Workshop Paper:

"**A Methodological Framework for the Analysis of Network Organizations**"

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Abstract:

The phenomenon of organizational networks is one of the most fashionable topics in management science. Accordingly, multiple books and articles have been written about the management and the formation of *network organizations* as well as their special features with regard to the organizational structures. Although many contributions in this field stress the significance of the relational patterns between the network members, the majority of empirical research sticks to traditional statistical methods. This is especially astonishing, since in related social science disciplines, *network analysis* has been successfully applied to the analysis of relational patterns.

In this paper, the main characteristics of network arrangements are discussed, leading to the conclusion that organizational network structures cannot be adequately analyzed with standard statistical methods. In fact, an analytical framework is necessary, which allows an integrated analysis of both attributive and relational data. For this purpose we introduce network analysis as an appropriate research method for the study of network organizations. To exemplify the functionality of network analysis, its basic features will be presented by using empirical network data.

Keywords: network organizations, network analysis, organizational structures

INTRODUCTION

The discussion about organizational networks has attracted much attention within the field of management and corporate governance within the last years. Networks structures, sometimes viewed as "organic arrangements" (Hage 1988; Gerlach 1992; Nohria 1992), are commonly suggested to adequately match economic changes and environmental complexity and hence gain competitive advantage (Miles & Snow 1984, 1992; Jarillo 1988; Bovasso 1992; Gomes-Casseres 1994; Park 1996; Jones, Hesterly & Borgatti 1997; Rall 1997; Oliver & Ebers 1998). Numerous reasons for the emergence of network structures have been presented ranging from globalization and economic devolution, shorter product live cycles, and increasing technological complexity to increasing corporate size and a growing number of different countries and markets with different cultures and customs caused by mergers and acquisitions that force enterprises to flexibly adjust to their competitive environment (Kutschker 1999; Perlitz 2000; Welge & Holtbrügge 1997; Hage 1988; Kutschker & Bäurle 1997; Park 1998).

At the same time, various theoretical approaches can be observed in order to explain the emergence of network structures both within and among firms. Amongst others, transaction cost economics, resource dependence theory, contingency theory and arguments suggested by exchange theory are used to address the network phenomenon (Husted 1994; Oliver & Ebers 1998). However, it is important to distinguish the network phenomenon and the theories being used to explain its emergence from network analysis, a methodology to examine network structures on an empirical basis (Wald 2000).

In this paper, we are not addressing the issue of how to theoretically explain the existence of organizational networks. Instead, building on a precise definition of the main characteristics of network arrangements we are going to introduce a methodological framework for the analysis of network structures based on social network analysis. By taking all kinds of economic as well as social relationships among the actors into consideration and by integrat-

ing formal and informal coordinating devices, we suggest that network analysis is useful to empirically assess organizational networks both among and within firms.

CORPORATIONS AS ORGANIZATIONAL NETWORKS

The Application of the Network Concept to Organizations

The definitions of network organizations that can be found in literature are manifold and often metaphorical (Nohria 1992) and are thus not always useful for the description of organizational network arrangements. However, the development of an analytical framework inevitably requires a precise definition of the term *network organization*. By reviewing the existing literature we present a definition integrating the various approaches whereby we consider the work of Jones, Hesterly & Borgatti (1997) of particular importance.

Network organizations consist of a well-defined, persistent, and structured set of semi-autonomous corporate actors engaged in numerous mutual exchange relationships in order to jointly reach the common network objectives. The relationships are based on implicit and open-ended contracts to adapt to environmental contingencies and to coordinate and safeguard exchange processes.

The term *well-defined* indicates that the members of the network can clearly be identified. Although several authors assume that it is not possible to exactly define the boundaries of a network organization (Thorelli 1986), we do not consider the membership to be a question of coincidence. Instead, building on Park (1996) we suggest that the membership is based on a conscious decision of the individual actors and that consequently the network can clearly be distinguished from its environment. The term *persistent* is used to indicate that the network organization is stable over time as its members work repeatedly and regularly together over time (Jones, Hesterly & Borgatti 1997). The expression *structured* is used to indicate that exchange processes are neither random nor uniform but result from a division of labor along

with the assignment of strategic roles to the individual network members (Thorelli 1986; Rank 2000).

We define *actors* as separable organizational decision centers (Aldrich & Whetten 1981; Thorelli 1986; Ebers 1997). Depending on the scope of the network the actors may either be individuals, entire corporations (which is the case for interorganizational networks) or organizational subunits, i.e. the corporate headquarters, its subsidiaries or other entities like strategic business units and profit centers (for the case of intraorganizational networks) (Lincoln 1982; Ghoshal & Bartlett 1990; Tsai & Ghoshal 1998; Oliver & Ebers 1998). We use the term *semi-autonomous* in order to indicate that the corporate actors are relatively independent from their partners as far as the achievement of their objectives is concerned while being economically and/or legally dependent on the rest of the network.[1]

The *relationships* that link the individual actors together comprise streams of transactions. These relationships can be differentiated according to their type and structure (Bonacich 1987; Ibarra 1993; Brass, Butterfield & Skaggs 1998). They consist of exchange processes, which include but are not limited to economic transactions in a narrower sense. More comprehensively, all sources of mutual advantage may form the basis of exchange. As a consequence, relationships among the actors can be found involving transfer of goods and services, diffusion of information and knowledge, development of trust and friendship, and the flow of legitimacy (Thorelli 1986; Easton & Araujo 1989; Cliffe 1998).

Finally, the phrase *implicit and open-ended contracts* is used to indicate that means of adapting, coordinating, and safeguarding exchange processes are not primarily derived from authority structures or from legal contracts, although formal contracts may exist between specific dyads of members (Jones, Hesterly & Borgatti 1997).

Coordinating Mechanisms in Network Organizations

It can be assumed that not all actors within a network organization are equipped with an equal degree of power and control. Hence, by pursuing their objectives the individual actors will strive to increase their control. With this respect two processes are conceivable. First, control can be increased through formalized structures and processes coming into existence through explicit contracts and rules which are codified. Second, actors can increase their level of control and power through ad-hoc and informal coordination of activities directed towards specific objectives (Araujo & Brito 1997). In this sense, Welge (1999) proposes that only a well-balanced mix of both formal and informal instruments will assure the integration of the widely dispersed economic activities of firms.

As far as coordination among the network members is concerned the used mechanisms and processes are commonly reviewed with respect to market and hierarchy, each suggesting different coordinating forms (Williamson 1975). Within markets the participants act basically independent from each other, they are equipped with equal rights and are characterized by a limited rational and opportunistic behavior. Therefore, market-based relationships are suggested to be elusive and rather competitive. In contrast to this, instructions among mutually dependent actors are the main coordination device within hierarchies. Hierarchical relationships are usually applied as long-term relations and are ideally cooperative (Macneil 1978; Sydow 1992).

But how do these two basic coordinating mechanisms actually cohere as far as organizational networks are concerned? Within management literature, two major positions can be distinguished (Kappelhoff 2000; Wald, Rank & Peske 2000). Academics following the intermediary position propose that network organizations may be located on a continuum somewhere between market and hierarchy (Thorelli 1986; Williamson 1991; Seibert 1991; Sydow 1992). In contrast to this, the autarkic position suggests that networks form an organizational

structure on its own besides markets and hierarchies, although embodying characteristics of both (Powell 1990; Semlinger 1993).

Whatever position one is in favor of, there seems to be no doubt that the coordinating mechanisms of network organizations consist of a synopsis of market and hierarchy as it relates to the fundamental coordinating devices of both. It is suggested that the decisive factors, which determine the kind of coordinating mechanism are the levels of competition and uncertainty the network organization faces. With respect to coordination, a positive correlation is proposed between the levels of competition and uncertainty and the degree to which the network actors rely on closeness and trust in contrast to market-based arrangements (Borys & Jemison 1989). This matter is closely related to the question of centralization versus decentralization. According to Perrow (1986), the decentralization of responsibilities in networks results in prudent responses to unplanned contingencies. In contrast, centralized authority produces relatively quick reactions based on rigid obedience.

Moreover, both formal and informal coordinating mechanisms act side by side depending on the number and importance of the individual activities to be coordinated (Håkansson & Johanson 1988). Bovasso (1992) suggests that ideally, the formal organizational structure is superseded by the informal social networks that emerge from exchange processes. In this context, specific attention is being paid to the role of cooperation and trust as it influences the actors' commitment towards the network relationships, their reaction to unanticipated problems, their recourse to contractual remedies, and their style of conflict resolution (Jarillo 1988; Husted 1994; Ring & Van de Ven 1992; Ring 1997; De Laat 1997). In order to enhance cooperation on common tasks, network organizations primarily rely on social coordination and control, e.g. occupational socialization, collective sanctions, and reputations rather than on authority or legal recourse (Jones, Hesterly & Borgatti 1997). As a consequence, the structural embeddedness of the actors in network organizations has to be taken into account, since

it constitutes a framework, which provides opportunities for and constraints on action (Granovetter 1985; Stinchcombe 1986, Wasserman & Faust 1998).

IMPLICATIONS FOR THE ANALYSIS OF NETWORK ORGANIZATIONS

It becomes obvious that networks are highly complex organizations. Although a huge amount of literature on the concept of network organizations can be found and different theoretical approaches have been presented in order to explain the emergence of organizational networks, the question of how to analyze this organizational device seems to attract by far less attention. The multitude of empirical studies on networks still favorite statistical methods analyzing attributive data in order to assess network structures (Bartlett & Ghoshal 1989; Ghoshal & Nohria 1993; Taggart 1997; Kraatz 1998). The emanating question however is, whether standard statistical methods are suitable in order to approach organizational networks appropriately from an empirical point of view.

We have argued that *relations* play a particular important role within networks. Consequently, the focus has to be put on relational data. Network data require measurements on the relationships among the actors as well as on the attributes of the actors, whereas statistical methods *alone* are not suitable to assess organizational networks appropriately (Wasserman & Faust 1998).

Similarly, it has been shown that within network organizations *formal* and *informal* instruments are being used to safeguard exchange processes. In order to maintain or enhance their levels of control the individual network actors use both devices likewise. Consequently, an analytical framework has to assure that both formal and informal structures and processes are taken into account simultaneously. There are various different relationships between actors. For this reason, a framework for the analysis of network organizations has to cover the entire spectrum of possible relationships ranging from elusive and competitive forms as the

market element would suggest to long-term and cooperative relationships, which can be found within hierarchically arrangements.

Moreover, in network organizations limited rational and opportunistic behavior, as well as behavior that is induced by the subordination of hierarchies, is likely to occur. On the one hand, the corporate actors of network organizations may pursue different strategic objectives. The reason for this can be found in the fact that differing strategic roles are assigned to the specific entities as the result of the strategic process. On the other hand, the individual actions of the network members have to be coordinated with regard to the common network objectives. In network organizations, this coordination is predominantly achieved by stable patterns of exchange relationships, which, once established, create trust and make individual action more predictable. Therefore, an analytical framework has to match a concept of individual and corporate action, which is neither under- nor over-socialized, but takes into account the affection of behavior by social relations (Granovetter 1985).

Finally, we have argued that the characteristics of economic and legal independence are not suitable to determine whether a network is *inter-* or *intraorganizational*. It can be assumed that there is no discrete point at all, which distinguishes unequivocally interorganizational arrangements from intraorganizational networks. With this respect, an analytical framework has to be designed to be usable for the analysis of both intra- or interorganizational network structures.

The application of social network analysis to the field of business organizations allows to adequately take all these facts into account. Hence, in the following chapter, network analysis will be introduced as a method that is suitable for the analysis of complex organizational network arrangements. Being a well established research methodology in several academic disciplines, e.g. political science, surprisingly few applications to the analysis of corporation's organizational structure can be found (e.g. Ghoshal & Bartlett 1990). For the sake of

the introductory nature of this paper, we will focus on the basic features of network analysis as well as on examples of its application to empirical data.

NETWORK ANALYSIS

Key Characteristics of Network Analysis

Originating from sociology, sociometry, and anthropology, social network analysis is a method to investigate social structures. It can be applied to a wide range of topics within several academic disciplines. Generally, a network consists of a set of actors, which are connected through different relations or ties (Wasserman & Faust 1998). As already mentioned, the relations linking the actors can be of manifold type. Hence, an important precondition of every network analysis is the definition of the relations, which have to be taken into account. Another step is the system delineation, i.e. the identification of the relevant actors (Pappi 1993).

Having standard social science research in mind, the key characteristic of network analysis is that the focus is put on patterns of relations between the actors rather than on their attributes as suggested by statistical methods. An example may illustrate this important distinction. A research problem typically analyzed with standard statistical tools is the question, whether the profit contributions of the individual subsidiaries of a multinational corporation (MNC) are related to the management know-how of their respective top-executives. In contrast, the relations between the managers, e.g. knowledge and information flows, would be the research object when applying network analysis. In this case, the related research question would be, whether the profit contributions of the individual MNC's subsidiaries are related to the managers' position in the network of information flow. However, the position of a specific manager within the network cannot be identified by simply considering his individual attributes but by analyzing the ties connecting him to the other managers in the network. It needs to

be mentioned that once the network position has been identified by the means of network analytical tools, it can be treated as an individual attribute on its own. As a consequence, network analysis and standard statistical methods are not alternative but *complementary* methods, allowing an integrated study of both attributive and relational data. For example, using network analysis as well as regression analysis Burt (1992) found empirical evidence that managers with a specific pattern of relationships get promoted faster than others. Unfortunately, no data sets with large samples of organizational networks are available so far. Due to the high costs of collecting network data, network studies are predominately carried out in the form of case studies. Thus, statistical analysis of the coherence between relational properties and attributive data has been limited to single cases.[2]

To study organizational structures, network analysis serves two purposes: First, it can be used as a descriptive tool to analyze the complex relational patterns between the network actors as well as to reduce complexity by identifying the underlying macro-structure, i.e. dominant patterns of relationships of multiple networks. Second, network analysis can be applied to test hypothesizes on structural properties of networks or on the interaction of structural properties and attributive characteristics as far as the scope of theory-guided research is concerned (Wald 2000). Moreover, network analysis is suitable for different organization theories such as resource dependence theory, exchange theory, transaction cost economics or contingency theory.

Having introduced the key characteristics of the social network perspective, the next chapter will outline the methodological approach of network analysis by using an empirical example. Moreover, we will discuss how network analysis can be used as a descriptive tool.

Descriptive analysis of an organizational network

To illustrate the methodological approach we use the data on Krackhardt's high-tech managers being available from Wasserman & Faust (1998). The networks comprise 21 man-

agers of an US high-tech firm, hence we deal with an intraorganizational network. The actors in our example are individuals and not corporate actors. There are two *informal* networks consisting of friendship and advice. Another network tells us about who reports to whom, representing the *formal* organization (Krackhardt 1987; Krackhardt & Hanson 1993). Figure 1 depicts the three networks in a so called *sociomatrix* (adjacency matrix). Each actor of the network is listed in both columns and rows of the matrix. The actors in the rows are the senders of the respective exchange content while the actors in the columns represent the receivers. An entry in the cell of the matrix where a column intersects with a row indicates that there is a tie (a relation) between the two actors. Consequently, the absence of an entry in the intersecting cell means that the row actor and the column actor are not adjacent. Take for example the friendship network: Manager 1 names manager 8 as a friend, whereas number 8 does not confirm this friendship since he only names manager 4.

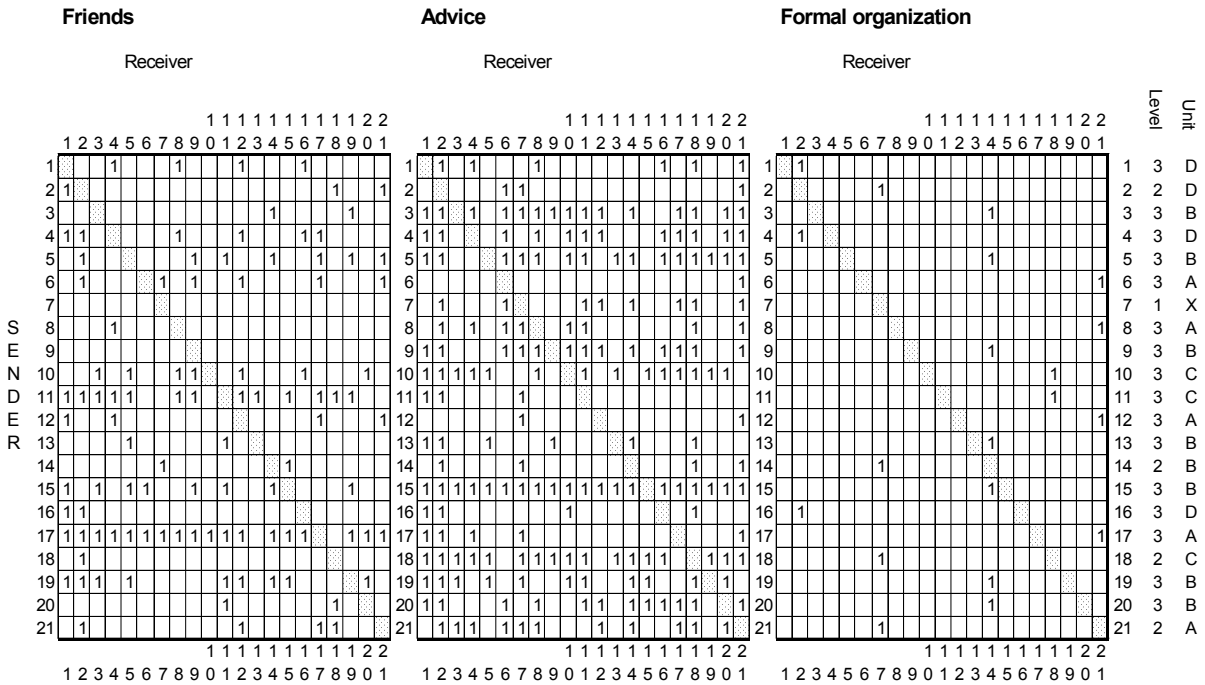

Figure 1: Intraorganizational networks of friendship, advice and formal organization of a firm
Source: Adapted from Wald (2000:648).

The last two columns of Figure 1 contain information on the managers' individual attributes. They are located on three different hierarchical levels and belong to four different

departments (A, B, C, D). Only the CEO (manager 7) is not affiliated to a department (X). The network of *formal* organization in Figure 1 reads as follow. The senders state to whom they report, naming their direct superior. Thus, the managers 3, 5, 9, 13, 15, 19, 20 are all located on third level and belong to department B. They report to manager 14 who heads the department. Manager 14 in turn directly reports to the company's CEO.

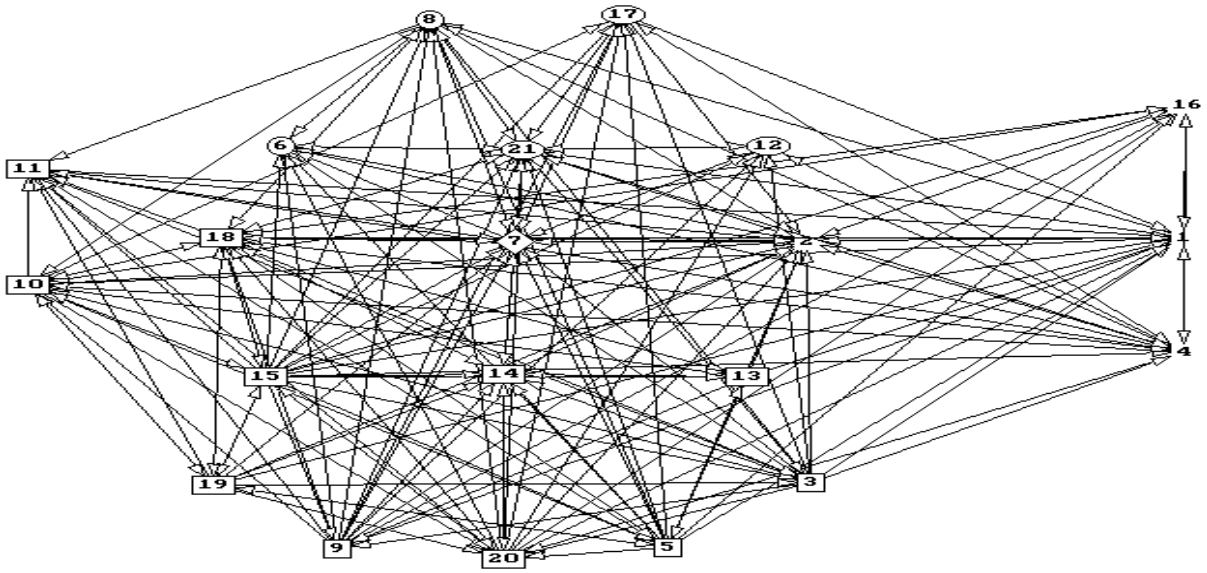

Figure 2: The advice network in graph-form[3]

An alternative way to present network data is the graph theoretic notation. For this purpose we use the advice network of the previous example. As illustrated in Figure 2 the actors are nodes marked with their numbers. A relation between two actors is indicated by a line connecting them. The direction of the relation is shown by an arrow at the end of the line. The sociomatrix in figure 1 and the graph in figure 2 reveal exactly the same information with regard to the advice network. In any case, the graph theoretic notation appears to be more confusing and badly arranged. This is especially true for large and complex networks. As we deal with organizational networks with a multitude of actors, the sociomatrix is a more appropriate form to present network data.

Several conclusions about the organizational structure of the firm can be directly drawn from network matrices and graphs. In our example it is obvious that there are considerable

deviations between formal (formal organization) an informal (friendship, advice) structures. The informal networks are much denser than their formal counterparts. Moreover, there are many ties connecting actors of different departments and hierarchical levels, which are not part of the formal organization.

The illustration and visual analysis of network graphs and matrices is the first step when studying organizational structures. On the second level, a variety of network analytical measures can be computed to systematically analyze the organization under examination. In this context, three analytical levels have to be distinguished (Lincoln 1982). The analytical focus shifts depending on whether one analyzes the properties of the entire network (e.g. network density), the properties of single relationships in the network (e.g. dyads, triads), or the positional properties of single network nodes (actors).

On the analytical level of the whole network, *density* is a measure often used to characterize networks. The density can be calculated as the ratio of actual ties to potential ties.[4] As already assumed when looking at the network matrices, the density of the networks in our example varies noticeably. The advice network is the densest one with 45,2%, indicating that information flow in the network is not restricted by formal structures. The friendship network follows with 24,2% while the density of the formal organization only amounts to 4,8%.[5] It becomes obvious that both formal and informal structures have to be taken into account when analyzing organizational networks.

Turning to the level of single network nodes, the *centrality* of actors is often used as a proxy for power. Although centrality is not equal to power, a high correlation is assumed especially in networks of information flow (Bonacich 1987). Actors occupying a central position in a network are considered to be powerful since they have direct access to a number of critical resources (Brass & Burkhardt 1992). Table 1 shows the centrality measures of degree, closeness, and betweeness for the actors on rank one to five. The *degree*[6] measures how often

an actor is named by other actors in the network. The underlying assumption is that many ties create opportunities for valuable transactions. The concept of *closeness*[7] is based on path distance and indicates how close an actor is to the other actors of the network. An actor with a high closeness is able to reach the other actors either directly or via short paths. Consequently, he does not depend on the brokerage of other actors, which saves him from high transaction costs. *Betweeness*[8] in turn bases on brokerage. It measures to what extend an actor is located on the *geodesics*, the shortest paths between nonadjacent actors (Wasserman & Faust 1998).

Advice						Formal Organization					
Rank	*Degree*		*Closeness*		*Betweeness*	*Rank*	*Degree*		*Closeness*		*Betweeness*	
1	Man. 15	20	Man. 15	1,00	Man. 15	0,05	1	Man. 14	8	Man. 7	0,56	Man. 7	0,75
2	Man. 2	19	Man. 2	0,95	Man. 15	0,03	2	Man. 21	5	Man. 14	0,49	Man. 14	0,59
3	Man. 3,	17	Man.	0,87	2, 3, 5, 9		3	Man.	4	Man. 21	0,43	Man. 21	0,37
4	18, 20		18, 20				4	2, 7		Man. 2	0,41	Man. 2	0,28
5							5	Man. 18	3	Man. 18	0,39	Man. 18	0,19

Degree = absolute values, Closeness and Betweeness = relative values

Table 1: Measures of network centrality for the advice network and the formal organization

Table 1 reveals that the precise definition of relations, which are the central object of the examination is crucial for every network analysis. The ranking of the most central actors varies according to the network type. As expected, the CEO (number 7) ranks high in the network of formal organization, whereas he does not even appear on the list of the top 5 as far as the informal network is concerned. Likewise, manager 15 is the most central actor within the advice network, even though he appears only at third level within the formal hierarchy. Occupying such a central position in the network of information flow (advice) it can assumed that his potential influence is much higher than the formal structure would suggest.

Reducing complex network structures

Besides centrality and other basic descriptive measures, several advanced methods exist, which can be applied to reduce complex network structures. Take for example the network of a multinational corporation comprising the headquarters and up to several hundred subsidiaries. When analyzing this kind of large and complex organizations it can be useful to reduce

the network to its underlying macro-structure. For our exemplary data, Table 2 shows the results of a clique analysis of the friendship network. A *clique* is a cohesive subgroup within a network where all members can reach each other through direct ties, i.e. they are adjacent (Wasserman & Faust 1998). Cliques of friendship almost exclusively occur between actors on the third level of hierarchy. In this context manager 17 and manager 11 play important roles, since they are member of three different cliques.

Friendship (confirmed ties only)			
	Actors No.	Department	Level
Clique No.1	17, 12, 4	A, A, D	3, 3, 3
Clique No.2	17, 12, 21	A, A, A	3, 3, 2
Clique No.3	17, 5, 11	A, B, C	3, 3, 3
Clique No.4	15, 19, 11	B, B, C	3, 3, 3
Clique No.5	19, 5, 11	B, B, C	3, 3, 3
Clique No.6	1, 4, 12	D, D, A	3, 3, 3

Table 2: Clique analysis of the friendship network

The identification of subgroups within network organizations is especially useful in the context of information networks. In the case of large geographically dispersed networks, it may happen that different *information islands* emerge being more or less isolated from each other. The existence of such islands hampers the free flow of information within the network. Another research topic could be, if social relations (e.g. friendship or trust) enhance the flow of information. From a methodological point of view, one would have to compare the cliques in the friendship network with results of a clique analysis of the advice network verifying if the cliques in both networks overlap significantly.

A different method to detect subgroups out of complex networks is *blockmodel* analysis. Here, in contrast to clique analysis, actors are not assigned to a block due to a high intrablock connectivity, but because of similar patterns of relationships to non-block members. Actors with similar patterns of relationships are *structurally equivalent*, since they occupy equal positions in networks (White, Boorman & Breiger 1976). This method is especially useful if one aims not only to reduce the patterns of one but of several networks to detect an underlying macro-structure.[9] The application of this methodological tool provides new insights to the

structure and functioning of network organizations. Take for example the literature on different role assignment to the subsidiaries of multinational corporations (Thorelli 1986; Rank 2000). In a first step, blockmodel analysis can be used to identify different groups of subsidiaries according to their embeddedness in network structures. In a second step it could be tested, if the assignment to a specific block is correlated with the assignment of strategic roles. Moreover, it may be tested if the members of different blocks differ according to their profit contribution, growth rate of turnover or other performance measures.

CONCLUSION

In this paper it has been argued that relations play a crucial role with respect to the understanding and management of network organizations. We have shown that a network organization cannot satisfactorily be analyzed by an examination of its members' attributes only. Instead, the structural embeddedness of the actors has to be taken into account. Furthermore, formal as well as informal relations play an essential role. As a consequence, standard statistical methods alone being designed for the analysis of attributes, are not suitable to study the patterns of relationships in organizational networks. In fact, a framework for the analysis of network organizations has to enable both the study of attributive and relational data.

We have presented network analysis as a method we suppose to be particularly well suited for the analysis of network organizations. Thereby, the main focus was put on the basic features of a network analysis. Due to the immense field of potential applications, a general standard procedure prescribing how to design network studies does not exist. Admittedly, there are few general approaches referring to fundamental concepts concerning system delineation, the definition of the types of networks, and the methods of data collection (Wassermann & Faust 1998).

According to the objective of this paper we aimed to demonstrate that the application of network analysis to organizational networks can generate new insights into the functioning of

this organizational form. Moreover, we are confident, that in a further step these insights can be used to derive recommendations for practitioners engaged in organizational tasks.

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NOTES

[1] Economic and legal independence is frequently used in the course of network definitions. However, we consider neither economic nor legal independence as appropriate characteristics of network organizations. From an economic point of view the actors are closely embedded in numerous exchange relationships with the other members of the network. Consequently, the assumption of completely independent market transactions seems to be unrealistic (Granovetter 1985). Also the term legal independence is somehow misleading in the context of network organizations. Although the actors may be legally independent, financial linkages exist between the network partners ranging from wholly owned entities, majority, parity, and minority investments towards different forms of cooperation and joint ventures (Bovasso 1992; Perlitz 2000). With this respect, both economic and legal independence of the actors are only relative.

[2] We highly appreciate the comments of an anonymous reviewer on earlier drafts of this paper who pointed to this problem.

[3] Figure 2 has been drawn with KRACKPLOT, c.f. Krackhard et al. (1994).

[4] In sociometric notation the density Δ of a (directed) network (matrix) X is calculated as: $\Delta X = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} x_{ij}}{n(n-1)}$ where n is the total number of actors and x_{ij} indicates a present tie from actor i to actor j. The density of a network can range from 0 (no ties are present) to 1, where all possible ties are present.

[5] All calculations of network measures have been done with SONIS, c.f. Melbeck (1995).

[6] Actually, two degrees of an actor j exist: The indegree $Din_j = \sum_{i=1}^{n} x_{ij} \quad i \neq j$ counts, how often an actor j is named by other actors i. The outdegree $Dout_j = \sum_{j=1}^{n} x_{ij} \quad i \neq j$ counts, how often actor j names other actors i.

[7] The closeness Cc of an actor j is the inverse of the sum of path distances $d(n_j, n_i)$ from j to all other actors i:

$$Cc(n_j) = \left(\sum_{i=1}^{n} d(n_j, n_i) \right)^{-1} \qquad i \neq j$$

standardized closeness: $C'c(n_j) = \frac{n-1}{\left(\sum_{i=1}^{n} d(n_j, n_i) \right)} \qquad i \neq j$

[8] Given g_{ik} be the number of geodesics between actor i and k. We further assume, that all geodesics are likely to be chosen equally by i and k. It follows that the probability that i and k choose a specific geodesic is $\frac{1}{g_{ik}}$. Moreover, $g_{ik}(n_j)$ be the number of geodesics between actor i and k which contain actor j. The probability $b_{ik}(n_j)$ that i and k choose a geodesic which contain actor j is $\frac{g_{ik}(n_j)}{g_{ik}}$. Finally, the betweeness of an actor j is the sum of the probabilities for all dyads in the network:

$$Cb(n_j) = \sum_{i}^{n}\sum_{k}^{n} b_{ik}(n_j) \qquad j \neq i \neq k$$

standardized betweeness: $C'b(n_j) = \frac{2Cb(n_j)}{n^2 - 3n + 2}$

[9] Technically the CONCOR-algorithm (for blockmodel analysis) is based on product moment correlation coefficients. The rows and/or columns of the original adjacency matrix are correlated in several iterations. Finally, the correlation coefficients between several actors converge to +1. These actors are assigned to a block. For further details c.f. White, Boorman & Breiger (1976) and Wasserman & Faust (1998).