be considered that cohesiveness based on direct relations across units may only be worth the cost of maintaining for noncodified knowledge

EQUIVALENCE

A fourth SNA concept is equivalence. Equivalence of two individuals in a network indicates that they are embedded in equal or very similar network structures. Note that this does not mean that both need to have a direct contact. Rather, equivalence measures indicate the extent to which two individuals have the same role in a network. Equivalence measures have been developed for sociometric positional and role analyses. These analyses group people on the bases of their similarity in relational patterns. For an overview of different equivalence measures, see Wasserman and Faust (1994). In their study, Reagens and McEvily (2003) suggest that knowledge flows more easily between two equivalent individuals, because they have more common knowledge. More research is needed to show the effects of equivalence on knowledge management outcomes.

KM Interventions

- To the extent that inter-team knowledge transfer is important, staffing policies of teams need to tap into the insights that the existence of common knowledge among team members of different teams is an important precondition for the ease of knowledge transfer between teams, particularly for complex, noncodified knowledge. One way to achieve this is to gather data on the networks of individuals and to use these data to maximize structural equivalence of teams, an insight that may be provided by SNA
- Installing a system of job rotation makes sense because experience at one task is shown to help in performing a related activity
- Dedicated network ability training programs also may help in expanding the capacities of individuals and teams to achieve equivalence with other individuals and teams

FUTURE TRENDS

The increasing attention for knowledge aspects in organizations is likely to boost the interest in SNA research and may be expected to influence the direction that research takes. The KM community may be expected to strengthen its embrace of SNA as a solid basis for diagnosis. As to the development of a knowledge-based SNA, a multitude of suggested research directions, ideas, and developments appear on the horizon. Two of these deserve special attention.

First, we anticipate SNA researchers that show an interest in the knowledge-based view of organizations to expand their focus that is currently mainly on the process of knowledge transfer. Other knowledge processes, particularly knowledge exploration and knowledge retention, have attracted the attention of SNA researchers, but not so much as knowledge transfer. The process of knowledge exploration, for instance, has been approached mainly via related concepts as creativity and idea generation. The process itself and the variety of learning and knowledge development models circulating in KM debates that involve elements of networks still remain largely outside the scope of SNA research. Also, an understanding of the core knowledge processes of knowledge exploitation and knowledge retention may greatly benefit from an inspection from a SNA standpoint. The same goes for the broad spectrum of supporting knowledge processes including knowledge acquisition, knowledge evaluation, knowledge identification, and knowledge combination.

Second, the further integration of SNA can be foreseen with qualitative studies that provide an in-depth examination of the intricacies surrounding the knowledge aspects of work. Hargadon and Sutton (1997) give an outstanding example of combining SNA with an extensive qualitative study of the mechanisms that shape the amalgamation of idea generation and knowledge retention. SNA addresses the crucial structural conditions for knowledge processes to develop. However, the intricate workings of the knowledge component in these processes remain a black box in a SNA. This is indicated by the fact that in much SNA research the term knowledge is easily substituted with the term information. Development of both knowledge-based SNA and qualitative inspections of organizational knowledge will advance due to their mutual connection.

CONCLUSION

Concepts from SNA strike a chord among adherents of a knowledge-based view of organizations. They recognize that knowledge, and especially organizational knowledge, is essentially situated on the fringes of connecting individuals with collectives. These concepts have inspired researchers from different origins and led to elaborations of network thinking into different directions, such as the economic theories of networks as

governance modes and organizational theories around concepts of organization structure (Wijk, Bosch, & Volbeda, 2003). Both in the domain of knowledge management research and in the domain of individual organizations drafting their knowledge management diagnosis and design efforts, SNA has great potential to further develop the knowledge-based view of organizations.

REFERENCES

Alavi, M., & Leidner, D.E. (2001). Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues. *MIS Quarterly 25,* 107-136.

Argote, L., McEvily, B., & Reagans, R. (2003). *Managing knowledge in organizations: An integrative framework and review of emerging themes. Management Science, 49*(4), (571-582).

Baker, W.E. (2000). *Achieving success through social capital: Tapping the hidden resources in your personal and business networks*. University of Michigan Business School management series (pp. XVII, 238). San Francisco: Jossey-Bass.

Blackler, F. (1995). Knowledge, knowledge work and organizations: An overview and interpretation. *Organization Studies 16,* 1021-1046.

Borgatti, S.P. (2002). *NetDraw: Graph visualization software*. Harvard: Analytic Technologies.

Borgatti, S.P., & Cross, R. (2003). A relational view of information seeking and learning in social networks. *Management Science, 49*(4), 432-445.

Burt, R S. (1992). *Structural holes: The social structure of competition* (p. 313). Cambridge, MA: Harvard University Press.

Burt, R.S. (2004). Structural holes and good ideas. *American Journal of Sociology* (in press).

Coleman, J.S. (1990). *Foundations of social theory*. Cambridge, MA: Harvard University Press.

Dekker, D.J. (2001). *Network perspectives on tasks in account management.* Erasmus University: Rotterdam.

Freeman, L.C. (1979). Centrality in social networks conceptual clarification. *Social Networks, 1,* 215-239.

Gargiulo, M., & Benassi, M. (2000). Trapped in your own net? Network cohesion structural holes, and the adaptation of social capital. *Organization Science, 11*(2), 183-196.

Granovetter, M.S. (1973). The strength of weak ties. *American Journal of Sociology, 78,* 1360-1380.

Hansen, M.T. (Ed.) (1999). The search-transfer problem: The role of weak ties in sharing knowledge across organization subunits. *Administrative Science Quarterly, 44*(1), 82-111.

Hansen, M.T. (Ed.) 2002. Knowledge networks: Explaining effective knowledge sharing in multiunit companies. *Oraganization Science, 13*(3), 232-248.

Harary, F., Norman, R.Z., & Cartwright, D. (1965). *Structural models: An introduction to the theory of directed graphs*. New York: Wiley.

Hargadon, A., & Sutton, R.I. (1997). Technology brokering and innovation in a product development firm. *Administrative Science Quarterly, 42,* 716-749.

Hendriks, P.H.J., & Vriens, D.J. (1999). Knowledge-based systems and knowledge management: friends or foes?, *Information and Management, 35,* 113-125.

Krackhardt, D. (1998). Simmelian tie: Super strong and sticky. In M. Neale (Ed.), *Power and influence in organizations* (pp. 21-38). Thousand Oaks, CA: Sage.

Krackhardt, D., & Kilduff, M. (1999). Whether close or far: Social distance effects on perceived balance in friendship networks. *Journal of Personality and Social Psychology, 76,* 770-782.

Luce, R.D., & Perry, A.D. (1949). A method of matrix analysis of group structure. *Psychometrika, 14,* 95-116.

McEvily, B., Perrone, V., & Zaheer, A. (2003). Trust as an organizing principle. *Organization Science, 14,* 91-103.

Padgett, J., & Ansell, C. (1993). Robust action and the rise of the Medici, 1400-1434. *American Journal of Sociology, 98*(6), 1259-1330.

Podolny, J.M., & Baron, J.N. (1997). Resources and relationships: Social networks and mobility in the workplace. *American Sociological Review, 62*(5), 673-693.

Reagans, R., & McEvily, B. (2003). Network structure and knowledge transfer: The effects of cohesion and range. *Administrative Science Quarterly, 48,* 240-267.

Rulke, D.L., & Galaskiewicz, J. (2000). Distribution of knowledge, group network structure, and group performance. *Management Science, 46,* 612-625.

Scott, J. (2000). *Social network analysis: A handbook* (2nd Ed.). London: Sage.

Tsai, W.P. (2002). *Social structure of "coopetition" within a multiunit organization: Coordination, competition, and intraorganizational knowledge sharing*. Unpublished manuscript.

Uzzi, B. (1997). Social structure and competition in interfirm networks: The paradox of embeddedness. *Administrative Science Quarterly, 42,* 35-67.

Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications*. New York: Cambridge University Press.

Wijk, R.v., Bosch, F.A.J.v.d., & Volbeda, H.W. (2003). Knowledge and networks. In M. Easterby-Smith & M.A. Lyles (Eds.), *The Blackwell handbook of organizational learning and knowledge management* (pp. 428-453). Malden, MA: Blackwell.

KEY TERMS

Brokerage: The activity of connecting two or more unconnected nodes in a network.

Centrality: The extent to which ties give an individual or subgroup a central position in a network.

Cohesion: The extent to which nodes form a group such that all members have mutual strong ties.

Network Structure: The overall configuration of the network, as reflected in the patterns of ties among nodes.

Social Network: A set of nodes (that represent actors, groups, etc.) and the ties that connect these nodes.

Social Network Analysis: The systematic analysis of empirical data describing social networks, guided by formal, mathematical, and statistical theory.

Structural Equivalence: The extent to which the tie patterns of two or more nodes of the network are equal.