STUDY ON THE KNOWLEDGE -SHARING NETWORK OF INNOVATION TEAMS USING SOCIAL NETWORK ANALYSIS

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Abstract: Under the conceptual framework of social network theory, we study the knowledge-sharing network of innovation teams by using the social network analysis methods. This paper puts particular emphasis on how does the structure of knowledge-sharing network impact on the knowledge flows at the overall level. We expect to find the key man and small groups in knowledge-sharing activities. Comparing with the actual organizational structure, we could improve the efficiency of knowledge flows within the organization.

1 INTRODUCTION

Team is a formal group composed of individuals who make great efforts and cooperate for common goals. Members of team committee common goals, and maintain the mutual responsible relationship. The differences between innovation teams and traditional teams are as follows: innovation team members may be more loosely organized, but they are brought together in a series of research and development projects or tasks. The main work of innovation teams is knowledge innovation. Innovation teams can be defined as: they are collaborative groups which are composed with members who have complementary skills and common mission objectives, and their main tasks are science research and development projects.

From the definition of innovation teams we can see that the efficient knowledge innovation is the most important goal of such teams. Therefore, the knowledge sharing within the team and collaboration capabilities determine the effectiveness of the task (Fu and Liu, 2008). Knowledge flows within the team is a transfer and diffusion process of knowledge. By the action of technology networks and social networks, knowledge flows within the organization exhibit network-like structure which is called knowledge-sharing network. From the perspective of occurrence process, the flow of knowledge exhibit the nature of the connection group, and that is called the feature of "network ". From the perspective of the essence, knowledge flows are strongly influenced by the behaviors of the actors, and that is called the feature of "social" (Chau and Xu, 2007).

Social network theory provides a theoretical basis which embed the actors of knowledge and knowledge-sharing activities into social networks (social structure). Social network theory was first proposed by Simmel. In the sixties and seventies of the 20th century, a series of mid-level theory formed, and at the same time, social network analysis (SNA) method was proposed to generate testable model. Therefore, from the perspective of social relations, under the conceptual framework of social network theory, we research innovation team's knowledge sharing network with the social network analysis method.

2 SOCIAL NETWORK ANALYSIS

Social network analysis views social relationships in terms of network theory consisting of nodes and ties (also called edges, links, or connections). Nodes are

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the individual actors within the networks, and ties are the relationships between the actors. The resulting graph-based structures are often very complex. There can be many kinds of ties between the nodes. Research in a number of academic fields has shown that social networks operate on many levels, from families up to the level of nations, and play a critical role in determining the way problems are solved, organizations are run, and the degree to which individuals succeed in achieving their goals. There are two types of social network which are ego-centered network and whole network. Since we expect to find the key man and small groups in knowledge-sharing activities, we use the whole network theory.

Metrics (measures) in social network analysis are as follows.

2.1 Centrality

This measure gives a rough indication of the social power of a node based on how well they "connect" the network. "Betweenness", "Closeness", and "Degree" are all measures of centrality.

1) Degree Centrality

The first, and simplest, is degree centrality. Degree centrality is defined as the number of links incident upon a node. Degree is often interpreted in terms of the immediate risk of node for catching whatever is flowing through the network. If the network is directed (meaning that ties have direction), we usually define two separate measures of degree centrality, namely indegree and outdegree.

The absolute value of the degree centrality is defined as follows:

$$C_D(n_i) = d(n_i) = \sum_j x_{ij} = \sum_j x_{ji} \qquad (1)$$

The value of x_{ij} is 0 or 1, which means whether there is relationship between the actor *j* and *i* or not.

The standardized value is defined as follows:

$$C'_D(n_i) = d(n)/(g-1) \qquad (2)$$

The definition of centrality can be extended to graphs. The graph *G* (group degree centrality) is defined as follows:

$$C_D = \frac{\sum_{i=1}^{g}\left[C_D(n^*) - C_D(n_i)\right]}{\max\sum_{i=1}^{g}\left[C_D(n^* - C_D(n_i))\right]} \qquad (3)$$

This formula means a gap between the largest degree centrality and the degree centrality of any other actor in the network. The greater this difference is, the higher the group degree centrality of the entire network is. The extreme is the star network.

The situation that the group degree centrality is too high means that the allocation of relationships is uneven in the group. Only several key men participate in the interaction, and this action will lead to the atrophy of knowledge sources and low efficiency of knowledge sharing. However, too low group degree centrality will affect the knowledge sharing within the team.

2) Betweenness

Betweenness is a centrality measure of a vertex within a graph. Vertices that occur on many shortest paths between other vertices have higher betweenness than those that do not.

The betweenness is defined as follows:

$$C_B(n_i) = \sum_{j<k} g_{jk}(n_i)/g_{jk} \qquad (4)$$

The group betweenness is defined as follows:

$$C_B = \frac{2\sum_{i=1}^{g}\left[C_B(n^*) - C_B(n_i)\right]}{\left[(g-1)^2(g-2)\right]} \qquad (5)$$

This formula means a gap between the largest betweenness and the betweenness of any other actor in the network. The greater this difference is, the higher the group betweenness of the entire network is.

In 1992, Burt proposed the concept of structural holes: in the network, if an actor links the other two who have no direct connection between them, then the actor's location is called structural hole, and the actor can control the flow of resources and thus place a profit. Structural holes mark the interest of the location in a network: when a member of an innovation team is on the structural hole, he has chances to access to two types of heterogeneous information flow, and at that time, across the structural holes, the redundancy of the information obtained is very low (Gammelgard et al., 2004).

In topology, a cut-point is a point of a connected space such that its removal causes the resulting space to be disconnected. For example, every point of a line is a cut-point, while no point of a circle is a cut-point. Cut-points are useful in the characterization of topological continua, a class of spaces which combine the properties of compactness and connectedness and include many familiar spaces such as the unit interval, the circle, and the torus.

In accordance with the Burt 's view, there will be small groups in the network which has excessive structural holes. If the network which the actor embeds is a reciprocal relationship network, he will pass information between two small groups which have no strong relationship, and the actor's role become a "bridge "—a position that can stimulate the circulation and sharing of knowledge. In a large creative team, the bridges are essential. For example, some key members of different groups play a bridge role. Through the bridge, small groups can get some overlapping research knowledge to promote innovation activities.

2.2 Small Group

Small group (subgroup or cliques) is a sub-group in which the relationships of the members are particularly close. Small groups can match the factions, which is the overall structure indicators of network.

There are two kinds of methods for the calculation of small groups. First, calculate the node degree, and view a group of connected nodes as a small group. Second, nodes that can be achieved in the distance will be viewed as a small group. In this paper, we select the most commonly used method—K-plex.

K-plex is a Sub-graph that contains g_s nodes. In the graph, each node is connected with g_s-k nodes in the same sub-graph.

The presence of small groups of knowledge-sharing activities has both positive and negative effects. On the one hand, the small group members can maintain a high level of strong ties, to strengthen knowledge sharing effect, and to stimulate knowledge innovation within small groups. In a large innovation team, members of different sub-groups easily form small groups, which is conducive to concentrate their limited forces and improve the stage activities. Another aspect is that if a small group is too self-closing, the knowledge of outside groups can not enter, and the knowledge within the group can not be shared. Extreme cases are: in a team that lacks of a common vision, each member come together only for research or development, and even the division of labor and cooperation can not be fully realized. In such team, knowledge sharing will not be able to achieve, and accumulation of knowledge and innovation also can not be achieved for the whole team.

3 BACKGROUND AND DATA PROCESSING

In this paper, we select a university innovation research team as a knowledge-sharing networks quantitative study object. The purpose of the study is to discover the team's knowledge sharing structure and the status, to identify and solve problems in the knowledge flow and to improve the flow efficiency within the organization.

In the team, there are 14 members engaged in the development of an information system project. We use letters A ~ N to indicate the members. The team's organizational structure is shown as figure 1. A is the leader of the team, while leading a team contained of B, K and H. C and D are assistants of A and they both lead a research team. C's group is the largest, and responsible for the most expensive part of the project. The organizational structure will be compared to the knowledge-sharing network in order to discover problems in the knowledge flow.

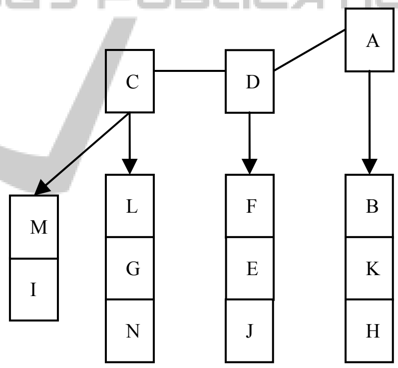

Figure 1: The team's organizational structure.

In accordance with the requirements of the whole network analysis, we first determine the analysis unit and social network boundary. This network is a closed social network composed of 14 members. Then, we determine the important relationship dimension to be analyzed. In this paper we use the 1 - mode network, which only measure the exchange of knowledge among the team members. Then, we design the questionnaire. There are 3 survey questions to answer, including "When confronted with the knowledge and technology difficulties, who would you ask for help?", "Who do you often get the most substantive help from? " and " who do you discuss the situation of the project with?". Three questions are designed to get more knowledge sharing status. Based on the analysis, ultimately the relationship between members is a binary data case. There is a relationship of knowledge sharing or not between any two members.

After gathering up the questionnaire, we must analyze the validity. First, check the questionnaire to delete the failure respondents. In the whole social network analysis, all names of the network will be given to select by the respondents. The answers of different members will be compared. For example, if A selects B in the 3rd title, B does not choose A. This means that the validity of the A's answer is doubt.

After confirming the validity of the questionnaire, we input the data. We use network analysis software UCINET. UCINET (University of California at Irvine NETwork) is a powerful social network analysis software, and originally developed by Linton Freeman who is a scholar in University of California in Irvine, and then maintained by Steve Borgatti in Boston University and Martin Everett in University of Westminster.

Enter the data into UCINET. The knowledge-sharing relationship matrix is shown as figure 2.

	1 A	2 B	3 C	4 D	5 E	6 F	7 G	8 H	9 I	10 J	11 K	12 L	13 M	14 N
1 A		1	0	1	0	0	0	1	0	0	1	0	0	0
2 B	1		1	0	0	0	0	0	0	0	1	0	0	0
3 C	0	1		1	0	0	1	0	1	0	0	1	0	0
4 D	1	0	1		1	1	0	0	0	0	0	0	0	0
5 E	0	0	0	1		1	0	0	0	1	0	0	0	0
6 F	0	0	0	1	1		0	0	0	1	0	0	0	0
7 G	0	0	1	0	0	0		0	0	0	0	1	0	0
8 H	1	0	0	0	0	0	0		0	0	1	0	0	0
9 I	0	0	1	0	0	0	0	0		0	0	0	1	0
10 J	0	0	0	0	1	1	0	0	0		0	0	0	0
11 K	1	1	0	0	0	0	0	1	0	0		0	0	0
12 L	0	0	1	0	0	0	1	0	0	0	0		0	1
13 M	0	0	0	0	0	0	0	0	1	0	0	0		0
14 N	0	0	0	0	0	0	0	0	0	0	0	1	0	

Figure 2: Knowledge-sharing relationship matrix.

4 SNA-BASED KNOWLEDGE-SHARING NETWORK ANALYSIS

4.1 Drawing of Network Diagrams

In UCINET, according to the relations matrix, the software can draw a network diagram, which is shown as Figure 3. As knowledge exchange and sharing is a two-way relationship, the arrows in the diagram are two-way. You can put the diagram as an undirected graph. This diagram can clearly show the knowledge flow within the team and propagation condition. However, in order to descript the problem more accurately, we must analyze the structural parameters of the network specifically.

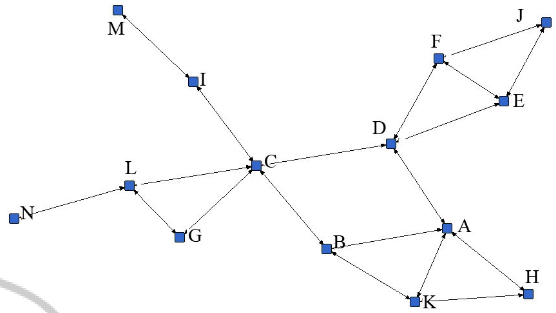

Figure 3: Network diagrams.

4.2 Analysis of Centrality

From the figure 3, we can see that A, C and D have more ties, and they are at the center of the network. Using UCINET, We calculate the degree centrality and betweenness centrality of each member.

The data of degree centrality is shown as Table 1. From the data we can see that, the degree centrality of C is the highest. The absolute value is 5, while the relative value is 38.462%. A and D follow C by the absolute value 4 and the relative value 30.769%. Table 2 shows the overall statistical parameters of degree centrality of the network. The average degree centrality of network nodes is 2.714, and overall relative degree centrality of the network is 20.51%.

Table 1: Degree centrality.

	1 Degree	2 NrmDegree	3 Share
3 C	5.000	38.462	0.132
1 A	4.000	30.769	0.105
4 D	4.000	30.769	0.105
2 B	3.000	23.077	0.079
5 E	3.000	23.077	0.079
6 F	3.000	23.077	0.079
11 K	3.000	23.077	0.079
12 L	3.000	23.077	0.079
7 G	2.000	15.385	0.053
10 J	2.000	15.385	0.053
8 H	2.000	15.385	0.053
9 I	2.000	15.385	0.053
13 M	1.000	7.692	0.026
14 N	1.000	7.692	0.026

Then, we calculate the value of betweenness. The data of betweenness is shown as Table 3. From the data we can see that, the betweenness of C is the highest. D and A follow C. Table 4 shows the overall statistical parameters of betweenness of the network. The average betweenness of network nodes is 51.68%.

Table 2: Statistical parameters of degree centrality.

DESCRIPTIVE STATISTICS

		1 Degree	2 NrmDegree	3 Share
1	Mean	2.714	20.879	0.071
2	Std Dev	1.097	8.441	0.029
3	Sum	38.000	292.308	1.000
4	Variance	1.204	71.247	0.001
5	SSQ	120.000	7100.592	0.083
6	MCSSQ	16.857	997.464	0.012
7	Euc Norm	10.954	84.265	0.288
8	Minimum	1.000	7.692	0.026
9	Maximum	5.000	38.462	0.132

Network Centralization = 20.51%
Heterogeneity = 8.31%. Normalized = 1.26%

Table 3: Betweenness.

	1 Betweenness	2 nBetweenness
3 C	48.000	61.538
4 D	35.000	44.872
1 A	14.500	18.590
2 B	13.000	16.667
12 L	12.000	15.385
9 I	12.000	15.385
6 F	5.500	7.051
5 E	5.500	7.051
11 K	2.500	3.205
7 G	0.000	0.000
10 J	0.000	0.000
8 H	0.000	0.000
13 M	0.000	0.000
14 N	0.000	0.000

Table 4: Sstatistical parameters of betweenness.

DESCRIPTIVE STATISTICS FOR EACH MEASURE

		1 Betweenness	2 nBetweenness
1	Mean	10.571	13.553
2	Std Dev	13.883	17.799
3	Sum	148.000	189.744
4	Variance	192.745	316.806
5	SSQ	4263.000	7006.903
6	MCSSQ	2698.428	4435.287
7	Euc Norm	65.292	83.707
8	Minimum	0.000	0.000
9	Maximum	48.000	61.538

Network Centralization Index = 51.68%

Comparing with the actual organization chart, we can see that A, C and D who have the highest degree centrality are just the team leaders. They are in the heart of knowledge-sharing network as the central figures which are consistent with their roles and responsibilities of work characteristics. They occupy the knowledge of the team, while they coordinate the members to start work and to exchange of views.

The actual position of B is not a leader, but his centrality is very high. He follows three leaders. This shows that B is very active in activities of knowledge sharing. The members N and M whose centralities are at the last two should arouse our attention. They belong to the group led by C, but the ties with other members are very less. This situation may due to the special nature of their tasks or to the design of the organizational structure, the character and ability of members. Thus, we need to analyze the actual situation.

4.3 Analysis of Small Group

In the analysis of small group, the parameter *k* and the Minimum Set Size require repeated attempts to obtain a reasonable classification. After several attempts, we choose *k* to 2, and specify the Minimum Set Size to 4. After calculation, we find that there are 3 knowledge sharing small groups: ABCD, ABHK and DEFJ. Small-group relationship matrix histogram is shown as Figure 4.

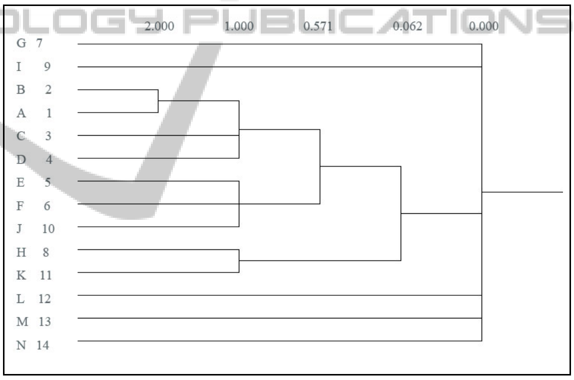

Figure 4: Small-group relationship matrix histogram.

The above words compare the centrality data with the organizational structure, and we analyze the status of knowledge sharing from the perspective of the individual. Now, we compare the knowledge-sharing small groups with the actual organizational structure to analyze the problems in the knowledge-sharing network.

First of all, A, B, C and D form a small group. A, C and D are leaders of the team. B is a very active member in knowledge sharing activities, who is likely to be involved in leadership group as a technical authority. A, B, H and K form a small group. Comparing with the actual organizational structure, we can see that the group is led by A. In this group, only B contact with other members outside the small group. D, E, F and J is just the small group led by the D. Except the leader D, other members have no contact with other small group members. D is the "bridge" of the team. Knowledge sharing within the group is conducive to the knowledge application, but desolation from the whole team will be conducive to failure.

The team led by C has not yet formed small groups, and members tend to conflicts. First, because the members of the group are too many. Second, partly because the work of members is low similar. Both reasons are the organizational structure design problems. As a leader, C should shoulder the task to strengthen knowledge sharing within the group. M and N are at the edges of the entire organization, who must improve their knowledge and communication skills.

5 CONCLUSIONS

Research on the knowledge-sharing networks in innovative team has important significance for improving the efficiency of the team. In this paper, under the conceptual framework of social network theory, using social network analysis methods, we quantitatively analyze the network structure of innovative team, identify the central figures and small groups, and find the knowledge-sharing network flows. Comparing with the actual organizational structure, we discover the defects of the organizational structure. These studies contribute to optimize the knowledge flow within the team.

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