An SNA-Based Evaluation Framework for Virtual Teams

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Abstract. Organizations are increasingly aware of the underlying forces of social networks and their impact on information and knowledge dissemination within virtual teams. However, assessing these networks is a challenge for team managers who need more complete toolkits in order to master team metrics. Social Network Analysis (SNA) is a descriptive, empirical research method for mapping and measuring relationships and flows between people, groups, organizations and other connected information/knowledge entities. In this article we establish a framework based on SNA to evaluate virtual teams.

Keywords: virtual teams, team performance, team evaluation framework, social networks, social network analysis.

1 Introduction

Globalization, the rise of the knowledge worker, the need for innovation, and the increasing use of information and communication technology (ICT) have given birth to virtual teams as a new form of organizational structure [1]. While virtual teams enable many organizations to enhance the productivity of their employees and tap into a global pool of talent, their implementation often faces significant organizational, technological, personal, and cultural barriers.

Research has thus closely examined how virtual teams are organized. And though teams are considered knowledge processing units [2], the literature around the subject tends to ignore the details of what knowledge was shared how, where, when, and for whom. There has also been little research conducted in the area of social interactions and their consequences on the functioning of virtual teams [3]. In fact, the interactions between team members are considered the logistics through which knowledge is accessed, transferred, and absorbed into new knowledge, ideas and insights [2]. It is thus important to understand the dynamics of social interactions within teams and their impact on team's performance. The study of these interactions is at the heart of Social Network Analysis (SNA). SNA is a discipline that draws concepts and techniques from network theory in order to examine the impact that social networks have on people's behavior [4]. While SNA has provided important measures to evaluate networks, choosing the most pertinent ones to use in a given context is a confusing process.

In this paper we examine the different network metrics that can be used to analyze virtual teams. The next section will make the case of using a network perspective for evaluating virtual teams. In the third section we will delve into Social Network

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Analysis metrics used to evaluate teams. The fourth section will present the framework for the assessment of virtual teams and give an overview on the application of the framework. We conclude by discussing the implications of the framework and future research directions.

2 Evaluating Virtual Teams: A Network Perspective

As organizations are becoming more information-based, more team-based and collaborative, more reliant on technological competence, more mobile and less dependant on geography, [5] their structuring is undergoing a major shift. Many organizations are evolving from the hierarchical, top down structure into a more fluid one, based on relentlessly changing templates, quick improvisation and ad hoc responses [6].

The new form of organizations enables them to innovate by continuously creating new (combinations of) resources. As a result, the functional and matrix team structures are being transformed into temporary virtual project teams and the top-down communication is flowing in a more democratized way. Virtual teams are actually defined as teams that have these key features [2]: (a) Members interact through interdependent tasks guided by common purposes, (b) They use ICT substantially more than face-to-face communication and (c) They are geographically dispersed from each other (a key feature of a virtual team's configuration but not a defining characteristic [1]).

Although these changes have offered speed and agility to organizations, they have also triggered many challenges mainly relative to communication and information flow. In fact, relying on information and communication technologies is thought to restrict the communication process [7] and to limit conveying non-verbal information, which is important for building trust among stakeholders [8].

Managing projects successfully in the midst of autonomous participants, diverse motives, interests and cultures relies on stakeholders sharing a common vision, on building and maintaining trust and on resolving conflicts effectively. Thereby the institution of effective communication and knowledge processes is crucial. While frequency of communication in virtual projects is significantly superior to traditional projects [9], the isolation of team members can decrease motivation and exacerbate distrust [1] causing information hoarding. Therefore the efficiency of the communication process –and thus of teams- needs constant monitoring, as it is easy to fall in the information overload or isolation traps.

Communication is a dynamic network phenomenon. During a project, (organizational or/and unofficial) ties among stakeholders are built to allow knowledge and information dissemination. As the project progresses, links are developed and some disappear, conflicts create barriers while familiarity between members produce enhanced communication channels. Given these dynamics, a "network perspective" can be a viable approach to understanding the underlying forces of project's communication and knowledge dissemination. Therefore techniques from Social Network Analysis (SNA) can provide an effective toolbox to help make sense of these flow patterns and examine the ties between the project's stakeholders under a network perspective. In the next section we present some of the concepts from SNA that would be included in our evaluation framework.

3 SNA on the Team Level

This section aims to define Social Network Analysis and position it in the team context by introducing the key measures used to assess networks in the team level.

3.1 Introducing Social Network Analysis

Social Network Analysis (SNA) is the discipline that studies networks as a mathematical representation of complex systems by expressing them in terms of relational patterns among actors. It is a descriptive, empirical research method for mapping and measuring relationships and flows between people, groups, organizations and other connected information/knowledge entities. SNA has four features [10]: 1) It is motivated by a structural intuition based on ties linking social actors, 2) It is grounded in systematic empirical data, 3) It draws heavily on graphic imagery, and 4) It relies on the use of mathematical and/or computational models.

SNA models complex systems as sets of networks. Networks are composed of "nodes" that represent agents (team stakeholders for instance) and "links" that show the interactions between these nodes.

SNA also provides a collection of measurements that supply specifications in term of patterns of relations, characterizing a group or social system as a whole [11]. These measurements, called structural variables, help validate theories made about group relational structure. Below, we overview key SNA measures that will help understand the framework we're presenting in section 4.

3.2 The Principal SNA Measures for Teams

Empirical literature on the subject of social networks in the team level identified a very diverse set of metrics that describe the structure of networks [3]. We have classified these metrics into three dimensions. Each dimension describes a different aspect of the network structure through a range of measures.

Network Density. Marsden [12] defines network density as "the mean strength of connections among units in a network". It is assessed in the literature of teams through two measures: density and cohesion. Density, according to [11], is the actual number of edges in the graph as a proportion of the total number of possible edges. Leenders et al. [13] define it as the overall level of interactions among the team members, analogous to the number of ties between them. Luo [14] introduced the notion of group viscosity, which is the number of arcs divided by the number of nodes. Density is considered a good estimator of the physical cost of a network (for example: the resources requirements). Cohesion is used by Kratzer et al. [15] as the mean number of contacts per team member. Shrader et al. [16] define it as connectedness, which is the degree to which group members are linked.

Centrality. Centrality is measured on three different levels. The centrality of a node measures how many of the shortest paths between all other node pairs in the network pass through it [17]. This is equivalent to the degree to which an individual is close to all other actors in the network, either directly or indirectly [18]. Kratzer et al. [15] look at centrality as the number of units directly connected to the unit under scrutiny and introduces Peripheral positions as low degree centrality. Mote [19] identifies

three measures: *Closeness centrality*, which is the potential independence of an actor in the flow of communication; *Betweeness centrality*, the extent to which a node is between two other nodes and eigenvector centrality which takes into account not only how many actors you know, but how many they know. *Group centrality or centralization* contrasts the gap between the largest actor centrality and the other values [17]. It ranges from 0 to 1, reaching the maximum when all others choose only one central actor (star) and the minimum when all actors have identical centralities (circle). For [13] it is the extent to which interactions are concentrated in one or a small number of team members rather than distributed equally among all of them. And for Luo [14], it is the variance owned by each group member. When the variance is low no group member is more important than another.

Network centralization is the dispersion of or variance in individual actors' in-degree centrality indices across the group [20]. According to Sparrowe et al. [21] it can be measured as the sum of differences between the largest individual centrality score and the scores of all other individuals in the network divided by the maximum possible sum of differences.

Disconnected Cliques and Bridges. Disconnected cliques and bridges have been measured in different ways through the literature of teams.

When the nearest neighbors of a node are also directly connected to each other they form a cluster. A cluster, also called clique or partition, is a subset of a signed graph where each positive line joins two nodes in the same subset and each negative line joins two nodes in different subsets [11]. Lin et al. [22] identify two members of the same cluster as members who belong to the same block or are structurally equivalent.

The absence of ties between two parts of a network creates structural holes. Balkundi et al. [23] define structural holes as the number of intransitive triads (sets of three connected notes) and vacuously transitive triads divided by the number of triads of all kinds.

Bridging structural holes is called Brokerage. Gluckler and Simon [24] measured a brokerage score based on two parameters: a) the extent to which communication relations are committed to non-redundant contacts and b) The frequency to which a person is on the shortest path connecting any other pair of actors in the network.

And finally, the heterogeneity of a network is measured as the number of distinct external groups upon which the group relies for knowledge. Yang and Tang [25] called this external network range. Oh et al. [26] define heterogeneity, or intergroup vertical bridging conduit, as the group member's informal socializing relationships with the formal leaders of different groups.

Now that we listed the most pertinent metrics related to teams in general, the next section will present a draft framework for the assessment of virtual teams. The framework will use, in addition to SNA metrics, other more commonly used measures that take into account the intrinsic features of the network nodes (team members) and the general outcome of the team (performance and satisfaction).

4 Towards an SNA-Based Framework for Evaluating Virtual Teams

We present in this section a framework for assessing virtual teams on six different dimensions using a three-factors-based model.

4.1 Assessing the Network

A network representing a virtual team is comprised of a set of nodes (team stakeholders) and links that embody the interactions between them. These interactions reflect information and knowledge dissemination among team members and can be collected from the mailing system or the collaborative platform the team is using for the project at hand. We propose that the built network will be assessed on three different aspects:

1) Structural aspect: the structure of a network plays an important role in its outcome.
2) Intrinsic aspect: Looking at the network-intrinsic features. Trust is one of the key factors influencing the performance of virtual teams [27]. Its existence or lack of it reflects the "health of the network".
3) Functional aspect: It evaluates the outcome of the network on two different dimensions: Performance and satisfaction.

Structural Aspect. Identifying the structure of the network is an important first step to examining a network. The table below summarizes the main metrics related to the structure of the network that were stated in the previous section. We utilize those same metrics in order to assess the structure of virtual team.

Table 1. Measures of the network structure

Assessment aspect	Dimension	Metrics
Network structure	Density	Density
		Cohesion
	Group Centrality	Centrality
		Group centralization
		Network centralization
	Disconnected cliques and bridges	Structural holes
		Brokerage score
		Partition/clique/clusters
		Heterogeneity

Intrinsic Aspect. While focusing on the structure of the network, we tend to view the relationships contained in the network as having positive connotations. But in most network settings, interactions between people or groups are regularly beset by controversy, disagreement, and sometimes, outright conflict [28]. It has also been proved that interpersonal trust has direct effect on important organizational processes such as communication, conflict management, satisfaction, and performance (both on the individual and unit level) [29]. Trust is thought to be one of the major challenges virtual teams must face [30]. It is therefore a good indicator of the health of relationships within the network and hence of the overall health of the network.

C. Li [31] introduced three elements that define the level of trust in a social group: Sincerity (are you saying what you genuinely feel or believe?) Competency (Do you have the ability to do what you say you can do successfully or efficiently?) and Reliability (can people depend on you?). Zhi-Ping F. et al. considered trust in the case of virtual teams and provided a more detailed model for trust estimation with two dimensions: Reputation and Collaboration. Reputation represents the trustworthiness

of members in the team and collaboration represents the cooperation situations between members [27]. For each dimension, Zhi-Ping F. et al. identified a range of attributes as described in the table below.

Table 2. Attributes for trust estimation on reputation and collaboration [27]

Dimensions	Attributes	Description
Reputation (R)	Integrity (R1)	Integrity is the member's quality of being honest and morally upright. It is also the normal rule of behavior towards other members
	Competence (R2)	Competence is the required personal qualification to fulfill the task. It reflects as the aptitude, knowledge and skills of Members
	Professionalism (R3)	Professionalism is an authoritative representation in certain fields. It shapes after a long period of learning, instruction and social contact in team cooperation
	Loyalty (R4)	Loyalty is the attitude that makes a member being faithful and endeavor hard to the team cooperation
	Benevolence (R5)	Benevolence is the assessment on how a member concerned about other members' welfare, or either advance other members' interests, or at least not impede them. It reflects as the accommodating behavior towards other members
Collaboration (C)	Cooperative outcomes (C1)	Cooperative outcomes are the work outcomes that one member collaborates with other members through information and resource share
	Collaboration satisfaction (C2)	Collaboration satisfaction is the mutual satisfaction between members in the process of cooperation

With a network perspective, we can argue that reputation attributes (R1, R2, R3, R4, R5) are mostly intrinsic features that characterize the nodes of the network. The cooperative outcomes (C1) and Collaboration satisfaction (C2) on the other hand can be considered as part of the third dimension of our framework that we will discuss in the next section.

Studying trust means thus studying the nodes, i.e. team members, examining how they view themselves and other members of the team and rating it on a 1 to 5 scale. Conducting a survey on egocentric networks can help collect these data. It is worth mentioning though that handling this type of surveys represents a big challenge, as it is difficult to design a rating system and survey questions that wouldn't generate biased final results.

Functional Aspect. Overviewing the literature on the outcome measurements of virtual teams showed that there are two different dimensions to evaluate network outcome: Performance and Satisfaction.

Team performance is defined as the extent to which a team accomplishes its goals or mission [32]. Glückler and Schrott [24] indentified 5 criteria for evaluating team performance: Cooperation, Quality of work, Reliability, Communication and flexibility.

Satisfaction is seen as the extent of the members' perception of decision and agreements with the eventual outcomes [33]. It can be evaluated on different levels: Members satisfaction measures to which extent members liked working in the groups.

Stakeholders' satisfaction measures their contentment with respect to team's achievements. There are two main aspects of satisfaction: "satisfaction with the process" (satisfaction with the interaction process, perceived quality of discussion, and level of teamwork) [34] and "satisfaction with the outcomes" (is related, in part, to the attitudes of the group members towards one another) [35].

Evaluating the outcome of the network can be done regardless of the network perspective. Performance can be measured using three types of methods: grader/ranking (members/supervisors rate team performance related criterions), discussion board/videotape (data is collected and discussions are analyzed), and questionnaires [36]. Satisfaction on the other hand is as intrinsic as trust and can only be examined through surveys destined to gauge team stakeholders' contentment with the final results or with each other.

4.2 Evaluating Virtual Teams

The framework we propose aims to provide an overview of network metrics that can be used to assess virtual teams. The framework is a three-factors-based model that assesses teams on the structural, intrinsic and functional aspects. Assessing virtual teams using this framework means evaluating them on six dimensions. These dimensions can be measured on multiple levels and each level can be evaluated using different metrics (cf. Table 3).

Table 3. Summary of the framework metrics

Assessment aspect	Dimension	Metrics
Network structure	Density	Density
		Cohesion
	Group Centrality	Centrality
		Group centralization
		Network centralization
	Disconnected cliques and bridges	Structural holes
		Brokerage score
		Partition/clique/clusters
		Heterogeneity
Health of the network	Trust	Integrity
		Competence
		Professionalism
		Loyalty
		Benevolence
Outcome of the network	Performance	Cooperation
		Quality of work
		Reliability
		Communication
		Flexibility
	Satisfaction	Satisfaction with the process
		Satisfaction with the outcomes

We have graphically summarized the six dimensions in figure 1. Of the six axes in the polar graph, Trust, performance and satisfaction are positively correlated with teams' well-being. For example, the more trust there is among team members, the better their relationships are and the more effective the team is.

The density axis reflects the level of interaction among the team members and can give an idea on the extent of information dissemination and knowledge exchange within the team. According to [20], [37], internal network density is positively related to team effectiveness. [26] affirms that density has an inversed U-shaped relationship with team effectiveness.

The centrality axis describes the distribution of links in the overall network. Centrality is often a good indicator of the availability of information and the effectiveness of the decision-making process. Studies [38], [39], [40], [20] that examined teams' centrality showed that decentralized networks are more efficient than centralized networks even when solving moderately complex problems. Another set of research [13], [14] on the other hand, found that team centrality is negatively related to its creativity and that only modest centralization has positive impact on team performance.

Finally, the disconnected cliques and bridges axis describes the clusters, structural holes and weak ties existing in the network. Weak ties are used to assess creativity, innovation and inter-units information dissemination. External range has been considered to have a positive impact on team performance [20] [37], [41]. [42] and [43] state that this is not always the case as weak inter-unit ties speed up projects only when the knowledge transferred is not complex. [23] affirm that moderate proportions of structural holes are positively related to team performance.

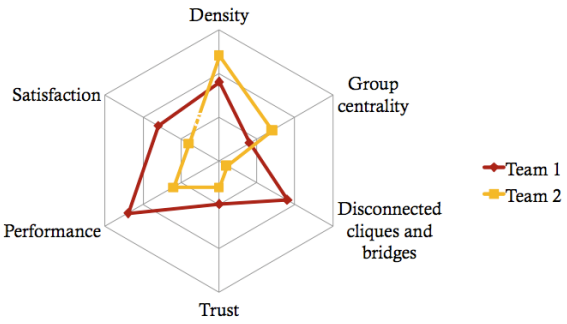

Fig. 1. The six metrics to assess virtual teams

Asserting the correlation between the last three axes and team well-being is hence still waiting to be confirmed by more experimental research. The most recent studies defend an inversed U-shaped relationship where an optimal value has to be reached. This middle value is however very context-based and depends on the nature of the project, the team and the organization. An estimation of this value can still be calculated based on a history of similar projects but wouldn't necessarily be accurate due to the multiple factors that come into play.

The virtual team is rated along each of the six axes and can thereby be visually evaluated. The closer from the periphery the ratings of the three first axes are, the more positive the team well-being can be. If the ratings of the last three axes are neither near the center nor at the periphery, there are more chances they can hit the optimal values.

Assessing virtual teams using this SNA based framework suggests that the evaluator uses the six dimensions mentioned above. It is important though that he chooses the right metrics for his objectives.

5 Conclusion and Future Work

The fundamental goal of this paper is to propose an SNA-based framework to evaluate virtual teams. The framework is a three-factors-based model that assesses teams on six dimensions. A range of metrics is available for every dimension. This suggests that it is up to the evaluator to choose the most adequate indicators to assess his team. A decision support system needs to be built to assist the evaluator in the process of choosing the metrics and weighting them based on their priority. The same system will have to determine how to calculate the metrics and restitute the global results for interpretation. This requires building the network using data collected from a collaborative platform. Further research will need to examine the process of building the network in more details and seek to improve visualization and therefore interpretation [46]. An experimental study will also have to be conducted to refine the framework by applying it on different teams and comparing the final results.

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