Constructing GIS: Actor Networks of Collaboration

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Abstract: *The social coordination of geographic information technologies relies on collaboration between actors from the public, private, and education sectors. Diffusion, implementation, information sharing, and studies of the use of geographic information systems (GISs) examine the collaboration in relation to specific activities. Applying concepts from actor network theories, this article examines the socio-technical context. The construction metaphor distinguishes social network approaches from actor network approaches. This research provides insight into the relationships of GIS socio-technical networks, which are invaluable for understanding the alliances, data sharing arrangements, and standards necessary for specific GIS tasks or functions. The results of research suggest that collaboration involve the construction and maintenance of hybrid networks that connect multiple human and non-human actors into strategic alliances. An important finding is that technologies are among the "key players" in the GIS community. Standards, an organizational technology, focus strategic alliances and involve diverse groups in mutually beneficial projects. These groups are in long-term relationships that the introduction of GIS technologies can substantially alter.*

Collaboration And Socio-technical Construction

Information technology researchers usually examine collaboration in the context of specific tasks or functions. Normally presented from a system engineering approach, the implementation of geographic information systems (GISs) considers isolated functional and technical issues. This approach extricates organizational and institutional issues and emphasizes tasks in a Taylorist analysis of functionality. Literature on GIS diffusion emphasizes the organizational setting in which agencies develop GIS in relation to administrative activities and GIS functions. Diffusion literature (Rogers 1983) contextualizes functions in their organizational setting.

Previous organizational research has shown the importance of social factors for GIS (Calkins and Obermeyer 1991, Nedovic-Budic and Godschalk 1994, Pinto and Azad 1994, Campbell and Masser 1995). Designing and developing GIS is a complex process involving a diverse range of professionals and administrators, among other groups. Research on data sharing demonstrates that institutional factors are the greatest impairment in developing GIS (Onsrud and Rushton 1995). Literature on diffusion underscores the importance of institutional factors. Campbell and Masser show that the effectiveness of GIS in practice is directly tied to the institutional adoption of the technology. Working in the diffusion paradigm, Assimakopoulos (1997) traced the social network in the GIS community in Greece and examined how GIS innovations were diffused in this network.

In traditional sociology, a network consists of individual nodes that exchange with each other through conduits for communication. The classical sociological understanding of a network focuses on relationships between individuals as representatives of groups. This work complements the actor network theoretical framework deployed in this paper to understand the context in which social coordination of GIS occurs. Where social networks study specific interactions between individuals and groups, actor network theories focus on examining actors' wide-ranging relationships and tracing activities in networks. The social coordination involved in developing and using a GIS can be understood through a construction metaphor and the collaboration necessary to construct a building. Where implementation and use studies examine construction in terms of the tasks involved, the construction metaphor looks at how activities are coordinated.

A construction metaphor is also useful for distinguishing actor network studies from social networks. From the functionalist viewpoint that characterizes most social network studies, construction is an undertaking defined by an objective and realized through the coordination of many individuals and groups. It orients itself to a plan and follows it closely. In actor network studies, the emphasis is on the skills and expert knowledge of the workers, craftspeople, and artisans, and their many relationships. In practical work, they must resolve unexpected challenges and maximize opportunities through solutions that ensure the stability of the construction and augment their position in society. In addition to acquiring and maintaining skills, craftspeople and artisans must collaborate with persons from other trades. They are engaged in multiple networks that go beyond the construction project at hand. Systems engineering and diffusion literature consider contingent networks of relationships only with regard to a particular activity. The study presented here explores the nature of relationships without limiting the analysis to a particular issue.

An additional strength of the actor network approach is that it transcends the limits of the construction metaphor. While the construction of a physical structure is finished at a point, a GIS has interest by many in the community; it is usually never com-

pleted, but is always being "built." In other words, GIS calls for constant construction to meet the changing demands of its "dwellers." This poses special challenges for studies of GIS construction, as with other large technological systems. Actor network theories provide a framework for understanding the ongoing coordination that precedes every building activity.

The activities of GIS technology specialists and professionals are social and technical. A relevant characteristic for actor network studies is the conviction that specialists are not "ivory tower" dwellers, but are actually deeply mired in the practical contingencies of everyday practices. Construction and maintenance are messy. Callon (1987) and others suggest that specialists such as engineers are not full-time technologists but are part-time technologists and part-time sociologists. They are continually enmeshed in relationships both within and outside their disciplines.

These points are especially pertinent for GIS. GIS is a "young" field that lies between many disciplines. Cartography, surveying, and computer science are pre-eminent, but many other fields use and develop GIS. Such specialists as surveyors, planners, and sanitary engineers come from distinct disciplinary backgrounds that involve constant arbitration with other groups. The relationships between different groups cannot be reduced to one network but consist of multiple networks with different degrees of membership. Just as people are not one-dimensional stereotypes, the subjects of this research carry out their activities and participate in networks in many different ways. For example, a surveyor may be a consultant most of the time, but will also need to program software, manage projects, converse with prospective clients, etc. Persons working with GIS wear different "hats" depending on the groups with which they associate. In actor network theories, these hats are different technological artifacts. Nevertheless, are these hats (software and hardware) just protective devices and enhancements to personal safety? Michel Callon, Bruno Latour, and others associated with actor network theories point out that they also indicate convictions and disciplinary affiliations. By stepping back from a focus on distinct issues to a perspective that engages the activities of actors involved in different groups, researchers can develop a better understanding of the contexts for the development and use of geographic information technologies. This is the foundation for analyzing how existing networks and relationships affect the construction and use of technologies. Actor network theories open the ways for GIS studies to develop a broader understanding of the geographic information technology construction.

Collaboration as the Network

The network metaphor offers social scientists a powerful perspective on the processes of social organization and coordination. Social organization and coordination are key to successful collaboration. In previous studies of GIS networks, the work of akopoulos (1997) stands out for its depth and detailed description of the Greek GIS social network. As outlined above, actor network theories deploy a different understanding of networks. This section presents a description of the actor network theoretical framework used in this research.

Fundamental differences in actor network versus classic sociological networks are relevant to this research. Traditional sociological network theories are structuralist (Giddens 1979) and find explanations for behavior in the tension between the potential for action and a framework that leaves possibilities open, but delineates possible action. Actor network theories are post-structuralist and hold that structures are also malleable and defined by action. In actor networks, humans and non-humans are both nodes to be explained; the network "links" between the nodes are traces of exchange (Mol and Law 1994). We can summarize an essential difference in what each type of network seeks to explain. An explanation of structuralist approaches focuses on the analytical contrast between structure and agency and the contingency of individual or group action. In actor network approaches, the methodological maxim is to "follow the actors" (Latour and Woolgar 1979) and explain what they do concerning other human and non-human actors. Bear in mind that the network is ill suited to metaphorically suggest the emphasis of actor network theories; it is a carryover from an earlier actor network theory incarnation that was structuralist (Callon et al 1986).

Works by Latour (1979, 1987, 1993, 1999), Callon (1986, 1991), and others (Akrich 1992, Demeritt 1996) on the actor network theory show that the network is a construct that indicates the relationships between actors. There are no links in the network theory, only traces of relationships. This theoretical approach is characterized in three ways: First, actor network theories emphasize the dynamic character of the social exchanges and political processes inscribing many interested parties in the building and use of technologies. Second, as the network in actor network theories refers to the dynamic character of relationships between groups and individuals, it includes non-humans. Technological artifacts are much more than surrogates for certain humans; they are actors who bundle multiple intentions and act in ways that complement and extend humans (Latour 1992). Common technologies, such as the answering machine, have major impacts on interactions and the organization of groups. Third, the construction of artifacts is a process of developing coherence between multiple actors. Continuing the example, answering machines ease new relationships and unexpected behaviors, such as conversation without the simultaneous presence of two parties. Technologies incorporate and merge different interests in bundled socio-technical relationships. In summary, the network model for actor network theories is that nodes are people, institutions, and artifacts; connections are agreements and exchanges.

The working definition of actor networks in this paper is: *The traces of relationships between people, institutions, and artifacts connected by agreements and exchanges.*

A refined description of actor network stresses that this theoretical framework explains the interactions without the strong reliance on contingency characteristic of Giddens' structuration theory and Bhaskar's critical realist structuration theory. Actor network theories are as much ontologies as epistemologies (Mol

and Law 1994), in which coordination is an issue of relationships.

A post-structuralist explanation puts the burden on explaining how actors came to collaborate. There is no *a priori* common ground in actor networks. Institutions and technologies are not natural but are socially constructed. Any common ground between actors is the result of exchanges and involvement. Different interests must be translated (i.e., coherent standpoints developed) and people from different groups enrolled. With an increasing enrollment of actors, that position becomes stronger and more relevant to other groups. The ascendancy of a software package to a *de facto* standard is a simple but illuminating example. Early on, it may be just one of many packages. As large agencies begin to use a particular package for characteristics that successfully distinguish it from other software packages, these advantages become inherent. Widespread use of the software follows and it becomes a necessity for participating in the market. The control of the operating software market by Microsoft and the proliferation of Windows software products is a case in point.

In actor network approaches, the network of relationships represents collaboration between humans and non-humans. A network is constantly in flux; it is not a static infrastructure of connections that people rely on to do business or politics. Information technology development never stops (Schuler and Namioka 1993) and the networks are constantly changing.

Exploring Socio-technical Relationships

This section presents an explorative research project that precedes the examination of GIS actor networks. The results of this research provided snapshots of issues. A survey was undertaken to help guide in the formulation of interview questions. The findings of this study are presented only to contextualize the interview methodology. The initial survey sample was selected from the mailing list of the department of rural surveying at the Swiss Federal Institute of Technology in Lausanne, Switzerland (EPFL). The survey was sent by mail to 632 persons who had been added over several years to the mailing list. Two weeks after the original mailing, a "reminder" was sent to all individuals who had not returned their survey by that point. After 6 weeks, partially completed surveys had been returned by 212 people. We evaluated and analyzed the 128 fully completed surveys.

The questions of the exploratory survey were divided into three sections:

1) Who are you?
2) What do you do?
3) Whom do you work with?

Question 1 was designed to gather information about each respondent's relevant demographic characteristics, the type and length of employment, education, and an evaluation of their own GIS competence. Question 2 asks for information about the respondent's work in more detail. Example queries are: How often does the respondent work with GIS, what kind of problems do they find are more important, and the number of GIS software packages they use. In Question 3, the responses are designed to determine the amount of time the respondents work with persons from different sectors and organizations and the number of contacts they maintain.

The research examines GIS activities occurring in communities in the French-speaking portion of Switzerland. This includes the cantons of Fribourg, Geneva, Neuchatel, Jura, Vallis, and Vaud. The population of these cantons is approximately 1.5 M people. The results of the survey aided in the formulation of research questions for interviews with persons from public, private, and education sectors in this area. Included were interviews with representatives from these groups.

Who Works with GIS?

All of the 212 respondents to the demographic questions are over the age of 23 years and most are in their late 30s or early 40s. They are predominantly male. Only 6% of the respondents are women. A total of 37% of the respondents work in surveying-related fields, 40% work in private offices, and 60% work in organizations employing fewer than 30 people.

Generally, the respondents have been doing the same activity and working at the same job for a long time. A total of 43% have been carrying out the same activity for more than 12 years and 32% have been working at the same position for more than 12 years. This cuts across sectors. In many ways homogeneous, the respondents are well distributed over the three sectors: private offices (40%), public administration (39%), and higher education (11%); 10% are employed in other activities. Few of the respondents have a doctorate (10%), and the majority have a license, master's degree, or professional diploma (74%). Interestingly, although 76% consider further training and seminars important, only 44% of the respondents indicate that they have had specialized GIS training.

What Do GIS Users Do?

The respondents to the questionnaire work with a diverse set of persons within a wide range of organizations. Fewer than 28% of the survey respondents work daily with GIS, and only 14% consider themselves to be specialists (see Tables 1 and 2). The tasks that they work on range from landscape architecture to surveying. The actual use of GIS in collaborative work with persons from the same and different sectors was raised in the last section of the interview (see the following section) and in interviews when specific tasks could be explored in terms of collaboration.

The majority of respondents work for private organizations (40%). They also work for small organizations with small GIS groups. Thirty percent of the respondents work for organizations with fewer than 10 employees, and 30% for organizations with between 11 and 30 employees. The number of employees working specifically with GIS is also small. A total of 78% of the respondents indicated that fewer than 10 persons in their organization work with GIS. Curiously, in response to the question of

whether the respondent works more with technical or organizational problems, 41% say they work mostly on technical problems and 23% work usually on organizational problems; however, 36% show that they their work is both technical and organizational. This response suggests the importance that respondents afford dealing with both technical and organizational problems.

Interestingly, although 4% of the respondents never work with GIS directly and do not consider themselves GIS-competent, they do work on GIS-related issues. Although almost 30% work on a daily basis with GIS, the majority of respondents work less frequently with GIS. The small size of the organization and the many activities described by the respondents suggest that GIS is one component of their work; only in the rarest cases is GIS the sole or main focus of work. Again, the majority of respondents do not consider themselves specialists for GIS. More than half of the respondents to the survey indicate that organizational activities are more or as important as technical issues.

In other words, GIS is but one of the tools used for diverse activities. The workload of respondents involves many more tasks than GIS alone. The role of GIS-related tasks in their work could vary widely.

With Whom do Respondents work?

Instead of requesting names of collaborators in the questionnaire, which would supply an exact description of individual activities in the networks but be met as a possible invasion of privacy or business interests, general questions regarding collaboration offer insight into disciplinary relationships and involvement in activities. This format preserves the anonymity of the respondents.

Responses to questions about actual contact time with other individuals inside and outside of the organization provided issues to pursue in interviews. Although on average, 47% of the respondents' time is spent with contacts from public administrations, the contact time with municipalities, cantons (states), and federal organization varies greatly by organization type. The most contacts any individual in the study has to cantonal organizations are 30, but the average is only two. This suggests that a small number of people have a very broad network. Most people have smaller networks.

Most surprising is the low importance that the respondents give standards. Thirty percent indicate standards are of no importance, 26% indicate that they are of little importance, 21% say they are important, and only 22% say they are very important or essential. In the diverse activities of respondents, this response suggests that standards lack relevance for the broad range of tasks for which GIS is used. Since the majority of survey respondents work less than daily with GIS, collaborative activities only partially involve GIS. The responses suggest that GIS activities largely involve collaboration inside the discipline. Cross-sector collaboration is limited to a few individuals whose work consists of network maintenance and project management.

Interview Methodology

The interviews focus on issues that provide insight into the actor network relationships. Issues identified in the explorative study were the foundation for questions that explored the multifaceted dimensions of coordination. We selected three of those interviewed from the public, the teaching and research, and the private sectors who had indicated a willingness to participate in an interview and who had fully completed a survey. Nine interviews, each 2 to 3 hours in duration, were held within 3 months of mailing the initial survey.

The interviews followed semi-structured approaches; questions based on the initial exploratory survey were prepared using our evaluation of the exploratory survey. We tape-recorded and transcribed the interviews in French. The semi-structured approach provided detailed insights into perspectives of the interviewed person on activities and practices of actor networks. Methodologically, the most difficult aspect is assessing the role of technologies in actor network terms. Obviously, technological artifacts do not answer interview questions. In the interviews, we laid great emphasis on questions about the use and problems associated with using GIS technology, particularly regarding the role of standards for data sharing. From the different responses, we can interpolate the varying roles of artifacts for groups within different groups.

Issues Identified in the Exploratory Study

An analysis of the exploratory survey leads to the identification of several issues to pursue through interviews. Determining characteristics of diverse relationships in actor networks includes identifying degrees of participation and alliance building in networks, motivations for participating in conferences and associations, and the role of technologies in these relationships. While the explorative analysis offers insights into the general characteristics of persons working with geographic information, some ambiguous and surprising indications of possible tensions in collaborative activities emerged. The low importance of standards in relation to data sharing is a case in point.

The following questions were raised in interviews:

- What is your function and role in the organization where you work?
- How many people work in your organization?
- What kind of work do you do and for whom?
- How many people work on the same project?
- What kind of relationship does your work involve with people outside your organization?
- What software do you use?
- How did you choose this software?
- How does the choice of software affect your work with other organizations?
- How do you share data?
- What role do standards play for you now?
- What role can standards play in the future?
- Are technical or organizational problems more important?
- How do you coordinate you work?

- What kinds of networks do you think exist between groups using GIS?

From these questions, we chose to focus on discussions surrounding cross-sector network relationships. Because of the small number of interviews, we were unable to describe actual network connections in great detail or to better determine the types of network relationships in which people engaged. Instead of trying to construct a model of a particular set of network relationships in detail, we chose to focus on issues that offered insights regarding the manner in which networks are constructed and maintained.

Theses about GIS Actor Networks

These issues guided the formulation of a set of theses regarding the GIS actor networks. Methodologically, the postulates, the hypothetical dimensions of the actor networks, the articulated relevant aspects of the actor networks, and the concrete issues identified by the explorative study were identified as areas to focus on in interviews. The following list provides an overview of theses formulated before the interviews:

- Networks are relatively stable for small groups of individuals.
- Relationships with public administration agencies dominate networks.
- Professionals develop GIS skills to improve specific abilities and projects as needed.
- Professionals have very diverse work.
- Standards are not very relevant because of perceived autonomy loss.
- The utilization of GIS software influences relationships, and relationships influence the utilization of technology.

Assuming that the theses adequately describe the actor networks, an image of the GIS actor networks as an archipelago whose islands are not all equally reachable renders a useful spatial metaphor. Persons from islands on one end of the archipelago tend to stick together and have few exchanges with persons from other islands. These limited actor networks promote group activities, but constrain participation to the established hierarchy. The ability to overcome hierarchies and "distance" in the actor network archipelago is enhanced by sharing technology with "distant" individuals.

Interview Results

The results are insightful into the relationships that those interviewed engaged in to coordinate a variety of GIS activities. They are also thought-provoking and indicative of the need for continued research. The following overview presents key characteristics of the actor networks. The findings are then discussed in relation to the key issues of standards and data exchange, actor network alliances, and the role of technologies.

Characteristics of Actor Networks

- **Actor network stability**
  There is no single network that connects all GIS professionals, but diverse networks are constructed and disbanded as needed. Contacts are developed in accordance with application perspectives. Individuals develop GIS in the most convenient fashion following established users. There is a tendency to scorn other individuals and groups who use a different GIS.

  Each network is effectively stable as long as shared group perspectives do not substantially diverge. Continual development of the networks allows change that otherwise may threaten to destabilize the network.
- **Network domination by public administration**
  Networks are oriented by contacts to cantonal (state) offices. Contacts with federal and municipal offices are less important. Academic institutions regularly conduct research for the cantons. Private offices work for and receive data from the cantons. Communities have data of interest for the canton and are often better equipped. The federal government provides data and special skills.
- **Diversity of activities**
  GIS is just one area of the participants' wide-ranging activities.
- **Data exchange problems are important**
  In the eyes of those being interviewed, data exchange problems are relative because they are so common. In practice, the respondents find a solution, yet "wish" there were global solutions. "Global" means standards for everybody. However, none of those interviewed want to adopt standards from outside their discipline. External standards constrain flexibility, reduce independence, and allocate power, yet would ease collaboration if others would adopt them.
- **The role of technologies**
  The existing use of technologies in a network has a strong influence on the actions of people. The multiple networks that people belong to reinforce the use of particular artifacts, and artifacts become distinctive characteristics of the network.

The archipelago metaphor is a good simplification of actor network relationships, but is restrictive because the actor networks do not take place in three-dimensional space, but in n-dimensional space, where each dimension is a relationship between actors. Additionally, technologies are also active and not mere tools.

The interviews verified the theses, but needed to be slightly modified:

- Networks are stable for small groups of individuals.
- Relationships with public administration agencies dominate networks.
- Professionals develop GIS skills to improve specific abilities and projects as needed.
- Professionals have very diverse work.

- Standards are divisive.
- The utilization of GIS software influences relationships, and relationships influence the utilization of technology.

One thing we found unusual in the interviews and that varies from most descriptions of networks in terms of the stability we find today is a misplaced idea that suggests static rigidity in the face of change. Actor networks of humans and non-humans are not physically secured and maintained in the same manner as pipelines, sewers, telephone cables, and other technical elements. They are flexible, dynamic, and highly diverse. They are as unstable as their societies. Instead of a "network" metaphor, "web" is a better metaphor for social organization defined in terms of the proximity between nodal points. This is not geographic proximity, but social proximity: an affinity between actors that corresponds to their interests (for various reasons) in maintaining and supporting collective or collaborative activities with others. Webs are as dynamic as the individuals, groups, artifacts, and outsiders that change.

At the same time, the results of the interview suggest that actor networks are not wildly oscillating. Disciplines remain homogeneous and install gate-keeping procedures to retain and expand their influence and income. Change is extremely slow because it must be digested by the entire network and acted on by a few power wielders before it affects individual practice.

The networks are correspondingly not very mobile, but are subject to slow and certain change through the passing of time. Artifacts appear to play an important role in refining intradisciplinary relationships, but their role in relationships involving broader circles would seem more divisive. Comments from those interviewed suggest that artifacts play a more important role as a significant idea in these relationships. This is an interesting idea, for it implies strong symbolic associations with artifacts, but one whose examination lies outside the context of this research project.

Key Aspects Identified in the Survey

The results of research regarding key GIS aspects identified in the explorative survey are described below.

Standards and Data Exchange

Data exchange is an issue rife with conflict. This study of actor networks examined data exchange as a key activity in terms of standards. In Switzerland, concerns with data exchange have been approached most visibly through standards (Keller and Thalmann 1999). The limiting of data exchange to a matter that will be resolved on the basis of standards is a prevalent attitude among GIS experts (Interessengemeneinschaft ARC 1997, Harvey 1998, Albrecht 1999). Although standards are sought after to improve interdisciplinary relationships, this research suggests that standards are not blanket agreements but a part of the pragmatic solutions involving GIS in extremely varied activities. Without national or international standards, the use of GIS appears to offer advantages to many people. In fact, most of those interviewed suggested that differences are part of the daily routine and are to be expected. A town surveyor stated that, "Data exchange is at the heart of everything, but not necessarily a problem." Agencies in his town defined "rules" for exchange. He maintains that, in the future, these "rules" will become quite important. They will become conventions. In contrast, a private consultant said that standards are not an issue at all. For him, the main issue is coordination; however, this has been unsuccessful because agencies with resources (i.e., large utilities) work in an autonomous manner that does not consider the needs of groups with fewer resources. These latter groups are forced to struggle to keep up. Regarding standards, the private consultant noted a substantial difference between *de facto* standards created in practice and top-down "designed" standards. Designed standards fail or are out of date. *De facto* standards "work" and are an improvement. An example of a *de facto* standard is the DXF format. This format is used by surveying engineers in federal agencies to exchange data. The cadastre standard INTERLIS is of possible relevance in the future, but it is not sure if it will be widely adopted. Another viewpoint expressed was that of a private consultant working for a GIS software company who stated that "standards are necessary."

The term "convention" emerged several times as the key concept in the creation and use of standards for data exchange. Its use was contingent on the disciplinary and employment of those interviewed, an openness toward a federated approach, and their assessment of the importance of forming a strategic alliance. Those interviewed who sought to involve other agencies in GIS at the same administrative level spoke overwhelmingly in a positive light about conventions. One surveyor described standards in this case as mutually agreed upon "sets of rules." Standards that were not agreed upon were perceived by those interviewed as "edicts" and as being political-economic means to enforce market positions. One consultant from a GIS software company clearly stated that "it is no longer possible to work without standards." Others may not dispute that but insist on using their own standards.

These results demonstrate that locally developed GIS standards play an essential role in the development of actor networks by becoming critical for the enrollment of actors and enhancing positions. One person stated during a discussion of data exchange that standards facilitate associations. These associations are political and strategic. A standard that is adopted by half of the agencies augments the importance of the group behind the standard. Groups who are included in the development of standards see how they enhance their respective actor network positions, which can lead to improved social and economic relationships. These groups become critical to arrangements between multidisciplinary groups. There are technical advantages to having diverse groups agree to a convention, however, politically, these advantages accrue to the associates and members of the group. The proponents of GIS standards follow politics that will make them a key player in mediating the activities of standards and interdisciplinary collaboration. While the results of this survey do not permit making any statements about inter-organiza-

tional data sharing, it provides a framework for exploring data exchange in its political and strategic dimensions.

Alliances, Allegiances, and Collaboration

As the responses showed, GIS activities make up only a portion of the respondents' activities. GIS is an integral part, but not the *sine qua non,* of work. The remarks of those interviewed suggest that GIS is interwound in networks constructed and maintained according to politically strategic social relationships. Collaboration takes place in a web of affiliations and long-term relationships between agencies that, in some cases, have existed longer than a generation. While the interviews did not provide insight into the historical contexts, one person interviewed who works for a state agency discussed the relevance of diverse representations of the same object (i.e., a building) due to disciplinary differences. In his eyes, this was done because of the emphasis in the last century on design that has influenced different disciplines in varying degrees. According to him, a big reason for this is education and training, but it is also substantially influenced by the long-term historical roles that each discipline takes up in the administration.

In this historical institutional context, developing alliances is a complicated activity. Even with an excess of historical hubris, actor networks are constrained although not obstructed by past relationships. The need to learn new technologies leads to relationships between actors that deviate from prior organizational relationships. Private consultants play a key role in helping agencies move beyond their organizational confines. Young consulting groups are frequently upsetting older companies through the innovative use of GIS technologies. From this comes contracts, but this leads to tensions in previously established relationships. For instance, surveyors receive criticism from those in government positions because of the surveyors' slow adoption of GIS and, therefore, a slowing down in the development of state GIS. Pornon (1992) reports that conflicts between surveyors and computer specialists are common in Europe.

Those interviewed describe relationships in terms of disciplinary networks. Their comments reflect a strong division of labor and settled disciplines in their work. Their perceptions of alliances and, accordingly, of actor networks vary. One private consultant interviewed stressed the importance of the state actively promoting cooperation between different public and private groups. This is contradicted in an earlier statement that the state should play a less active role in coordinating different groups. The consultant desired a reduced state role, accompanied by an increased emphasis on private groups fulfilling government activities. His contacts with the state underlie this interpretation. To be in the right place at the right time, it is necessary to work on building alliances that will insure his involvement in governmental GIS activities, regardless of whether the state privatizes GIS activities or not.

GIS technologies also lead to tensions with other groups. The development of GIS in a state in Switzerland illustrates this well. Several of those interviewed spoke appreciatively of the coordination that the state of Vaud developed between 1985 and 1995. They also pointed out that this coordination was largely internal. Collaboration with groups outside the state administration was weak and became a contested terrain. One person interviewed from a state agency stated that the organized activities encouraged freeloading on the state. Still, he suggested that the political leadership lies with the state. The state continues to occupy a central position because of the number of contracts that it provides. Its role in defining public policy is another critical reason. This process and the use of GIS technologies are not without dispute, making any project with GIS part of a broader political arrangement. The actor networks that those interviewed describe between individuals in governmental, state, and education sectors are only a small part of the myriad web of relationships connecting people and agencies.

A curious finding regarding coordination between groups is the limited number of allegiances that are formed. Small groups of persons only agree to cross-disciplinary allegiances that have amply displayed their allegiance to their specific discipline; often, many years in the discipline and professional position are required. Most of those interviewed have few contacts outside their discipline. When queried, they remarked that the same applied to their colleagues. The higher an individual sits in the social hierarchy of the discipline, the more important they become in arbitrating external influences, intradisciplinary relations, and in maintaining the profile and position of that particular discipline.

Persons who join networks have various motives and contribute to the network for various reasons. In the construction and collaboration of networks, technical artifacts can play an important role. By facilitating the definition of group membership, they appear to find it crucially important to determine who is included or excluded. However, the degree to which inclusion or exclusion depends on prowess with a technical artifact is unclear and may be strongly influenced by other factors.

In these spaces, relationships follow diverse rationales. A private consultant will seek relationships with cantonal officials in the hope of being recognized by state contracts. The same consultant may avoid a relationship with a consultant who uses the same software in a different town because of possible competition. However, he or she will seek a relationship with a consultant using the same software from the same town to assure that the competitive situation does not result in leaving personal business interests high and dry. A strategic alliance that may be sought in this case is really an environmental strategy for dividing limited resources. Of course, the rationale for "sharing" may be lost if a stronger group is developed that is competitive enough to stand on its own.

The Roles of Technologies

The representation of technology as tools in GIS work, which implicates a "user," complicates the study of actor networks. From comments with those interviewed, the practical work of GIS always involves some aspects of technology. For the most part, per-

sons differentiate between technology and organization according to their use of GIS technologies. This is influenced from selection to use and modification by the discipline. A good example of the importance of disciplines in structuring perspectives on the role of technologies can be found in the formation of user groups. For instance, an association was formed by users of a particular GIS who work for competing electrical power companies to ensure that data can be mutually exchanged. These groups augment existing disciplinary dominance by insuring the involvement of all groups in the technology.

Data exchange is greatly complicated due to entrenched representational differences. Because of the separation of technology from social relationship, those interviewed typify technology as a tool that is distinct to each group. The representation of GIS technologies as a tool is politically essential for maintaining power and position in the actor networks. The comments discussed earlier regarding standards underscore the importance of technologies in the actor networks of GIS. The abilities to use, control, or standardize tools are power. Alliances and collaboration often manifest themselves through use of a particular technology. The description of a tool is also a description of the relationships between activities and the collaboration involved.

Technological artifacts are the silent partners of humans as they construct solutions, but are crucial to relationships. Through the construction of certain types of technologies, a substantial amount of effort goes into reducing friction with non-humans by congealing groups around specific mutually reinforcing constellations of things and people. Standards and conventions that facilitate particular relationships and are intended to ameliorate interdisciplinary collaboration are extremely contentious because of the manner in which they constrain participation and reinforce particular disciplinary perspectives. GIS technologies are not merely tools, they are a key component of all organizational and disciplinary relationships.

Conclusion and Outlook

This research shows that collaboration between the various actors constructing and coordinating GIS activities relies on complex networks between different individuals and groups that is optimally described as a "web." The web is a dynamic arrangement characterized by multiple links between actors who have previously defined roles and affiliations. This research presents a few essential points that can be refined in future comprehensive projects.

These results are relevant for broad considerations of GIS practices, including diffusion and implementation. From a methodological pragmatic sense, actor networks can be used to identify the "contexts" of GIS use. In the case of diffusion research, this context is similar but broader than Assimakopoulos' research into the Greek GIS social network. The two approaches are complementary at this level. It is only when research turns to the actual use of GIS in its diverse social contexts that actor networks ease an intensive examination of GIS design and use from their epistemological equity between humans and non-humans. Beyond research, this examination of truth and knowledge also permits a more participatory engagement with GIS design than systems engineering approaches.

Research into the practice of GIS actor networks presents a framework for jointly considering GIS technology with those who develop it. Coordination and collaboration rely on established technologies, by which "established" suggests more political and social acceptance, not necessarily the objective technical merits. Designers have implicitly considered this in data modeling and system implementation. Through actor network theories, it is possible to make these aspects explicit and an element of the design process.

Some methodological ideas for future actor network studies emerge from this work. While the results of this research show the importance of network relationships, this study fails to indicate particulars of collaboration and exchange (e.g., data sharing practices). Beyond intensive participant observation of relationships and the roles of technologies, extensive research on diffusion actor networks could be conducted to identify specific actor network relationships using a "snowball" questionnaire approach. By beginning with one actor and having that person pass questionnaires to related collaborators, researchers could identify the actual connections and collaboration between particular actors. This would permit the identification of "traces" of alliances. Based on the interview experiences, the role of information technologies can be assessed by a more ethnographic, long-term case study, that "follows the actors" (Latour 1987). The final methodological lesson is that interviews with small focus groups appear to be an invigorating alternative to interviews in order to assess actual forms and opportunities and pitfalls of collaboration.

Collaboration between diverse groups is crucial to successful GIS implementation and diffusion. This research shows the important insights into actor network approaches that help to understand the broader context of specific GIS tasks and functions. Social coordination is essential for any organization. Understanding the issues involved in using information technologies calls for methods that consider the complex relationships between humans and non-humans. Actor network theories can complement GIS research in a variety of ways (Harvey and Chrisman 1998).

About the Author

Dr Francis Harvey's research encompasses multiple facets of geographic information science, including developing approaches to organizational issues that draw on behavioralist and social constructivist work. Previous projects have examined GIS implementation and design issues through a social constructivist approach that examined the relationships between private, public, and education sector actors. Current funded research focuses on potentials and difficulties for developing the National Spatial Data Infrastructure (NSDI) at local and regional levels. His interests also include Ger-

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