Mapping knowledge flows in virtual teams with SNA

Dr Frank D. Behrend,
Dipl.-Ing. (RWTH), MBA, DBA,
ELIQOS Consulting & Research, Germany
fbehrend@eliqos.com

And

Prof Ronel Erwee,
Faculty of Business, University of Southern Queensland,
Australia,
Erwee@usq.edu.au

Abstract

Purpose - The aim of the paper is to illustrate the use of Social Network Analysis (SNA) to map information and knowledge flow in six virtual project teams with members of diverse cultures in private and public sector companies in different sectors

Methodology/approach - Due to the area of research, we supplemented the in-depth interviews with an embedded SNA questionnaire and two stage analysis.

Findings - The SNA findings demonstrated that network ties are useful predictors of how information and knowledge flows in virtual project teams and can be better indicators than formal project structures. assessment of participants' prestige, activity and influence and their generic formal team functions, thus leadership, member and support roles.

Research limitations/implications – SNA does not yield information about causal factors, context or history of the team contributing to the current team relationships

Practical implications - SNA as a method in this study delivers information on diverse members' influence, prestige and specific team member-related brokerage roles. It highlights what boundary-crossing knowledge sharing activities they engage in and maps the knowledge and information flows between members of the virtual project teams within the companies

Originality/value of paper. The multi-method research design represents a sound approach to target knowledge management in virtual project environments in international contexts.

Introduction

Virtual teams present unique leadership challenges as their members are geographically dispersed, and usually engage in complex projects that necessitate members to coordinate their inputs and contributions. Leaders of virtual teams have to develop practices that ensure that their members benefit from participating in these virtual teams and that the competencies and diversity in experience or insight of members are understood and leveraged (Malhotra, Majchrzak and Rosen 2007). Understanding how members identify each other's competencies and consult each other, builds a map of the emerging social networks within a virtual project team. This delivers information on members' influence, prestige, specific team member-related brokerage roles and what boundary-crossing information and knowledge sharing activities they engage in (Behrend, 2005). Furthermore virtual team leaders use a diversity of communication technologies to monitor work cycles and meetings or to establish and maintain trust. Such technologies can also be used to map information and knowledge flows within the team as well as provide insight into social networks.

One approach to knowledge management is to focus on capturing and transforming organisational knowledge into a corporate asset (Mason and Pauleen 2003; Salojarvi, Furu and Sveiby 2005)) or creating a global knowledge-sharing system (Voelpel, Dous and Davenport 2005) .This approach views knowledge as a process and as being largely a management issue which can be solved via creativity and innovation in the organisation. In contrast to the approaches that focus on increasing access to knowledge through enhanced methods through hypertext linking, databases and searches (Malhotra 2000; Turban and Aronson 2001), the 'soft' approach requires a holistic view of the organisation and acknowledges that it is necessary to get employees to share what they know to make knowledge management work (Gupta and Govindarajan 2000; Malhotra, Majchrzak and Rosen 2007).

In the latter approach to the process of knowledge management in organisations there are often attempts to map the flow of knowledge between people in departments (Poh, 2001; Poh and Erwee 2005), between departments (Leibowitz, 2005), between virtual teams (Behrend, 2005; Behrend, 2006; Furst, Reeves, Rosen and Blackburn 2004), knowledge sharing between far-flung teams (Malhotra and Majchrzak 2004) or between members in regional or international networks (Brown and Erwee 1999; Lake and Erwee 2005). Such studies can reveal broad trends in how members cooperate to complete tasks or it can delve more deeply into members' boundary spanning roles and the consultative practices that evolve due to members' perceived prestige, influence and expertise. One of the aspects that arise in such studies is what are the most appropriate research designs and analytical methods for particular research questions and issues.

A research question that necessitated a range of analytical techniques was "*What are the socio-cultural enabling conditions and network-related processes which support the optimal knowledge creation and exchange in virtual project teams*?" The research issues included aspects of trust, shared language and a common vocabulary, informal networks, boundaries and risk associated with uncontrolled (boundary-spanning) knowledge exchange in virtual teams (Behrend, 2005). A case study approach based on semi-structured depth-interviews represented the primary investigative methodology for this study. Focusing on interview data the overall analysis process started with a within-case analysis, followed by a cross-case analysis and ended with a cross-cluster analysis. Due to the challenging area of research (dynamic social processes within a virtual environment) and limitations of the case study methodology, the qualitative methodology has been supplemented by an embedded Social Network Analysis (SNA).

The aims of this paper are to discuss approaches to SNA and to focus on illustrating the usefulness of SNA to map information and knowledge flow in six virtual project teams with members of diverse cultures in private and public sector companies in international contexts.

Uses Of Social Network Analysis

In many of the previous studies, case study methodology revealed some aspects of the knowledge-creation process of project teams in Singapore-based telecommunications companies for developing customer proposals when responding to a customer's Request for Proposal (Poh, 2004; Poh and Erwee 2004). Case study methodology was also used to investigate how tacit knowledge is made explicit and how relationships and trust are built through the process of knowledge exchange in a regional business network (Lake and Erwee 2005). From other case studies the concept of a Knowledge Integrator Node (KIN) was elicited to refer to persons who deliberately integrate explicit knowledge gained from peers in knowledge creation crews and then disseminate it across organisational boundaries (Brown and Erwee 2002). This concept of '*boundary-spanning'* by knowledge integrators includes and emphasises the way in which they take knowledge gained from working with intra firm knowledge creation crews and progress this knowledge both within the organization and its peripheral stakeholders but also progressively upwards within the organization to more senior management levels as potential inputs into corporate policy decisions (Poh, 2002). In facilitating this knowledge creation and adoption process, the management of knowledge is critical to the efficient functioning of the networked multinational or other company. However, case studies do have their limitations in capturing the complexity of relationships between embedded actors in a network.

Social Network Analysis (SNA) can be used to map knowledge flows and measure relationships between actors in a network (Liebowitz, 2005). It provides a perspective not only on how embedded are actors in a network, but also on how a structure emerges from the interactions of actors in the network. One type of SNA approach advocates collecting information about each actor's ties with all other actors in a network (Hanneman, 2001) whereas another method uses a snowball technique by identifying key actors, gathering information on their relationships and then about the subsequent relationships with an expanding set of actors. A third method would be to use 'egocentic' methods (Liebowitz, 2005) with the selection of certain individuals as focal nodes and analysing their immediate relationships.

In each of the approaches to SNA the information can be collected with measures that could be on a nominal, ordinal, interval or ratio level. InFlow, Krackplot and NETMiner are some of the tools that are most often used in SNA (Liebowitz, 2005). In the analytic hierarchy process (AHP) the strength of ties between actors in a network are calculated on an interval/ratio level and the stepwise process for integrating AHP with SNA to map knowledge in organisations is described by Liebowitz (2005). One of the perceived advantages of AHP's weightings or values graphs is that it could highlight preferences of key actors in a network that could enhance SNA knowledge maps. However, many of the approaches have particular drawbacks such as isolated individuals in a network may be overlooked, data collection of full networks can be costly or it is difficult to identify the key nodes or origin of the network.

Social network analysts use two kinds of tools to represent information about patterns of ties among social actors: graphs and matrices (Hanneman, 2001). A graph (sometimes called a sociogram) is composed of nodes, or actors or points connected by edges or relations or ties. Graphs are very useful ways of presenting information about social networks. However, when there are many actors and/or many kinds of relations, they can become so visually complicated that it is very difficult to see patterns.

In this study we developed and applied a web-based survey to explore team-based knowledge sharing activities around the following key variables a) exchange of information or knowledge, b) knowing other team member's knowledge and skills, c) valuing the expertise of a team member's own work, d) access to other team member's knowledge and e) the cost of seeking information or advice from other team members. Additional control variables 'Gender', 'Tenure', 'Proximity' and 'Sub-group' provided further contextual evidence. One of the most common areas of utilisation for SNA is the investigation of similarities and dissimilarities between the formal organisational structure and the mostly invisible, informal layer behind it and this is illustrated in the second level of analysis of the data.

The focus in the rest of this paper is on the case-based visual analysis of the collected SNA data using graphs. Only *one* of the six cases will be used to illustrate the first stage of the analysis. Thereafter the calculation of actor-related and network-related indices as well as a Correlation Analysis (QAP) complemented the SNA part of the research methodology.

Methodology

Sample: The collected case data originated from six international project teams with an average team size of 14 individuals and team members from Europe, the USA, Australia, Africa and Asia. Participants included private, governmental and non-profit organisations from the IT, telecom, transportation, airline and environmental sector. Further case-independent input from 29 knowledgeable business professionals and international academic sources enriched the overall data basis resulting in a total of 53 interviews.

The *number of SNA questionnaires* depended upon the actual size of the investigated virtual project team. The desired collection of full network data, thus the whole virtual project team, allows for very powerful descriptions and analyses of social network structures, e.g. informal groups within a given team (Hanneman 2001). In essence, this approach is taking a census of ties in a population of actors - rather than a sample. Because information is collected about ties between all pairs or dyads, full network data provides a complete picture of relations within the individual case study setting and therefore represents an ideal supplement to the conducted case study interviews. Given the different team sizes, within a range of 9 to 27 members in each investigated case, a total of 71 SNA questionnaires have been completed.

SNA questionnaire: The utilisation of an online tool, which collects information directly from the subjects, was the most suitable approach for this research. Collecting data from the team members of internationally distributed project teams, using any other method was not practical, due to cost of using postal questionnaires, telephone interviews or onsite visits. A password protected version of the IKNOW Gateway provided by the University of Illinois at Urbana-Champaign has been used for data collection and partly analysis. The application was customised for this research, so that it was able to collect supplemental data and information to support the verification of the research issues and the research question.

The information has been collected from team members of the virtual project teams, by a self-administered profile, based on a number of attributes. The attributes used for the SNA questionnaire and initial profiles for members of each individual case, have been created based on a study by Borgatti and Cross (2003) as well as referring to preliminary discussions with case-related key-informants. In essence, the questionnaire is structured around the idea that information / knowledge exchange is a function of the extent to which a person *knows* and *values* the expertise of another, the *accessibility* of this person and the potential *cost* incurred in seeking information or knowledge from this person. The involvement of the team members in the SNA survey was promoted through a) using the project manager and relevant representatives of the involved groups/organisations as high level sponsors for the research; b) using a sophisticated web-based application to act as a single point of contact for the cost-effective and timesaving data acquisition, and c) the production of guidance documents and appropriate support to make using the application more straight forward (Swarbrick 2002).

SNA questionnaires (Quantitative Data analysis): Visual analysis of the collected SNA data using graphs played an important role. The tools IKNOW and UCINET allowed a visualisation of the network data in a various number of ways. To ensure a systematic and reliable analysis process, we used a fixed analysis sequence regarding the case-by-case investigation. In a first step, visible relationships in network graphs was identified, then central versus peripheral actors compared and finally subgroups investigated. In a second step, these first qualitative findings were compared and contrasted with calculated quantitative indices. This second part of the network analysis has been carried out using UCINET a comprehensive and advanced software package for social network analysis. The selection of the indices has been guided by findings presented by Cross and Parker (2004), Wassermann and Faust (1999) as well as based on feedback from two discussion forums (UCINET 2004; SOCNET 2004).

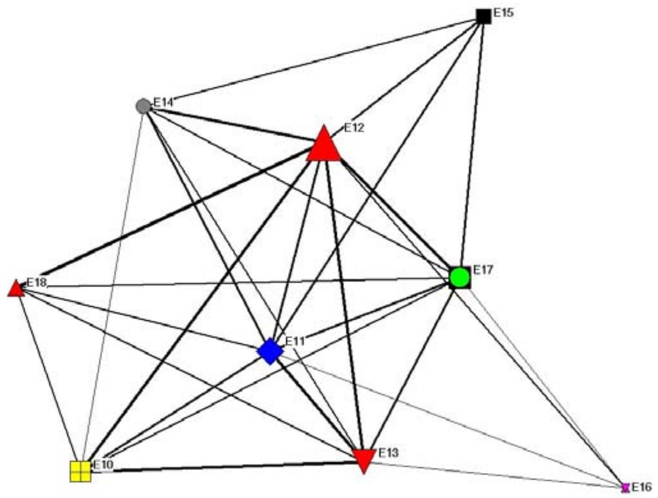
Results

Stage 1 Case Study analysis.

Only *one* case out of the six is used to illustrate the use of SNA graphs in this paper. This global multicultural team carried out a product development and implementation project targeting new customer-related travel benefits for one of the leading airline alliances. The nine team members represented nine different nationalities with a cultural background of 22 percent American, 33 percent European and 44 percent Asian origin. Two individuals belonged to the alliance headquarters and the remaining seven participants represented one individual member airline each. The project team included one female member and an average tenure of 31 months.

Information and knowledge sharing: The following graph (see Figure 1) depicts the team's information and knowledge sharing behaviour and highlights an individual's prestige using different shape sizes. The index is calculated by summing up all actor-related nominations and findings suggest, that team members 'E12', 'E11', 'E13' and 'E17' (in declining order) are the most prestigious ones.

Figure 1: Case E – Visualisation of information and knowledge exchange (Prestige)

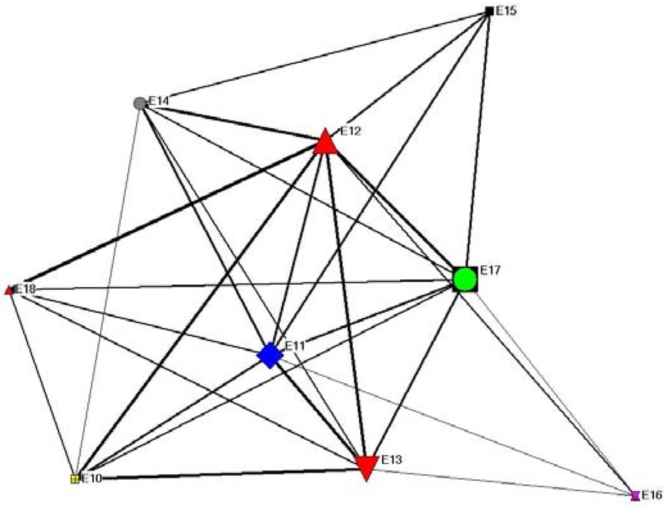


Sub-Unit		Geographic location	
Airline Alliance HQ	> 'Up Triangle'	Country 1	
Airline 1	> 'Down Triangle'	Country 2	
Airline 2	> 'Box'	Country 3	
Airline 3	> 'Diamond'	Country 4	
Airline 4	> 'Square'	Country 5	
Airline 5	> 'Circle'	Country 6	
Airline 6	> 'Thing'	Country 7	
Airline 7	> 'Circle in box'		

Source: Developed from field data using UCINET (2004)

Results from the calculation of degree centrality show that team members 'E12', 'E11', 'E13' and 'E17' (in declining order) are also the most active communicators in this case environment. From an information control perspective actors 'E12', 'E11', 'E13', 'E17' (all equal) followed by 'E14' are most influential (see Figure 1). Nevertheless, it has to be mentioned that, given the comparatively small team size and high member heterogeneity, this assessment has to be interpreted with care.

Figure 2: Case E – Visualisation of information and knowledge exchange (Betweenness)

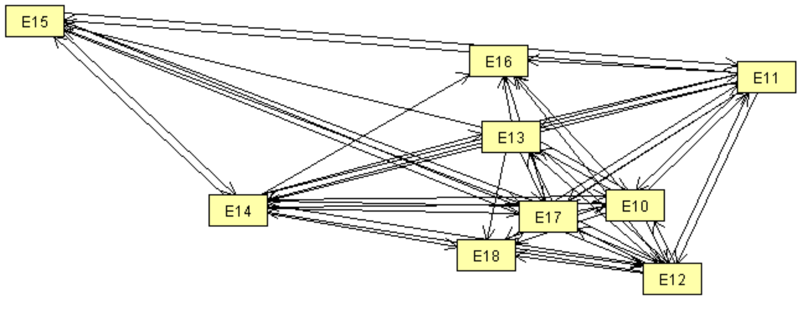


Source: Developed from field data using UCINET (2004)

The supplemental calculation of brokerage measures revealed only a weak liaison role (index value 1,09) for team member 'E13', thus this actor supports or facilitates the connection of individuals belonging to different network-related sub-groups (see Figure 2). Next, further variable-related distinctive attributes that are available in this application of SNA are discussed.

Additional variable-related characteristics: *Sub-group strength* indicates the degree of clustering within each variable-based network. This case environment showed a comparatively low strength across all variables ranging from 3,33 for 'Contact' up to 5,20 for 'Value'(see Figure 3). The visual analysis of *sub-group structure* provided no additional insights. In contrast, the examination of *central and peripheral positions* of team members, disclosed two separate sharing networks, hence 'E10', 'E11', 'E13' and 'E12', 'E16', 'E17', 'E18' focusing on team member's knowledge accessibility. Figure 3 pictures the team-based knowledge awareness and findings suggest that the specific competences and know-how of team member 'E14' and especially 'E15' are not quite transparent for the rest of the team.

Figure 3: Case E – Visualisation of project-related knowledge awareness



Source: Developed from field data using IKNOW (2003)

Regarding the aspect of 'Value', actor 'E12' holds a central position, hence his knowledge seems to be very important for other team members. In addition, the peripheral position of individual 'E15' targeting the variable of 'Cost' raise the notion that sharing information or knowledge with this team member is perceived as expensive. *Network density* increased from 1,694 ('Contact') up to 3,05 ('Value') , whereas *Network cohesion* varied between 0,690 ('GetInfo') and 0,840 ('Cost'). Given the comparatively small team size and high member heterogeneity the calculation of the *E-I index* provided no significant results. Next, relations between different investigated key aspects are discussed.

Cross-variable relationships: Regarding the SNA variables of 'Knowing', 'Value' and 'Cost' as well as 'Access' the Pearson index proved structural equivalence focusing on the project-related sharing network (see Table 1) thus these relational aspects are positively connected with information and knowledge exchange in this particular case environment. The average random correlation was zero with a standard error around 0,195, hence at a typical 0,05 level, these correlations could clearly be considered significant.

These relationships are depicted in Table 1 as Correlation analysis – SNA cross-variable influence on project-related information and knowledge sharing.

Table 1: Case E - Correlation analysis – SNA cross-variable influence on project-related information and knowledge sharing

* Control variables		Value	Signif	Avg	SD	P(Large)	P(Small)	NPerm
Knowing	Pearson Corr.:	0,627	0,000	0,000	0,191	0,000	1,000	10.000
	Jaccard Coeff.:	0,824	0,042	0,755	0,030	0,042	0,990	10.000
Value	Pearson Corr.:	0,649	0,000	-0,001	0,195	0,000	1,000	10.000
	Jaccard Coeff.:	0,824	0,041	0,755	0,030	0,041	0,992	10.000
Access	Pearson Corr.:	0,701	0,000	0,004	0,208	0,000	1,000	10.000
	Jaccard Coeff.:	0,824	0,042	0,755	0,030	0,042	0,990	10.000
Cost	Pearson Corr.:	0,591	0,000	-0,002	0,194	0,000	1,000	10.000
	Jaccard Coeff.:	0,809	0,046	0,743	0,030	0,046	0,990	10.000
Gender *	Pearson Corr.:	0,000	1,000	2,000	0,020	1,000	1,000	10.000
	Jaccard Coeff.:	0,889	1,000	0,889	0,009	1,000	1,000	10.000
Tenure *	Pearson Corr.:	0,015	0,320	0,000	0,031	0,320	0,681	10.000
	Jaccard Coeff.:	0,889	1,000	0,889	0,009	1,000	1,000	10.000
Proximity *	Pearson Corr.:	0,418	0,011	0,003	0,211	0,011	1,000	10.000

	Jaccard Coeff.:	0,094	0,709	0,083	0,018	0,709	1,000	10.000
Sub-Group *	Pearson Corr.:	0,591	0,000	-0,002	0,194	0,000	1,000	10.000
	Jaccard Coeff.:	0,809	0,046	0,743	0,030	0,046	0,990	10.000

Source: Developed from field data using UCINET (2004)

Focusing on the four examined control variables, only '*Proximity*' ($p < 0,05$) and '*Sub-Group'* ($p < 0,001$) revealed significant results with a correlation index of 0,418 and 0,591 respectively. With a numeric value of 0,709 for the Jaccard coefficient regarding 'Proximity', this index contradicts any structural equivalence. In this context, it has to be remembered that this measure is mostly appropriate for low density networks, which none of the analysed projects in retrospect really was. These findings suggest that, in contrast to 'Gender' and 'Tenure', both aspects modulate sharing activities in this particular project environment. Table 2 summarises key findings obtained from the case-related SNA.

Table 2: SNA – Summary of key findings – Case E

Information and knowledge sharing	
Most prestigious actors	'E12', 'E11', 'E13' and 'E17'
Most active actors	'E12', 'E11', 'E13' and 'E17'
Most influential actors	'E12', 'E11', 'E13', 'E17' (all equal) followed by 'E14'
Coordinator role	N/a
Consultant role	N/a
Gatekeeper role	N/a
Representative role	N/a
Liaison role	'E13' (weak)
• Given the comparatively small team size and high member heterogeneity, the calculation of team member influence on information control (Degree Betweenness) has to be interpreted with care.	
Additional variable-related characteristics	
Sub-group structure/strength	Comparatively low strength across all variables ranging from 3,33 for 'Contact' up to 5,20 for 'Value'. The visual analysis of sub-group structure provided no additional insights.
Central and peripheral positions	Focusing on team member's knowledge accessibility two separate clusters, hence 'E10', 'E11', 'E13' and 'E12', 'E16', 'E17', 'E18' could be identified. Specific competences and know-how of team member 'E14' and especially 'E15' are not quite transparent for the rest of the team. Regarding the aspect of 'Value', actor 'E12' holds a central position, hence his knowledge seems to be very important for other team members. The peripheral position of 'E15' targeting the variable of 'Cost' raises the notion that sharing information or knowledge with this team member is perceived as 'expensive'.
Network density	Increased from 1,694 ('Contact') up to 3,05 ('Value')
Network cohesion	Varied between 0,690 ('GetInfo') and 0,840 ('Cost')
E-I Index	Given the comparatively small team size and a high member heterogeneity the calculation of the E-I index provided no significant results.

Cross-variable relationships

- Regarding the SNA variables of ‘Knowing’, ‘Value’ and ‘Cost’ as well as ‘Access’ the Pearson index proved structural equivalence (p < 0,001) focusing on the project-related sharing network, thus these relational aspects are positively connected with information and knowledge exchange in this particular case environment.
- Focusing on the four examined control variables, only ‘Proximity’ (p < 0,05) and ‘Sub-Group’ (p < 0,001) revealed significant results with a correlation index of 0,418 and 0,591 respectively. These findings suggest that, in contrast to ‘Gender’ and ‘Tenure’, both aspects modulate sharing activities in this particular project environment.

In summary, this Stage 1 analytic step focusing on quantitative SNA results included a case-by-case analysis following a predefined three-stage procedural sequence. During the first stage, the case-specific information and knowledge sharing networks in Case E have been visualised and significant team member characteristics and positions e.g. central and peripheral graph positions or brokerage roles been analysed. Primary measures and techniques utilised were SNA graphs developed using IKNOW (2003) as well as NETDRAW (2004), hierarchical clustering (Borgatti, Everett andFreeman 2002) to support the identification of subgroups and a brokerage procedure proposed by Gould and Fernandez (1989) to uncover specific agent functions like gatekeeper, coordinator or liaison.

Stage 2: SNA Pattern analysis and summary

To allow for a better readability and transparency of the SNA method used in the study, this section has been structured based on a case-by-case analysis sequence of *all the cases* and starts with a focus on project-based sharing activities, then additional variable-related characteristics and finally SNA cross-variable aspects.

Information and knowledge sharing: This analysis yields information of similarities and dissimilarities between the formal organisational structure and the ‘invisible’, informal layer behind it. Table 3 presents the informal assessment of participants’ prestige, activity and influence and compares it with their generic formal team functions, thus leadership, member and support roles. Regarding cases A, B, E and F the informal assessment clearly reflects the formal project leadership roles. In cases B and D members of the central support team hold equally significant informal positions, whereby the later setting consists of three separate projects. The majority of corresponding informal leadership positions in case D were held by project sponsors and not designated members of the core team. Even clearer, the general informal assessment focusing on case C does not concur with the formal tripartite team structure as depicted in Table 3.

Table 3: Comparison of informal assessment and formal team roles regarding team-based sharing processes

Informal assessment	Case A		Case B		Case C		Case D		Case E		Case F	
	Actor	Formal	Actor	Formal	Actor	Formal	Actor	Formal	Actor	Formal	Actor	Formal
Prestige	A33	Member	B15	Leader	C10	Member	D25	Support	E12	Leader	F10	Leader
+	A11	Leader	B19	Support	C15	Leader	D18	Leader	E11	Member	F13	Member
	A37	Member	B20	Support	C11	Member	D24*	Member	E13	Member	F12	Member
-	A20	Member	B18	Support	C13	Member	D19*	Leader	E17	Member	F20	Member
	A13	Member	B16	Member	-	-	D10	Leader	-	-	F11	Leader
Activity	A11	Leader	B15	Leader	C10*	Member	D25	Support	E12	Leader	F10	Leader
+	A33	Member	B18	Support	C11*	Member	D18	Leader	E11	Member	F13	Member
	A17	Member	B19	Support	C15	Leader	D24	Member	E13	Member	F12	Member
-	A13	Member	B20	Support	C13	Member	D19*	Leader	E17	Member	F20	Member
	A18	Member	B16	Member	C12	Member	D10*	Leader	-	-	F11	Leader
Influence	A11	Leader	B15*	Leader	-	-	D22*	Leader	E12*	Leader	-	-
+	A33	Member	B18*	Support	-	-	D24*	Member	E11*	Member	-	-
-	A20	Member	B19*	Support	-	-	D25*	Support	E13*	Member	-	-
	A13	Member	B16*	Member	-	-	D15	Member	E17*	Member	-	-
	A22	Member	-	-	-	-	D19	Leader	E14	Member	-	-

* Indicates equal values; Source: Behrend 2005 ; case E was illustrated in the first section of the paper

Other descriptors of boundary-crossing information and knowledge sharing activities are specific team member-related brokerage roles. Table 4 compares the case-related types and quantities of agent positions, while simultaneously indicating team size and number of work locations. Team size seems to be one important prerequisite for the existence of appropriate functions (see cases A and D), yet it is not the only precondition as the comparison of cases B and F shows. Although both settings posses equal descriptive characteristics, case B shows a balanced spectrum of *brokerage roles*, whereas regarding case F two members hold strong liaison positions. The last two project settings reveal no brokerage activity (case C) or one very weak brokerage activity (case E).

Table 4 Quantity and type of case-related brokerage roles

	Case A	Case B	Case C	Case D	Case E	Case F
Team size / No. locations	26 / 3	11 / 4	9 / 4	16 / 11	9 / 7	14 / 3
Coordinator	1x	-	-	-	-	-

Consultant	2x	1x	-	2x	-	-
Gatekeeper	1x	1x	-	1x	-	-
Representative	1x	1x	-	1x	-	-
Liaison	3x	1x	-	3x	1x	2x

Source: Behrend 2005

Next, patterns and schemes emerging from the cross-case evaluation of additional variable–related characteristics are discussed.

Additional variable-related characteristics: The examination of *Sub-Group Strength* shows a generally stable pattern within a value range from 4,0 and 6,0, but with two exceptions. Case A results fluctuate between 10,0 and 12,4, whereas case D reveals a varying progression between 6,0 and 9,0 with two local maxima for variables 'Knowing' and 'Access'. Focusing on *Network Density*, three groups could be identified. Case A results are quite stable around a value of 1,0. Cases B, D and E show an increasing course ranging from 1,8 up to values 3,5 (B). And finally cases C and F, which both stay at a comparatively high level of around 4,0. In addition, nearly all cases show local maxima for variable 'Cost'. Regarding *Network Cohesion* five out of six cases reveal an generally increasing course with two minima for variables 'GetInfo' and 'Access' and a maximum for 'Knowing'. Only case C reveals a fluctuating pattern around a comparatively low value.

Interestingly, the progression of *Actor Simple Prestige* mean copies the case-related network density results patterns described above, although at a lower numeric level. Referring to the corresponding standard deviation cases C and D show a very varying progression compared to the other four cases. Referring to *Actor Degree Centrality* mean all cases exhibit very stable patterns across variables. Focusing on standard deviation, case C shows quite fluctuating and non-directional results. Very heterogeneous courses could be identified regarding *Actor Betweenness Centrality*, with cases A and F at the lower end (0,00) and cases D and E at the higher end (0,06) of the results spectrum. In concordance with earlier findings a highly irregular pattern for attribute-related mean as well as standard deviation could be found focusing on case C. Targeting the last investigated characteristic, *E-I Index*, mean and standard deviation result patterns reveal opposite pictures, thus cases with a low mean, e.g. case F, show a high deviation, whereas cases characterised by high average values, e.g. case A and E, display low deviation results. The subsequent part elaborates issues and relationships derived from a cross-variable correlation perspective focusing on project-related sharing processes.

In summary the *second stage* focused on the examination of additional variable-related characteristics. An important aspect was member-level evaluations focusing on knowledge awareness, knowledge relevance and cost of bilateral sharing. Main calculations and techniques applied were actor indices Actor Simple Prestige, Actor Degree Centrality and Actor Betweenness Centrality computed using

IKNOW (2003). These three measures have also been used in the first stage to investigate case-related information and knowledge sharing networks. Further, UCINET (2004) has been employed to identify and analyse sub-group strength and structure, compute network density and cohesion indices and, finally, to calculate the E-I Index, hence the balance of internal vs. external [communication/sharing] relationships.

Cross-variable relationships: In this final stage the examination of cross-variable structural equivalence focusing on project-related sharing processes (see Table 5) reveals a pairing of variables 'Knowing' and 'Value', thus in all cases these two variables show equivalent results. From a cross-case point of view, the variable 'Access' in general showed the highest correlation with the sharing matrix, whereas control variables 'Gender' and 'Tenure' expose no structural equivalence. Focusing on control variables 'Proximity' and 'Sub-group', the significance level is positive, thus either both of them show relevant correlation with team-based sharing activities or none of them (see cases A, B and E in Table 5). These three cases pose a recognisable and balanced spectrum of brokerage roles. In congruence with earlier SNA findings, case C reveals an abnormal behaviour referring described general patterns and notions.

Table 5. Assessment of cross-variable structural equivalence focusing on project-related sharing processes derived from SNA correlation analysis [1]

	Case A	Case B	Case C	Case D	Case E	Case F
Knowing	0,656 ***	0,599 ***	0,545 **	0,811 ***	0,627 ***	0,651 ***
Value	0,654 ***	0,599 ***	0,581 ***	0,814 ***	0,649 ***	0,647 ***
Access	0,712 ***	0,686 ***	0,699 ***	0,792 ***	0,701 ***	0,725 ***
Cost	0,654 ***	0,686 ***	-	0,755 ***	0,591 ***	0,637 ***
Gender *	-	-	-	-	-	-
Tenure *	-	-	0,109 **	-	-	-
Proximity *	0,296 **	0,591 ***	-	-	0,418 **	-
Sub-Group *	0,225 ***	0,756 **	0,702 **	-	0,591 ***	-

* Control variables
** $p < 0,05$
*** $p < 0,001$; Source: Behrend 2005

In summary this *third and last stage* focused on cross-variable relationships and tested the association between independent ('Knowing', 'Access', 'Value' and 'Cost') and control ('Gender', 'Tenure', 'Proximity' and 'Sub-Group') SNA variables or better networks, and project-related information and knowledge sharing activities. QAP-Correlation analysis (included in UCINET 2004) has been utilised to determine relevant Pearson correlations and Jaccard coefficients including their significance as well as other descriptive statistical measures.

[1] Based on Pearson correlation index calculated using UCINET (2004)

Conclusions

In this study this application of SNA made it possible to conduct a more holistic cross-case and cross-attributes pattern analysis to reveal possible relationships and common themes. First, a comparison targeting the informal assessment of participants' prestige, activity and influence and their generic formal team functions, thus leadership, member and support roles has been carried out. Then, case-related types and quantities of brokerage positions, under consideration of team size and number of work locations, has been contrasted and discussed. Further, the seven main descriptive attributes e.g. actor indices and network density, have been organised and systematically investigated to reveal general, thus case-independent, relationships and concepts. Finally, cross-variable structural equivalence (based on correlation results) focusing on project-related sharing networks has been assessed and general patterns and themes identified.

The results of the study contribute to our understanding of the emerging social networks within each virtual project team. SNA as a method in this study delivers information on diverse members' influence, prestige and specific team member-related brokerage roles. It highlights what boundary-crossing knowledge sharing activities they engage in and maps the knowledge and information flows between members of the virtual project teams within the companies.

Based on SNA results, five out of six cases included individual team members with a measurable difference between the potential accessibility of their knowledge and an incurred cost perceived by others of accessing their knowledge. Focusing on the aspects of *vocabulary and language* two thirds of the participants experienced communication problems in their virtual projects and about half of the interviewees reported negative experiences or problems focusing on knowledge sharing and utilisation. Despite the identified communication problems, more than half of the participants claimed that they share a common language in their virtual project team - technically as well as personally.

Notwithstanding the notion of some authors that *social networks* are the most important vehicles for information and knowledge exchange, the majority of participants assessed the formal project as the primary driving force. Nevertheless SNA findings demonstrated that network ties are useful predictors of how information and knowledge flows in virtual project teams and can be better indicators than formal project structures. In this context, interview findings revealed that on average team members searched around 13 hours per week for necessary information and knowledge and that a general preference for obtaining information from other people, rather than from documents prevailed. Further statistical evidence showed that not-collocated team members meet every 71 days during joint face-to-face project meetings.

Interview findings pointed out that there is a difference between team members who just do their jobs and *boundary* spanners (see also Brown and Erwee 1999; Poh and Erwee 2005) who can bring in new and on-demand knowledge from other areas, thus strengthening a project's reactiveness in dynamic and challenging situations. The application of SNA allowed the in situ calculation of brokerage positions within all investigated virtual project teams, thus supporting the common wisdom that personal networks (those you know) often have a great deal to do with content knowledge (what you come to know). Focusing on individual skills and competences, participant feedback highlighted the significance of project managers to be socially connective, thus linking small collocated cliques within the surrounding virtual fabric, especially in multicultural and interdisciplinary environments (Gupta and Govindarajan 2000;). Hence, in these types of project settings the character of an appropriate job profile of project managers shifts more and more from the managerial, procedural 'mechanic' to a socio-cultural empowered integrator of distributed minds (Behrend 2005; Malhotra, Majchrzak and Rosen 2007). Nearly all interviewees emphasised the need for additional socio-cultural and tool-related skills and characterised the 'ideal' virtual team member as open minded, proactive, flexible and positive person with good communication skills. Malhotra, Majchrzak and Rosen (2007) confirm that their virtual team leaders adapted their leadership practices and one of the challenges was for them to adapt collaborative technologies that be used in different regions in Europe to link team members.

Two thirds of the interviewees claimed that they were not aware of any knowledge losses with respect to their actual project, although half stressed that knowledge is always lost in either virtual or traditional project teams. Research findings supported the notion that project parties may have, deliberately or unconsciously, different perspectives on the direction and boundaries of the knowledge component in their exchange relationship. Referring to knowledge management in multi-institutional, multicultural project environments (see also Behrend, 2005; Poh, 2001) the analysis revealed several *risks* e.g. insecure property rights, loss of integrity during translation of codified knowledge or the fact that internal organisational guidelines of involved project partners may overrule project targets. In most investigated case environments reflective learning was not valued and not implemented systematically, thus knowledge was not secured and therefore lost, because of a primary focus on immediate (task or project-related) problem solving, however neglecting its organisational and long term importance as 'fuel' for cross-project and organisational learning processes (see also Lake and Erwee 2005; Voelpel et al 2005).

The calculation of specific case-related SNA indices enabled the informal assessment of each team member's prestige, activity and influence, thus allowing much more accurate interventions targeting the optimisation of information and knowledge sharing processes. In this context, research findings suggested that its very often socially-enabled tacit knowledge, what ensures the necessary reactivity and flexibility in challenging project situations. Given its contextual limitation and natural decay factor a primarily codification oriented knowledge management approach is doomed to fail in highly dynamic and heterogeneous work settings. Findings derived from qualitative as well as quantitative data showed that participants valued virtual projects as ideal learning environments, nevertheless the analysis also revealed that that virtual work [and related knowledge management], compared to traditional project settings, often puts additional stress on team members (Behrend, 2005). A correlation analysis of SNA-related variables identified several significant relationships, e.g. the extent to which a team member seeks information or knowledge from another individual is positively related to the aspects of ‘Knowing’, ‘Value’ and ‘Access’. In contrast, the variable ‘Cost’ is negatively related, hence if the cost level increases information and knowledge sharing activities decrease. A mediation of information and knowledge sharing by team member gender and tenure could not be confirmed, whereas the variables ‘Proximity’ and ‘Sub-group membership’ influenced sharing processes in half per cent of the investigated case environments.

In summary and given the dynamic and interconnected socio-cultural aspects investigated, this research showed that knowledge management in virtual environments is more complex than common business practice suggests. In contrast with organisations, which are supported by structure, routines and a comparably stable workforce to absorb knowledge, virtual projects miss any natural transfer mechanisms. The research showed that that many teams [and the involved parent organisations] tend to look at virtual project teams and related knowledge management through the filters of an old paradigm thus keeping the old models and old language in place. The nature of relevant knowledge objects, thus either tacit or explicit, and their transferability were not sufficiently taken into account. Nevertheless, projects are guided by the constraints of time, budget and quality, which make the reuse and harnessing of knowledge a necessity. But organisations often launch new initiatives without understanding the inner working of involved formal and informal networks, relying on the philosophy that more communication and collaboration are better.

Limitations of the implemented SNA survey methodology

A limitation of the SNA method is that it depicts the current networks between members, but does not reveal the causal factors, context or history of the team contributing to the current influence patterns or perceptions of prestige or knowledge flows within the team. The team history and context as well causes of the current relationship patterns can be investigated by additional in-depth interviews.

It is common tho assume that observations or measurements of a concept are an additive combination of the ‘true’ score plus error (Wassermann and Faust 1999). Thus it is likely that the developed visualisations of informal networks may differ to a certain degree from the ‘true’ structure. The online application used to collect the necessary SNA data was self administered by the case study participants. To avoid (or better control) operational and technical problems a well designed SNA questionnaire has been developed and tested. In addition, each respondent received appropriate explanatory material and has been offered additional support. Although each data set was checked, it is possible that some of the profiles could have been completed by proxy (Swarbrick, 2002).

Because this study was conducted outside of the remit of the organisation, it was unable to command the same status as other network initiatives that the particular organisations were involved in. This meant that busy team members were limited in the amount of time that they could allow to the study. To handle this potential problem a short, but methodologically sufficient questionnaire has been developed and used. Moreover, in cooperation with the respective project manager and other key-informants of the involved organisations/partners, the individual respondent's interest has been increased in advance using an adequate information (marketing) policy and, in addition, appropriate rewards, e.g. a summary of results, have been offered.

References

Behrend, F.D. (2005), "Socio-cultural challenge of knowledge management in virtual project environments", Doctoral Dissertation, University of Southern Queensland, [unpublished]

Behrend, F.D. (2006), "Trust in Virtual Project Teams – An influential facilitator for knowledge sharing", AWFBMAIT paper , pp 1-6.

Behrend, F.D. (2006), "Social [knowledge] networks – chances and challenges in modern project work". Unpublished paper, pp 1-5.

Borgatti, S.P. and Cross, R.(2003), "A Relational View of Information Seeking and Learning in Social Networks", Unpublished paper.

Brown L.R. and Erwee, R. (1999), "Key actors in networked international firms", in M. Uncles, Patterson, and J. Cadeaux (eds.) *Marketing in the Third Millenium'*, Proceedings of the Australia and New Zealand Marketing Academy Conference, University of New South Wales Sydney 28th November – 1st December

Cross, R., Parker, A., and Borgatti, S. (2002), "*A bird's-eye view: Using social network analysis to improve knowledge creation and sharing".* Available online at http://www-1.ibm.com/services/strategy/e_strategy/social_network.html [assessed February 13, 2003]

Furst, S.A., Reeves, M., Rosen, B and Blackburn, R.S. (2004), "Managing the life cycle of virtual teams". *Academy of Management Executive*, Vol. 18, No 2, pp 6 -20.

Gould, J. and Fernandez, J. (1989), "Structures of mediation: A formal approach to brokerage in transaction networks", *Sociological Methodology*, Vol. 19 , pp. 89-126

Gupta, A.K., and Govindarajan, V. (2000), „Knowledge Management's Social Dimension: Lessons from Nucor Steel", *Sloan Management Review*, Vol. 42, No 1 pp. 71-80.

Hanneman, R.A. (2001), *Introduction to Social Network Methods,* Department of Sociology, University of California, Riverside

IKNOW, 2003, IKNOW (Inquiring Knowledge Networks On the Web) Homepage, University of Illinois, http://iknow.spcomm.uiuc.edu, [Accessed September 4th, 2003]

Lake, P. and Erwee, R. (2005), "Knowledge exchange in a regional network", *International Journal of Organisational Behaviour,* Vol 9, No 1, pp 642-658. http://www.usq.edu.au/business/journals/intjob/articles.htm

Liebowitz, J. (2005), "Linking social network analysis with the analytic hierarchy process for knowledge mapping in orgnisations". *Journal of Knowledge Management*, Vol 9, No 1, pp 76- 86

Malhotra, Y. (ed.) (2000), *Knowledge Management and Virtual Organisations*, Idea Group Publishing, USA.

Malhotra, A., and Majchrzak, A. (2004), "Enabling knowledge creation in far-flung teams: best practices for IT support and Knowledge sharing", *Journal of Knowledge Management*, Vol 8, No 4, pp 75-88.

Malhotra, A., Majchrzak, A. and Rosen, B. (2007), "Leading virtual teams", *Academy of Management Perspectives*, 21 (1): 60-70.

Mason, D. and Pauleen, D.J. (2003), 'Perceptions of knowledge management: A qualitative analysis", *Journal of Knowledge Management*, vol. 7, no. 4, pp. 38-48

Poh, L.G. (2001), „Knowledge management and creation of project teams for developing customer proposals in Singapore telecommunications companies", Unpublished DBA dissertation, University of Southern Queensland, Australia.

Poh, L.G. and Erwee, R. (2005), „Knowledge creation and integration in project teams: A Study of international telecommunications companies in Singapore". *Journal of Management and World Business Research,* Vol 1, No 1, pp 23- 44. http://www.usq.edu.au/business/research/ijob/default.htm

Salojarvi, S. Furu, P and Sveiby, K-E. (2005), "Knowledge management and growth in Finnish SMEs". *Journal of Knowledge Management*, Vol 9, No 2, pp 103-122.

Swarbrick, A. (2002), *Visualising Knowledge Networks: Leveraging the potential of Work Based Communities*, Project report submitted as part of a BSc (Hons) in Information Technology, Business Management and Language degree in the Department of Computer Science at the University of York.

Turban, E., and Aronson, J.E. (2001), *Decision Support Systems and Intelligent Systems*, 6th edn, Prentice Hall, USA.

UCINET, 2004. Ucinet for Windows: Software for Social Network Analysis. Harvard, MA: Analytic Technologies.

Voelpel, S.C., Dous, M. and Davenport, T.H. (2005). "Five Steps to creating a Global Knowledge-Sharing System: Siemens' Sharenet". *Academy of Management Executive*, Vol 19, No 2, pp 9-23.

Wasserman, S., and Faust, K. (1999), *Social Network Analysis: Methods and Applications*, Cambridge University Press, Cambridge, United Kingdom

About the authors

Prof Ronel Erwee

Ronel is Professor and Director of the USQ Australian Graduate School of Business, Faculty of Business, University of Southern Queensland and manages the postgraduate program portfolio of The Faculty of Business. She teaches in International Management, Management Consulting and the DBA program. She supervises PhD and DBA candidates. Her research interests include knowledge management, cross-cultural business networks, managing diversity, internationalisation of companies and organisational change. She has consulted on diversity management in Education Victoria, city councils and other institutions and designed and presented management development programs for Queensland Health, Queensland Police, Lucent Technologies and others.

She serves on the Academic Boards of the Australian Council for Applied Psychology; Australian Institute of Management (QLD&NT) and the Queensland Police Service.

Frank Behrend

Frank obtained a Dipl.-Ing in Germany in aeronautics and astronautics, a MBA from the Netherlands and a Doctor of Business Administration from the University of Southern Queensland, Australia, He has fifteen years of experience as management consultant, coach and researcher in project-, process-, and knowledge management. He is a EFQM and GPM Assessor as well as a certified Project Management Professional.