2014 47th Hawaii International Conference on System Science

Global Team Boundary Complexity: A Social Network Perspective

J. Alberto Espinosa
Kogod School of Business
American University
alberto@american.edu

Gwanhoo Lee
Kogod School of Business
American University
glee@american.edu

William DeLone
Kogod School of Business
American University
wdelone@american.edu

Abstract

In this paper we propose and develop a "global team boundary complexity" construct based on coordination and complexity theories, to quantify the complexity of the global collaboration environment, from a coordination perspective. The construct contains four formative components: the number of boundary types spanned by the team; the actual number of boundaries spanned; the extent to which boundaries align; and the team member dispersion across these boundaries. We argue that each of these components increases the number of information cues the team needs to process to coordinate the task. We operationalize this measure using social network analysis methods, thus providing a nuanced approach to the study of global team coordination.

1. Introduction

How would you rank the top 10 baseball players in the world? Would you evaluate various attributes independently, or would you use some composite index? Some players may have a higher batting average; others better pitching skills, and so on. Similarly, how would you rank the complexity of the collaboration environment of 10 different global teams? Some global teams span multiple locations and time zones; some have more cultures represented than others, some have more even distribution of members across boundaries, and so on. We argue in this paper that such a metric is not only useful, but necessary to understand what drives effective coordination and top performance in global teams. Furthermore, prior research has shown that more complex global environments lead to additional effort required by team members to succeed [1]. The global boundary complexity metric proposed in this paper can help estimate this additional effort. Because global boundaries often co-exist (e.g., geographic distance, time zone separation, cultural differences, etc.) including all of them in a research model creates problems of multi-collinearity, while excluding some of them causes problems of omitted variable bias. In the end, it is a balancing act. A composite metric that takes into account how much each global boundary in a team contributes to the complexity of the collaboration environment, from the perspective of work coordination, solves this problem. With this objective in mind, we propose and formulate a metric we call *"global team boundary complexity,"* developed in accordance with coordination [2] and complexity [3] theories, and operationalized using social network concepts [4].

In this paper we first discuss coordination theory to ground the concept of global team boundary complexity from this perspective. We then discuss global and virtual team research, with a particular focus on global team boundaries. We follow this discussion with the development of our proposed global team boundary complexity construct, grounded on complexity theory. Next, we provide an overview and brief illustrations on how to operationalize this construct using social network analysis methods, followed by a discussion of results from preliminary analysis and concluding remarks.

2. Coordination Theory

Some task activities can be carried out independently, whereas others are dependent on other activities. Dependencies can be: pooled – i.e., activities depend on some shared resource (e.g., a budget, equipment, etc.); sequential – i.e., a task activity depends on another, but not the other way around (e.g., a software module cannot be tested until the programming phase is complete); or reciprocal – i.e., two task activities are dependent on each other [5]. As dependencies become more tightly coupled and interdependent, they become more difficult to manage. Coordination is precisely defined as the management of these dependencies [2].

This definition has important implications for the definition of our proposed global team boundary complexity construct. First, tasks with relatively independent activities do not require much coordination. Second, coordination processes can defined as the processes employed to manage dependencies. Third, if the dependencies among a number of task activities are the responsibility of a single individual, then there is no need to coordinate

978-1-4799-2504-9/14 $31.00 © 2014 IEEE
DOI 10.1109/HICSS.2014.48

these activities with others. Fourth, if the dependencies among a number of task activities are the responsibility of various team members, these members will need to coordinate with each other. And, finally, to the extent that such members are separated by global boundaries, the management of their dependencies will be hindered. So, how task activities are assigned to various team members and how these members are separated by global boundaries will make the global collaboration environment more or less complex, from a work coordination perspective.

Team members coordinate their work through "mechanistic", "organic" and "cognitive" processes. Mechanistic coordination is achieved by programming or organizing some of the most predictable aspects of the task through things like plans, schedules, procedures, routines, division of labor, etc. [5-7]. Less predictable aspects of the task are generally coordinated organically, through team interaction and communication [5-7], formally or informally [8], in groups or through one-on-one interaction, face-to-face or electronically, etc. As team members become more familiar with each other and each other's task activities, they coordinate some of their work implicitly. Such implicit coordination is based on "unspoken assumptions about what others are likely to do" [9], developed through shared knowledge acquired from training or working with each other over time (e.g., sports teams).

We argue that coordination is negatively affected when global team boundary configurations become more complex, making it more difficult to coordinate organically, because communication is hampered and the team is forced to coordinate mechanistically. Similarly, as team interaction is hindered by global boundaries, the development of shared knowledge within the team, necessary for implicit coordination is also impeded. While each type of boundary will have its unique effects on communication, we argue that the team's ability to coordinate their work will be affected by factors, such as: the various boundary types spanned by the team; the average number of boundaries present for each boundary type; the extent to which these boundaries align; and the dispersion of members across these boundaries, among other things.

3. Global and Virtual Teams Research

There is no denying today that organizational work has become predominantly global. Improved communication tools, the popularity of social media, and offshore outsourcing are examples of factors that have contributed to this trend [10]. It is most common today for a technical project team to be largely virtual and global, working in a complex, geographically distributed collaboration arrangement, seeking to lower costs by leveraging internal and external resources [11]. Such global teams are divided by various boundaries, including distance, temporal, organizational and cultural [12, 13], which impose substantial barriers and challenges to coordinate the work necessary to complete the task [14], creating discontinuities that raise coordination costs [15]. These boundaries often co-exist within a given team and the resulting complexity of collaborating across these multiple boundaries becomes an important risk factor for project success.

Research on virtual teams has proposed concepts like "virtuality" [16-18] and "boundedness" [19] to operationalize the global virtual work environment. These constructs are very useful, but they have limitations when studying team coordination in complex geographic configurations. Some examples of unanswered questions include: how does virtuality or boundedness change as the number of locations or time zones changes in a team or as the distribution of team members across these locations or time zones varies? More importantly, how do these affect how teams coordinate their work? We propose that the complexity of the global team boundary context helps us better understand the coordination challenges faced by global teams.

In this research we develop and propose a construct to quantify this complexity. We posit that it is not the global team boundaries themselves that make it more difficult to manage these dependencies and coordinate, but the complexity of the global team boundary configuration resulting from having to work across multiple boundaries. Therefore, understanding this complexity is very important in figuring out how global teams can coordinate their work more effectively.

4. Global Team Boundary Complexity

In this section we define the global team boundary complexity construct and propose four formative factors [20] that make up this construct. Global team boundaries create barriers that make it difficult for members to communicate and work together [13-15, 21]. How these various boundaries are arranged within a team can make a big difference. Take for example the familiar outsourcing relationship between a U.S. and an Indian firm working together on a technical project. Team members in this context are in only two locations, but the geographical boundary dividing this team aligns perfectly with organizational, distance, time zone, cultural and language boundaries. This alignment of boundaries creates a "faultline," [22] which has been argued to be very difficult to bridge [23]. However, one study [1] has found empirical evidence that team members in two such locations adjusted quite well. They learned how to work effectively with each other because the location, time, organizational, cultural and language differences were well understood by all, so team members were able to implement effective coping mechanisms (e.g., shift work hours, more detailed documentation, use of mobile communication devices, etc.) to work together.

In contrast, another study [24] found that when a team operates in several locations spanning multiple time zones, cultures, languages, and organizations things become more unpredictable and the team has a more difficult time finding a rhythm to coordinate their work effectively. In fact, there were so many locations and time zones represented in one team that team members shifted their work hours so dramatically that some co-located team member had non-overlapping work hours. We refer to this diversity of boundaries, combined with the dispersion of members across these boundaries, as "global team boundary complexity." We refer to complexity theory to better explain this concept [3].

Wood [3] argued that task complexity increases when more information cues need to be processed to carry out the task and indicated that tasks not only have a "structural" component that is inherent to the task, but also have a "coordinative" complexity that is affected by the task context [25]. For example, when a task with interdependent activities is carried out by many team members, their actions need to be coordinated, adding further complexity to the execution of the task. When the context makes it difficult to exchange the information cues necessary to carry out the task – i.e., the task context is more complex – it affects the team's ability to coordinate the task, but this complexity is not captured in the concept of "virtuality". The virtuality dimensions proposed in the literature include: physical distance among team members; level of technology support; percentage of time apart in the task [16]; synchronicity – to distinguish between "real-time" and "lagged-time" interaction [17]; and workplace mobility – to capture the extent to which team members work at various sites, telecommute and use mobile devices [18]. These dimensions are useful but have limitations in helping us understand coordination, particularly when teams are dispersed in more complex geographic configuration arrangements involving several sites. For example, some teams may be widely dispersed (i.e., balanced), while others may have the majority of members in one site with a few isolated members in other sites (i.e., unbalanced) [26], and some teams may be dispersed on a North-South axis with little time zone difference, while others may be dispersed along an East-West axis with substantial time zone differences [24, 27].

As we discussed above, we argue that coordination becomes more challenging when the global team boundary configuration becomes more complex because team members needs to process more information cues to work with each other. As the global team boundary configuration becomes more complex it becomes more difficult to communicate – i.e., coordinate "organically" – because the team is forced to coordinate "mechanistically" using task programming mechanisms like schedules, plans, and division of labor, which are not as effective when task conditions are less routine [6]. Generally speaking, any attribute that forces a team to process more information cues to communicate increases the complexity of the global team configuration.

Consequently, we define the concept of **"global team boundary complexity"** as *the characteristics of the collaboration environment that increase the number of information cues that need to be processed by team members to coordinate their task activities effectively.*

Because this complexity increases as more information cues are added to the global team configuration, we propose that this construct is "formative" [20], composed of a number of factors, each contributing additively to the complexity of the global collaboration environment from a coordination perspective. We propose four such important factors, although we don't claim that these are exhaustive: (1) the different of types of boundaries spanned by the team; (2) the number of boundaries present for each boundary type; (3) the extent to which these boundaries align; and (4) the dispersion of members across these boundaries. In the next few sections we elaborate on each of these factors and formulate propositions associated with their effect on coordination. While various indices and constructs have been proposed to characterize concepts, such as dispersion [27], boundedness [28] and virtuality [16-18, 29], the global team boundary complexity construct we propose in this paper is the first attempt to quantify the overall complexity of the global collaboration environment with a single index, from a task coordination perspective.

4.1 Types of Boundaries Spanned

Members in teams need to process more information cues to get the job done when there are more boundary types (e.g., distance, time zones, organizational, cultural) represented in the team [14]. For example, compared to co-located teams, the complexity of the global collaboration environment increases if spatial boundaries are added to the work environment. The complexity of the global collaboration context increases even further if we then add multiple times, cultures, etc. A team working out of a single location, without any cultural differences, will have less trouble coordinating their work than a team spanning multiple locations, time zones, cultures and organizations. Each boundary present in the team's collaboration environment will create a different type of discontinuity that will increase coordination costs and make it more challenging to communicate [15]. For example, if a co-located team incorporates new members from another location, a discontinuity between the two locations will be created, which will need to be bridged with processes or technologies to work together [1]. Because adding a spatial boundary increases the number of information cues the team needs to process to work on the task, the complexity of the global collaboration environment increases. In other words, the task remains the same, but the global boundary complexity is increased. Similarly, if the two locations are in different time zones, the temporal boundary between the two locations will need to be bridged, making it more challenging to coordinate because team members now need to keep track of when their colleagues come to work and leave for the day and plan their workflow more carefully. Thus, we posit:

Proposition 1: *As the number of boundary types spanned by the team increases, coordination is hindered.*

4.2 Number of Boundaries Spanned

If a single boundary type (e.g., spatial or geographic distance) is represented in a team, then the number of locations in which a team operates will make a big difference [27]. A team operating out of two locations will have some members co-located and others separated by geographic distance. For example, a team of 10 working out of New York and Miami will have, at most five or half of its members separated by distance (i.e., when members are evenly distributed across both locations). However, if the same team is distributed across five locations, then a given member may be separated by distance from eight members or so. As more locations are added the probability of having to cross a spatial boundary to collaborate goes up. Furthermore, team members now need to take into account the specific location of each team member, thus increasing the information cues they need to process to work together. The same is true as more time zones, cultures and organizations are added to the collaboration environment. Thus, we posit,

Proposition 2: *Keeping the number of global boundary types spanned by the team constant, as the number of boundaries spanned by the team within each boundary type increases, coordination is hindered*

4.3 Boundary Alignment

Boundary alignment can also affect communication and coordination. Lau and Murnighan [22] argued, and others confirmed with empirical studies [23] that it is more difficult to work together when group attributes correlate within a subgroup rather than cutting across subgroups because this creates "fault lines", which exacerbate team dynamics with subgroups and fracture a team into subgroups. In the context of geographically distributed teams, fault lines occur when team boundaries correlate within one geographic location more strongly than across geographic locations, resulting in a stronger salience of subgroups by location [30]. Naturally, one would expect fault lines across geographic locations in which multiple boundaries align to hinder coordination. However, data from empirical studies [1] suggest that when teams have incentives to produce and pressures to deliver, team members adjust and learn how to bridge these fault lines, whereas multiple misaligned boundaries create more confusion about how and when to interact [24]. We argue that this confusion stems from the fact that team members need to process more information cues – i.e., the collaboration context is more complex – to figure out who to communicate with and how to interact with them. A team that is divided by a given number of boundary types and a given number of boundaries within each type will need to process more information cues when the different boundaries do not align. For example, a team with distance, time zone, cultural and organizational boundaries operating in three sites will develop familiarity about their collaboration environment faster if each location has the same work hours, culture and organizational membership. Despite the fact that sites are divided by fault lines because all the boundaries align, members will figure out how to collaborate with each site. Conversely, if the same boundary types are distributed across locations, such that each location has more than one set of work hours (i.e., time separation), cultures and organizational memberships, team members will need to process more information cues to collaborate with each of the other sites. Thus, we posit:

Proposition 3: *Keeping the number of global boundary types and number of boundaries spanned by the team constant, as the global team boundary alignment decreases – i.e., boundaries are less aligned, coordination is hindered.*

4.4 Member Dispersion Across Boundaries

Empirical research has provided evidence that a team's geographic configuration – i.e., how team members are distributed across locations, makes a difference [27, 31]. For example, one team with twelve members operating in three sites within the same time zone and without cultural or organizational membership differences will need to process more information cues if there are 4 members in each site (i.e., widely dispersed or evenly balanced) than if ten members are in one central location and each of the other two members are in each of the other two locations (i.e., unevenly balanced or unbalanced). The same is true with respect to time zones, cultures and organizational memberships. Furthermore, recent research has shown empirical evidence that a composite indicator of dispersion across various boundaries has more power predicting team coordination effectiveness than the individual boundary dispersion variables [32]. This is so because team members will need to process more information cues when members are widely spread (or evenly balanced) distribution across time zones, cultures and organizations, than when team members are largely concentrated within a given time zone, culture and organizational affiliation respectively. For example, a team with a high concentration of members in the US and one or two isolated members in India will have less difficulty working as a group than if team members are equally divided between the two locations. The latter will need to bridge more boundaries to communicate and coordinate.

Proposition 4: *Keeping the number of global boundary types and number of boundaries spanned by the team constant, as the member distribution becomes more evenly dispersed across boundaries, coordination is hindered.*

5. A Social Network Perspective

Members in a team have multiple complex relationships with each other, which create structures beyond the simple aggregate of their members [33]. However, a substantial amount of empirical studies involving global teams often collect data at the individual level and aggregated to the team level. This approach works well for smaller and rather homogeneous teams, but it does not provide nuanced insights into how team configurations and processes affect outcomes, especially as teams get larger. Take for example a team of twelve members. The interaction, communication, and coordination in this team will differ widely if all members are interdependent with each other than if there is a central member that acts as a coordination and communication hub. Similarly, there may be other structural properties of the team, like diversity, cliques, isolates, centralities, and clusters, which help better understand how teams coordinate and perform.

Teams are inherently social aggregations of individuals who communicate, interact and share knowledge through communication and actions, creating complex relationships that need to do analysis at a more fine grained level to help explain team dynamics, process, coordination and performance. This exchange can best be represented as a social network. In other words, teams are better understood if viewed as a collection of dyads, rather than as a collection of individuals, with each dyad having a number of relationships, like friendship, advise, supervisory, etc. [34]. This is not a new idea and team research studies are increasingly adopting a social network perspective [31, 35].

Because a given global boundary, by definition, separates two groups of members, using dyadic relationships to represent boundary separations as a social network is an ideal way to model and study global team boundaries. The importance of studying team boundaries with a social network perspective is also not a new idea. The concept of "boundedness" and the importance of understanding social network boundaries was introduced many years ago [36]. Wellman [19] later applied this concept to virtual teams characterizing networks as tightly or loosely bounded in terms of how connected these networks are to external ties. While the concept of global boundary complexity we describe in this paper applies to teams and not to external ties to the team, we find the concept of "boundedness" useful in our conceptualization. One can view global teams as a collection of sub-teams with tightly coupled ties within each boundary, and loosely coupled ties across boundaries, which are more costly to bridge to coordinate work.

For example, we could model how each dyad in a team is separated by time zones and then correlate this with things like communication effectiveness and coordination delay. In fact, prior empirical research has used this approach to studying coordination [31] and trust [29] in global and virtual teams. Employing a social network perspective allows the use of a wealth of methods and tools available to analyze relations between members, such as temporal and spatial differences, communication frequency, dependencies, etc. This approach is also being applied to study knowledge relationships within teams [35]. The limited space in this paper precludes us from an in-depth discussion of social network analysis concepts, but our brief discussion below is important to ground our proposed metrics on sound principles.

5.1 Basic Social Network Concepts

A social network is composed of a number of social actors with a number of relationships among them [37]. Actors may have multiple individual (e.g., intelligence, experience, age, etc.) and relational (e.g., friendship, communication frequency, dependency, etc.) attributes. The two primary forms of network representation used for analysis are sociograms and sociomatrices [4]. Sociograms are diagrams that provide a visual representation of the social network, with social actors as depicted as nodes and their relationships are depicted as links between the nodes. Sociograms can be: "undirected" (i.e., no arrows) when the direction of the relationship doesn't matter – e.g., geographical distance from A to B is the same as from B to A; or directed (i.e., with arrows) when the direction of the relationship matters – e.g., A knows the expertise of B (i.e., A → B), but B may not know the expertise of A. Also, diagrams can be valued when the thickness of the link represents the strength of the tie, or dichotomized with a link depicted when the relationship exceeds a certain threshold and no link otherwise. Generally speaking, dichotomized sociograms are preferred because they provide better visual representations than valued sociograms, which tend to be too dense and cluttered.

A sociomatrix is the quantitative representation of the social network. It is a matrix containing one row and one column for each actor in the network. An off-diagonal cell in the matrix provides the quantitative value of the relationship between the row and column members. Diagonal cells can be left blank if individual attributes don't matter, or contain the value of the individual attribute if important. For example, in knowledge networks an off-diagonal value represents the shared knowledge of the row and column members, whereas the diagonal value represents the knowledge of that member. Sociomatrices can be "symmetric" (i.e., the values above the diagonal are identical to those below the diagonal) for undirected networks or "asymmetric for directed networks. Like sociograms, sociomatrices can be valued, with actual tie strengths represented in the cells, or dichotomized with 1's where links exist in the sociogram and 0's otherwise.

Social networks often represent various complex relationships and are said to be "multi-dimensional" or "multi-attribute" with one sub-network represented for each relation of interest. Each sub-network, layer or dimension can be used as a separate variable in social network analysis software to run analysis like Quadratic Assignment Procedure (QAP) correlations or regressions [37, 38]. Figure 1 provides representations of various relationships for an illustrative software team. Notice in the dependency sub-network that there are 2 dependency cliques, one among software architects and one among testing engineers. Also note that member 8 is the most central member in terms of dependencies, which is not surprising since she is the project manager. The remaining networks depict how members are separated by each of the four boundaries spanned by the team – spatial, temporal, cultural and organizational. In this particular example, we chose to show the dependency links in all sociograms and represent the global boundaries as solid dividing bars because boundaries only matter for coordination when members have dependencies. However, the corresponding sociomatrices show a 1 in a cell if the two members are separated by a boundary and 0 if not. Also note that the temporal boundary sociomatrix has two versions. The valued sociomatrix shows the actual time zone difference between the row and column members. Since prior research has shown that time zone matters when temporal separation exceeds 8 hours [31], we illustrated a dichotomized sociomatrix for temporal boundaries using this value as a threshold (i.e., 1 if the time zone difference exceeds 8 hours and 0 otherwise). These sociomatrices provide the exact distribution of members across boundaries, which can then be easily entered into social network analysis software like UCINET for rich analysis.

5.2 Global Team Boundary Complexity (GTBC) Measure

Figure 2 illustrates the importance of the global team boundary complexity concept. Figure 2a show all the global team boundaries illustrated in Figure 1, together in the same sociogram. The confusing pattern of boundary lines should provide a clear indication of the complexity of the global collaboration environment and the amount of information cues that any two members need to process before they can interact on the task. In contrast, Figure 2b show how much simpler the collaboration environment would be if all the boundaries aligned into a fault line. The fault lines create deep divisions, but because there are only two sides to the fault line team members can figure how to work together with the other side. The ability to represent global team boundaries in sociomatrices as the ones depicted in Figure 1 provides a great opportunity to quantify the GTBC measure. We would like to be careful to state that the measure we propose is a first attempt to provide such a single measure that will encompass the aggregate complexity of the global collaboration environment. As such, we don't make any claims that the boundaries we used are the only ones that should be used, nor that the components we used are exhaustive. More research needs to be done to further develop and validate this measure.

We now discuss how to compute our proposed measure. We use this formula:

GTBC = Average (boundary types, number of boundaries, alignment, member dispersion)

We construct each of the four components of the GTBC measure so that each component assumes a value from 0 to 1, from lowest to highest complexity. It is important to note that this is a straight average, but other weighting schemes are possible, depending on the research goals of the particular study.

- ***Types of Boundary Spanned (TBS):*** this component can be computed by assuming that there are four main types of global team boundaries – i.e., spatial, temporal, cultural and organizational. Therefore, this measure assumes a value of 0, 0.25, 0.50, 0.75 or 1.00 when the team spans zero, one, two, three or four boundaries respectively. Naturally, if other global team boundaries are of interest for a particular study, this measure can be adjusted accordingly. In the example illustrated in Figure 1, TBS = 1.00

- ***Number of Boundaries Spanned (NBS):*** this component can be computed by counting the number of boundaries spanned for each type and dividing this number by the total number of boundaries possible for a team of that size. The number of boundaries of each type in our illustration yield 6 locations (5 boundaries), 4 time zones (3 boundaries), 7 cultures (6 boundaries), and 2 organizations. The maximum number of possible boundaries of each type is 16, since the team has 16 members. Therefore, in our illustration,
NBS = (6+4+7+2)/(4x16) = 0.30.
- ***Boundary Alignment (BA):*** this measure can be computed by comparing all the sociomatrices. While an aggregate comparison is possible, it is more accurate to compare 2 boundaries at a time and computing their respective similarities. The more dissimilar the matrices, the less aligned the boundaries are, and the more complex the global team collaboration environment. This computation can be done by taking one sociomatrix and computing the number of ties in the other sociomatrix that would need to be inverted to make them identical [37]. Take for example the spatial and cultural boundary sociomatrices. Cell (1,2) are 0 and 1 in the spatial and cultural matrices respectively. To make them identical, we would need to switch the 0 to 1 or the 1 to 0. In contrast, cell (1,3) are both 1 in both matrices, so no cell values would need to be switched. Counting the total number of cells that would need to be switched to make the matrices identical, we get: 58 spatial-temporal; 25 spatial-cultural; 43 spatial-organizational; 61 temporal-cultural; 15 temporal-organizational; and 58 cultural-temporal. The maximum number of ties that would need to change is 120 for each pair of boundary types in our illustration. Therefore,
BA = (58+25+43+61+15+58)/(6x120) = 0.36
- ***Member Dispersion across Boundaries (MDAB):*** this measure can be computed as the ratio of total boundaries spanned to the maximum number of boundaries that could be possible spanned by a team of that size. In our illustration, the total number of boundaries spanned can be computed by counting the 1's in the corresponding sociomatrix (i.e., 106 spatial, 48 temporal, 95 cultural, and 63 organizational). The maximum number of possible boundaries spanned in a team of size n is n(n-1)/2 or 16x15/2 = 120 for each boundary in our illustration. Therefore, in our illustration:
BS = (106+48+95+63)/(4x120) = 0.65

So, in our illustration, GTBC = Average (1.00, 0.30, 0.36, 0.65) = 0.58

6. Preliminary Results

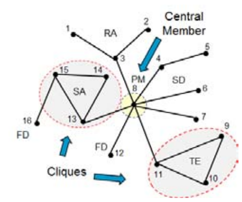
While we have not collected social network data to fully validate our measures, data from a previous study [32] allows us to do some preliminary analysis. In this prior study we collected survey data on 80 global software development projects. We applied survey scales adapted from prior studies [31] to compute a variable on coordination effectiveness. We also used survey responses and geographic data to count the number of locations, time zones, cultures and organizations in each team, as well as the member dispersion across these boundaries. We formulated regression models to find the best predictors of coordination effectiveness. Table 1 displays the preliminary results of this analysis, showing that team member dispersion over multiple boundaries has a stronger negative impact on coordination effectiveness than team dispersion on any individual boundary. While this is insufficient to validate our measure, it provides some preliminary evidence that composite measures that encompass all boundaries are stronger predictors of coordination effectiveness than other individual measures.

Team Boundary Measure	p-value
Team dispersion on all boundaries	0.002
Team dispersion over locations	0.018
Team dispersion over time zones	0.124
Team dispersion over cultures	0.020
Team dispersion over organizations	0.005
Number of locations	0.147
Number of time zones	0.105
Number of cultures	0.439
Number of organizations	0.590
Number of all boundaries	0.183

7. Discussion

This paper is a first attempt to define and formulate a method to compute an aggregate index of global team boundary complexity based on solid principles informed by coordination theory, global and virtual teams research, complexity theory and social network analysis methods. While we are confident that our measure provides an effective way to quantify the complexity of the global team collaboration environment, we realize that much more research is necessary to further refine and validate this measure. Nevertheless, the construct and method proposed here represent an important first step. As we argued earlier, having an effective measure of global team boundary

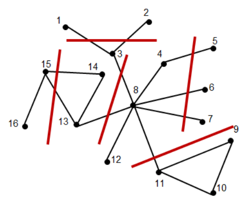
a) Dependencies



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Tot
1		0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2	0		1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
3	1	1		0	0	0	0	1	0	0	0	0	0	0	0	0	3
4	0	0	0		1	0	0	1	0	0	0	0	0	0	0	0	2
5	0	0	0	1		0	0	0	0	0	0	0	0	0	0	0	1
6	0	0	0	0	0		0	1	0	0	0	0	0	0	0	0	1
7	0	0	0	0	0	0		1	0	0	0	0	0	0	0	0	1
8	0	0	1	1	0	1	1		0	0	1	1	1	0	0	0	7
9	0	0	0	0	0	0	0	0		1	1	0	0	0	0	0	2
10	0	0	0	0	0	0	0	0	1		1	0	0	0	0	0	2
11	0	0	0	0	0	0	0	1	1	1		0	0	0	0	0	3
12	0	0	0	0	0	0	0	1	0	0	0		0	0	0	0	1
13	0	0	0	0	0	0	0	1	0	0	0	0		1	1	0	3
14	0	0	0	0	0	0	0	0	0	0	0	0	1		1	0	2
15	0	0	0	0	0	0	0	0	0	0	0	0	1	1		1	3
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		1

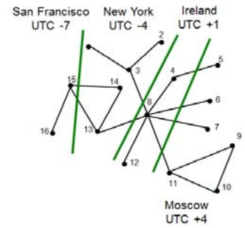
Note: SA–SW architect; RA–Requirements analyst; FD–Functional domain; PM–Project manager; SD–SW developer; TE – Testing engineer

b) Spatial Boundaries



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	0		1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1		1	1	1	1	1	1	1	1	1	0	0	1	1
4	1	1	1		1	1	1	0	1	1	1	0	1	1	1	1
5	1	1	1	1		0	0	1	1	1	1	1	1	1	1	1
6	1	1	1	1	0		0	1	1	1	1	1	1	1	1	1
7	1	1	1	1	0	0		1	1	1	1	1	1	1	1	1
8	1	1	1	0	1	1	1		1	1	1	0	1	1	1	1
9	1	1	1	1	1	1	1	1		0	0	1	1	1	1	1
10	1	1	1	1	1	1	1	1	0		0	1	1	1	1	1
11	1	1	1	1	1	1	1	1	0	0		1	1	1	1	1
12	1	1	1	0	1	1	1	0	1	1	1		1	1	1	1
13	1	1	0	1	1	1	1	1	1	1	1	1		0	1	1
14	1	1	0	1	1	1	1	1	1	1	1	1	0		1	1
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1		0
16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	

c) Temporal Boundaries



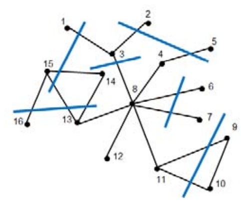
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		0	0	3	8	8	8	3	8	8	8	3	0	0	3	3
2	0		0	3	8	8	8	3	8	8	8	3	0	0	3	3
3	0	0		3	8	8	8	3	8	8	8	3	0	0	3	3
4	3	3	3		3	3	3	0	3	3	3	0	3	3	8	8
5	8	8	8	3		0	0	3	0	0	0	3	8	8	11	11
6	8	8	8	3	0		0	3	0	0	0	3	8	8	11	11
7	8	8	8	3	0	0		3	0	0	0	3	8	8	11	11
8	3	3	3	0	3	3	3		3	3	3	0	3	3	8	8
9	8	8	8	3	0	0	0	3		0	0	3	8	8	11	11
10	8	8	8	3	0	0	0	3	0		0	3	8	8	11	11
11	8	8	8	3	0	0	0	3	0	0		3	8	8	11	11
12	3	3	3	0	3	3	3	0	3	3	3		3	3	8	8
13	0	0	0	3	8	8	8	3	8	8	8	3		0	3	3
14	0	0	0	3	8	8	8	3	8	8	8	3	0		3	3
15	3	3	3	8	11	11	11	8	11	11	11	8	3	3		0
16	3	3	3	8	11	11	11	8	11	11	11	8	3	3	0	

Valued (actual time zone difference)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		0	0	0	1	1	1	0	1	1	1	0	0	0	0	0
2	0		0	0	1	1	1	0	1	1	1	0	0	0	0	0
3	0	0		0	1	1	1	0	1	1	1	0	0	0	0	0
4	0	0	0		0	0	0	0	0	0	0	0	0	0	1	1
5	1	1	1	0		0	0	0	0	0	0	0	1	1	1	1
6	1	1	1	0	0		0	0	0	0	0	0	1	1	1	1
7	1	1	1	0	0	0		0	0	0	0	0	1	1	1	1
8	0	0	0	0	0	0	0		0	0	0	0	0	0	1	1
9	1	1	1	0	0	0	0	0		0	0	0	1	1	1	1
10	1	1	1	0	0	0	0	0	0		0	0	1	1	1	1
11	1	1	1	0	0	0	0	0	0	0		0	1	1	1	1
12	0	0	0	0	0	0	0	0	0	0	0		0	0	1	1
13	0	0	0	0	1	1	1	0	1	1	1	0		0	0	0
14	0	0	0	0	1	1	1	0	1	1	1	0	0		0	0
15	0	0	0	1	1	1	1	1	1	1	1	1	0	0		0
16	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	

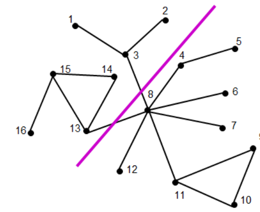
Dichotomized ΔTZ>8

d) Cultural Boundaries



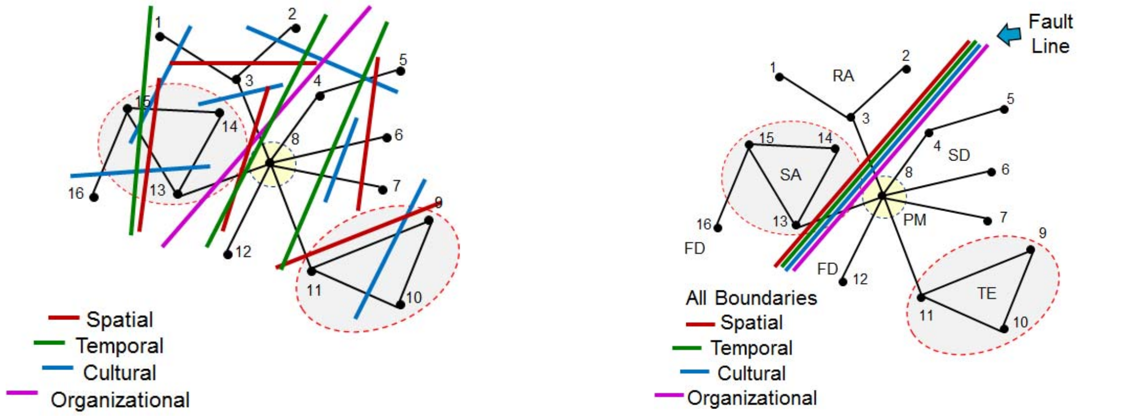
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
2	1		1	1	0	1	1	1	1	1	1	1	1	1	1	1
3	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1		1	1	1	0	1	1	0	0	0	0	1	0
5	1	0	1	1		1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1		0	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	0		1	1	1	1	1	1	1	1	1
8	1	1	1	0	1	1	1		1	1	0	0	0	0	1	0
9	1	1	1	1	1	1	1	1		0	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	0		1	1	1	1	1	1
11	1	1	1	0	1	1	1	0	1	1		1	0	0	1	0
12	1	1	1	0	1	1	1	0	1	1	1		0	0	1	0
13	1	1	1	0	1	1	1	0	1	1	0	0		0	1	0
14	1	1	1	0	1	1	1	0	1	1	0	0	0		1	0
15	0	1	1	1	1	1	1	1	1	1	1	1	1	1		0
16	1	1	1	0	1	1	1	0	1	1	0	0	0	0	0	

e) Organizational



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		0	0	1	1	1	1	1	1	1	1	1	0	0	0	0
2	0		0	1	1	1	1	1	1	1	1	1	0	0	0	0
3	0	0		1	1	1	1	1	1	1	1	1	0	0	0	0
4	1	1	1		0	0	0	0	0	0	0	0	1	1	1	1
5	1	1	1	0		0	0	0	0	0	0	0	1	1	1	1
6	1	1	1	0	0		0	0	0	0	0	0	1	1	1	1
7	1	1	1	0	0	0		0	0	0	0	0	1	1	1	1
8	1	1	1	0	0	0	0		0	0	0	0	1	1	1	1
9	1	1	1	0	0	0	0	0		0	0	0	1	1	1	1
10	1	1	1	0	0	0	0	0	0		0	0	1	1	1	1
11	1	1	1	0	0	0	0	0	0	0		0	1	1	1	1
12	1	1	1	0	0	0	0	0	0	0	0		1	1	1	1
13	0	0	0	1	1	1	1	1	1	1	1	1		0	0	0
14	0	0	0	1	1	1	1	1	1	1	1	1	0		0	0
15	0	0	0	1	1	1	1	1	1	1	1	1	0	0		0
16	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	

Figure 1: Multi-Dimensional Network Illustration of a Software Team



a) **Global Team Boundaries Don't Align**

b) **Global Team Boundaries Align into a Fault Line**

Figure 2: Multi-Dimensional Network Illustration of a Software Team

complexity can help overcome the serious methodological problems faced by global teams researchers that arise because, while global team boundaries are very distinct in nature, they often correlate with each other. Thus, studies who do not include all boundary measures in their research models will suffer from omitted variable bias and lack of appropriate controls.

On the other hand, studies that include all boundaries in the models will often run into problems of multi-collinearity due to the strong correlation among boundary variables. Thus, having a single composite measure of global boundary complexity is an important contribution towards resolving this serious methodological challenge. Our study contributes to the research literature on global teams by providing a more nuanced approach to study how teams coordinate by relying on a global team boundary complexity measure, while providing rich details afforded by social network analysis methods, which can help uncover interesting structural properties of the various network layers, such as clusters, cliques, centralities, isolation, etc. Our study also contributes to practice by illustrating an effective way to characterize the complexity of global team collaboration environments, which can influence management decisions regarding team configuration and coordination methods.

8. Acknowledgements

This study was financed by the Center for Information Technology and the Global Economy (CITGE) at the Kogod School of Business at American University, Washington, D.C.

9. References

[1] Espinosa, J.A., Lee, G., and DeLone, W.: 'Global Boundaries, Task Processes and IS Project Success: A Field Study', Information, Technology and People, 2006, 19, (4), pp. 345-370

[2] Malone, T., and Crowston, K.: 'The Interdisciplinary Study of Coordination', ACM Computing Surveys, 1994, 26, (1), pp. 87-119

[3] Wood, R.E.: 'Task Complexity: Definition of the Construct', Organizational Behavior and Human Decision Processes, 1986, 37, (1), pp. 60-82

[4] Scott, J.: 'Social Network Analysis: A Handbook' (Sage Publications, 1991. 1991)

[5] Thompson, J.: 'Organizations in Action' (McGraw-Hill, 1967. 1967)

[6] March, J., and Simon, H.A.: 'Organizations' (John Wiley and Sons, 1958. 1958)

[7] Van de Ven, A.H., Delbecq, L.A., and Koenig, R.J.: 'Determinants of Coordination Modes Within Organizations', American Sociological Review, 1976, 41, (2), pp. 322-338

[8] Kraut, R.E., and Streeter, L.A.: 'Coordination in Software Development', Communications of the ACM, 1995, 38, (3), pp. 69-81

[9] Wittenbaum, G.M., and Stasser, G.: 'Management of Information in Small Groups', in Nye, J.L., and Brower, A.M. (Eds.): 'What's Social about Social Cognition?' (Sage Publications, 1996), pp. 3-27

[10] Carmel, E., and Tjia, P.: 'Offshoring Information Technology : Sourcing and Outsourcing to a Global Workforce' (Cambridge University Press, 2005. 2005)

[11] Powell, A., Piccoli, G., and Ives, B.: 'Virtual Teams: A Review of Current Literature and Directions for Future Research', Data Base for Advances in Information Systems, 2004, 35, (1), pp. 6-36

[12] Lipnack, J., and Stamps, J.: 'Virtual Teams: Reaching Across Space, Time, and Organizations with Technology' (John Wiley & Sons, 1997. 1997)

[13] Orlikowski, W.: 'Knowing in Practice: Enacting a Collective Capability in Distributed Organizing', Organization Science, 2002, 13, (3), pp. 249-273

[14] Espinosa, J.A., Cummings, J.N., Wilson, J.M., and Pearce, B.M.: 'Team Boundary Issues Across Multiple Global Firms', Journal of Management Information Systems, 2003, 19, (4), pp. 157-190

[15] Watson-Manheim, M.B., Chudoba, K., and Crowston, K.: 'Discontinuities and Continuities: A New Way to Understand Virtual work', Information, Technology and People, 2002, 15, (3), pp. 191–209

[16] Griffith, T.L., Sawyer, J.E., and Neale, M.A.: 'Virtualness and Knowledge in Teams: Managing the Love Triangle of Organizations, Individuals, and Information Technology', MIS Quarterly, 2003, 27, (2), pp. 265-287

[17] Kirkman, B.L., and Mathieu, J.: 'The Dimensions and Antecedents of Team Virtuality', Journal of Management, 2005, 31, (5), pp. 1-19

[18] Lu, M., Watson-Manheim, M.B., Chudoba, K.M., and Wynn, E.: 'How Does Virtuality Affect Team Performance in a Global Organization? Understanding the Impact of Variety of Practices', Journal of Global Information Technology Management, 2006, 9, (1), pp. 4-23

[19] Wellman, B.: 'For a Social Network Analysis of Computer Networks'. Proc. ACM SIGCPR/SIGMIS Conference on Computer Personnel Research 1996 pp. Pages

[20] Petter, S., Straub, D., and Rai, A.: 'Specifying Formative Constructs in Information Systems Research', MIS Quarterly, 2007, 31, (4), pp. 623-656

[21] Cummings, J.: 'Work Groups, Structural Diversity, and Knowledge Sharing in a Global Organization', Managment Science, 2004, 50, (3), pp. 352-364

[22] Lau, D., and Murnighan, J.K.: 'Demographic Diversity and Faultlines: The Compositional Dynamics of Organizational Groups', Academy of Management Review, 1998, 23, (2), pp. 325-340

[23] Polzer, J.T., Jarvenpaa, S., Crisp, C.B., and Kim, W.Y.: 'Extending the Faultline Model to Geographically Dispersed Teams: How Colocated Subgroups Can Impair Group Functioning', Academy of Management Journal, 2006, 46, (4), pp. 679-692

[24] Espinosa, J.A., and Pickering, C.: 'The Effect of Time Separation on Coordination Processes and Outcomes: A Case Study', in Editor (Ed.)^(Eds.): 'Book The Effect of Time Separation on Coordination Processes and Outcomes: A Case Study' (IEEE, 2006, edn.), pp.

[25] Xia, W., and Lee, G.: 'Complexity of Information Systems Development Projects: Conceptualization and Measurement Development', Journal of Management Information Systems, 2005, 22, (1), pp. 45-83

[26] O'Leary, M.B., and Mortensen, M.: 'Go (Con)figure: Subgroups, Imbalance, and Isolates in Geographically Dispersed Teams', Organization Science, 2009, 21, (1), pp. 115-131

[27] O'Leary, M.B., and Cummings, J.N.: 'The Spatial, Temporal, and Configurational Characteristics of Geographic Dispersion in Teams', MIS Quarterly, 2007, 31, (3)

[28] Wellman, B., Salaff, J., Dimitrova, D., Garton, L., Gulia, M., and Haythornthwaite, C.: 'Computer Networks as Social Networks: Collaborative Work, Telework, and Virtual Community', Annual Review of Sociology, 1996, 22, pp. 213-238

[29] Jarvenpaa, S., and Leidner, D.: 'Communication and Trust in Global Virtual Teams', Organization Science, 1999, 10, (6), pp. 791-865

[30] Cramton, C.D., and Hinds, P.: 'Subgroup Dynamics in Internationally Distributed Teams: Ethnocentrism or Cross-National Learning?', Research in Organizational Behavior, 2005, 26, pp. 233-265

[31] Cummings, J., Espinosa, J.A., and Pickering, C.: 'Crossing Spatial and Temporal Boundaries in Globally Distributed Projects: A Relational Model of Coordination Delay', Information Systems Research, 2009, 20, (3), pp. 420-439

[32] Lee, G., Espinosa, J.A., and DeLone, W.: 'Task Environment Complexity, Global Team Dispersion, Process Capabilities, and Coordination in Software Development', IEEE Transactions on Software Engineering, in press

[33] Wooley, A.W., Chabris, C.F., Pentland, A., Hashmi, N., and Malone, T.W.: 'Evidence for a Collective Intelligence Factor in the Performance of Human Groups', Science, 2010, 330, (6004), pp. 686-688

[34] Krackhardt, D.: 'Predicting With Networks: Nonparametric Multiple Regression Analysis of Dyadic Data', Social Networks, 1988, 10, pp. 359-381

[35] Espinosa, J.A., and Clark, M.A.: 'Team Knowledge Representation: A Network Perspective', Human Factors, In press

[36] Laumann, E., Marsden, P., and Prensky, D.: 'The Boundary Specification Problem', in Burt, R., and Minor, M. (Eds.): 'Applied Network Analysis' (Sage

1983), pp. 18-34

[37] Wasserman, S., and Faust, K.: 'Social Network Analysis: Methods and Applications' (Cambridge University Press, 1994. 1994)

[38] Borgatti, S.P., Everett, M.G., and Freeman, L.C.: 'UCINET for Windows: Software for Social Network Analysis', in Editor (Ed.)^(Eds.): 'Book UCINET for Windows: Software for Social Network Analysis' (Analytic Technologies, 2002, V edn.), pp.