# Social Network Analysis as a Tool for Technology Policy in the Diffusion of GIS Innovations: the Emergence of the Greek GIS Community

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# Social Network Analysis as a Tool for Technology Policy in the Diffusion of GIS Innovations: the Emergence of the Greek GIS Community

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## 1 Introduction

Technological innovations do not diffuse in a vacuum. People, groups and organisations attach meaning to new ideas and technologies. The diffusion of new technological systems takes place in a social and economic matrix of existing relations. Consequently technological innovations shape and are shaped by various actors and groups. The organisational and strategic consequences of the diffusion of innovations have generally been underestimated in the diffusion literature (Rogers, 1983). However in other fields considerable attention has been given to the interplay between technology and organisational context resulting in what it can be called a socio-technical approach to the study of technological systems (Bijker, Hughes and Pinch, 1987; Law, 1991; Bijker and Law, 1992). This approach, coupled with social network analysis, could be a fruitful way for the formulation of technology policy in the management and diffusion of innovations. Clearly the analysis of how various institutional and disciplinary groups interact would be useful in looking how technology policy develops at national and international scales. Perhaps it is time for social constructs such as institutional setting and disciplinary background to be taken into account in informing technology policy at the European and national level (Assimakopoulos, 1997a).

Geographic Information Systems (GIS) are a computer-based technology dating back approximately 30 years (Coppock and Rhind, 1991). In the last decade or so, GIS has emerged as a major area of applications for many groups of interest coming from a broad range of public and private sector organisations as well as an increasing number of professional communities who handle geographic information world wide. However, for many experts GIS is still an ill-defined technology (Goodchild, 1995). This suggests that GIS might be translated in different countries or contexts according to an increasing number of different technological traditions of practice. Each of these traditions encompasses various networks of GIS system builders who come from a broad range of organisational settings in a number of geographical locations, institutional settings and disciplinary backgrounds. Over time separate networks of GIS actors share and exchange information and other scarce resources giving birth to a new GIS community of practice that is composed of individuals, groups and organisations who share a common interest and play complementary roles with respect to GIS innovations.

The overall thesis of this research is that the development of GIS technology in Greece can be studied through the emergence of a Greek GIS community (Assimakopoulos, 1997b, 1997c, 1997d). Based on this assumption the following questions are addressed:

- How can we use concepts and methods of social network analysis to study GIS stakeholders and GIS linkages that make up a new technological community related to GIS in Greece?

- What is the influence that different social constructs such as institutional and disciplinary groupings have on the formation of the Greek GIS community?
- Is it possible to gain some understanding of the prominence or domination of relevant social groups related to GIS diffusion in Greece from a network analysis of a graph of the Greek GIS community?
- What are the implications of this methodology for the formulation of technology policy in terms of the allocation of funding and other scarce resources at a national or European Union scale?

With these questions in mind the paper will be divided into four sections. Firstly, the main concepts from two complementary theoretical perspectives of diffusion of innovations and socio-technical change will be discussed. Secondly, the research methodology will be explained. Then, the analytical findings will be presented based on a graph of 51 small groups and 95 socio-economic linkages. The structure of the Greek GIS community is explored in terms of two social constructs institutional setting and disciplinary background, with respect to two network analysis models, cohesion and structural equivalence. Finally, the fourth section draws conclusions and comments on the value and potential importance of the underlying concepts and methods for the formulation of technology policy in the diffusion of innovations.

## 2 Main Concepts

Rogers (1983, 5) defines diffusion of innovations as the process by which information about an innovation is communicated through certain channels, over time, among the members of a social system. Many researchers in the past have emphasised the importance of communication networks in the diffusion of innovations as these are considered as the routes through which information and other resources about an innovation spread. In particular Rogers and Kincaid (1981, 344) argue:

> *"...that most individuals (and organisations) do not decide to adopt an innovation on the basis of their evaluation of the technical qualities and performance of the new idea. Instead, they depend on the subjective experience with the innovation of others like themselves, conveyed through peer networks, to give meaning to the new idea."*

Social interaction and communication between and among those who have a stake in technological development underlie not only the adoption but also the implementation and the utilisation of technological innovations (Tornatzky and Fleischer, 1990). Such interactions can be framed as sociomatrices that can consist of a large number of actors and relationships. The pattern of relationships connecting a broad range of stakeholders can highlight leadership, collaboration and competititon. In other words the sociomatrix embodies the development path of a technology like GIS in either different countries or different contexts.

### *2.1 Social network analysis*

According to Wasserman and Faust (1994, 5) social network methods focus on dyads (two actors and their ties), triads (three actors and their ties), or larger systems (subgroups as well as entire networks of different actors). As a result different sets of actors and network ties have to be analysed either manually or using specialised computer software to make sense of the structure of a social system. Social network analysis is defined as a method of research for understanding the structure in a social system. Rogers (1987) defines structure as the arrangements of the elements in a social system and the set of relationships that connect these parts together. Thus structure deals not only with the actors forming a social system but also with the relationships (linkages, connections, ties) between the actors. As Wasserman and Faust (1994, 6) point out the fundamental difference between a social network explanation and a non-network explanation of a process like the diffusion of innovations is the inclusion of concepts based on information exchange relationships among units of the system.

In particular a social network consists of a finite set of actors and the relations between them (Wasserman and Faust, 1994, 20). A network in its simplest form can be represented either as a graph of nodes and links, or as a binary sociomatrix of 1 (if the link between two actors exists), or 0 (if the link is missing). The former method has its roots in graph theory (Harary, 1969) while the latter is based on sociometry (Moreno, 1934). The representation of social networks as graphs is meaningful and can effectively depict network structures when the number of actors is relatively low (for example less than 50). An easier way to handle and analyse larger social network data sets is to use a sociomatrix where the lines and columns represent the relationships between each pair of actors in the system. A sociomatrix is usually indexed by the set of originating actors for its rows and the set of receiving actors for its columns. The sociometric notation is more elegant than the graph one and has been widely used for social network analysis through computer software packages such as UCINET IV (Borgatti, Everett and Freeman, 1994) and KRACKPLOT 3.1 (Krackhardt, Blythe and McGrath, 1994).

The structure which social network analysis brings to light is mostly invisible to the participants in a system because actors like individuals generally know their connections and do not have an overview of all the connections that make up the system. Social network analysts like Wellman (1988, 26-27) propose two alternatives for the study of such 'deep' structures. The first one which is used for the purposes of this research views social networks much as astronomers view the universe: as outside observers studying relationships connecting all members of a system. The second is defined from the standpoint of particular individuals as it studies smaller egocentric or personal networks, providing Ptolemaic views of social networks as they are perceived by the individual actors at their centres.

### *2.2 Structural equivalence*

The diffusion of technological innovations can be explored through a social network analysis of patterns of direct linkages between and among members of a social system. According to Valente (1995, 14) "modeling the adoption behaviour of those with whom we are in direct contact is referred to as the contagion of innovations by cohesion". Burt (1987) argued that social contagion and thus innovation is more likely to occur when actors have similar patterns of connections within the network (structural equivalence) rather than when they have direct contact (cohesion). According to Wasserman and Faust (1994, 356) two actors are structurally equivalent if they have mathematically identical connections to and from all other actors in a network.

In practice it is unlikely that any actors in a social system will be exactly equivalent. As a result a measure of stuctural equivalence is needed so that the extent to which actors are equivalent can be shown. In the following equation structural equivalence is measured by Euclidian distance (Burt, 1987). The calculation of Euclidian distances follows Equation 1 and is based on the sociometric representation of a network as a square sociomatrix consisting of g actors. As a result k counts from actor 1 to actor g, while $x_{ik}$ represents the value of the tie from actor *i* to actor *k*. If actors *i* and *j* are structurally equivalent, then the entries in their respective rows and columns of the sociomatrix will be identical and thus the Euclidian distance ($d_{ij}$) between them will be equal to zero. To the extent that two actors are not structurally equivalent, the Euclidian distance between them will be large. Euclidian distance has the properties of a distance sociomatrix. Such a sociomatrix can be computed for Equation 1 using specialised software such as UCINET IV (Borgatti, Everett and Freeman, 1994).

$$(1) \qquad d_{ij} = \sqrt{\sum_{k=1}^{g} [(x_{ik} - x_{jk})^2 + (x_{ki} - x_{kj})^2]} \qquad \text{for} \quad i \neq k, j \neq k$$

Usually structural equivalence is visualised using 2-dimensional scaling so that the proximities between actors are presented in a graphical way with (x,y) coordinates. 2-dimensional scaling is part of a wider family of techniques called Multi Dimensional Scaling which seek to represent similarities or dissimilaries among a set of actors so that actors that are more similar to each other in the input data are closer in a two (or higher) dimensional space, while actors that are less similar to each other are farther apart in that space (Wasserman and Faust, 1994, 288). UCINET IV also computes 2-dimensional scaling of a set of actors in terms of a measure of structural equivalence such as Euclidian distances between them. Recently specialised social network visualisation software has been developed. It takes as input the coordinates of 2-dimensional scaling to represent graphically the structure of a system according to a specific relation.

### *2.3 Technological community*

One way to study GIS diffusion is to adopt a technology centered approach. An alternative way is to start from existing technological traditions of practice and examine various individuals, groups or organisations who adopt and implement GIS innovations. It is possible to start either from the new idea itself or the actors and relevant social groups which shape the new idea through adoption and implementation processes (Pinch and Bijker, 1987). GIS like other computer-based innovations is an interdisciplinary technology which crosses the boundaries of many well established technological traditions of practice. As a result, a broad range of actors and groups construct the meaning of GIS innovations at a local, national and international scale.

Edward Constant, a historian of technology, put forward the notion of a technological community in his book about the development of turbojets (Constant, 1980), mainly based on the ideas of Thomas Kuhn, the historian of science. Kuhn (1970) basically argues that the cognitive locus of science is a well-defined community of scientists which is tautological with some paradigm. Constant (1987) argues that the social locus of technological knowledge is a community of practitioners who creates and follows a technological tradition of practice associated with the evolution of a particular technology. A good indicator of the existence of technological communities are the different engineering societies. These kinds of professional groupings are institutionalised, highly specialised and well-defined social entities which embody knowledge, development and innovation at the collective level. Such technological communities may be composed of individual adherents, university laboratories, private firms and government organisations.

Technological traditions of practice constitute what binds communities of technological practitioners together. In this sense technological traditions of practice are analogous to Kuhn's (1970) paradigms and exemplars which scientists share in invisible colleges

(Crane, 1972). However as Constant (1984) argues it is not clear that a technological tradition of practice comprises a set of specific exemplars in the same sense that a scientific paradigm, in its most narrow and precise usage does. A technological tradition has both a knowledge and a sociocultural dimension. The former includes scientific theory and methods and hardware and software. The latter includes social stuctures as well as systems of value and belief. In other words a technological tradition of practice as a source term for a technological community encompasses a wide array of different elements such as relevant scientific theory, specialised instrumentation, persisting patterns of social interaction and a set of values and beliefs which guide the actions of its members.

## 3 Research Methodology

This research has adopted both a social network perspective (Wasserman and Faust, 1994) and an ethnographic approach (Hammersley and Atkinson, 1983) in studying GIS actors and GIS linkages. In the past, many network ethnographic studies were carried out in small and inward looking social systems such as traditional villages, monasteries and ocean vessels where the boundaries were clear, the total population was known and as a result the identification and sampling of actors and linkages was easier. Unlike these studies a major challenge for this research was to draw the boundaries of the Greek GIS community, and to identify the GIS actors who adopted and implemented GIS across a broad range of institutional settings and disciplinary backgrounds from the early 1980s to the early 1990s throughout Greece. For this reason a multi-stage and a multi-site approach was followed since it was not possible to identify the various stakeholders of the Greek GIS community at one location or in a single round of fieldwork.

As a result of in-depth interviews and participant observation data the author incrementally updated and extended his list of contacts selecting the individuals, groups and organisations who most often came up as important to meet either because of their formal positions and relations, or because of their experiences and knowledge of GIS technology. The main criteria for the choice of the people and groups forming the GIS community in Greece, were their experience with GIS adoption and implementation as well as their key role in the development of GIS applications through various projects in a broad range of settings. Supporting evidence for the commitment of these individuals and groups in adopting and implementing GIS technology in Greece as well as their critical contribution to the development of GIS applications was provided in a variety of contexts through their peers.

Snowball sampling of actors and linkages as suggested by Rogers and Kincaid (1981, p.109) was used for the field-research which was carried out in three different stages between April 1992 and June 1994. In the snowball sampling approach an original random sample of respondents ("starters") are asked to name their peers who then become the respondents in a second phase of data gathering, their contacts thus nominated become respondents in a third phase, etc. In this way tracing and studying the chains of linkages is a process similar to that of a snowball rolling downhill as the sample grows slowly in the beginning and increasingly faster in later stages. The obvious advantage of the snowball sampling method is that the researcher does not arbitrarily impose the boundaries of the social system under study but gradually uncovers them through the different responses of the participants in the research. Moreover such a sampling method provides a significant advantage to reseachers who also want to use qualitative methods like participant observation as it gradually allows both the identification and interaction with the respondents, following the network linkages of the "starters" in a multistep sequence.

In practice however, this research did not start from a random sample of Greek GIS experts. The author had already a certain amount of knowledge of the social system under study in December 1991 because of his work experience at the University of Patras and his participation at the Ursa-Net (Urban and Regional Spatial Analysis Network for Education and Training) meetings in June 1990 and 1991. Moreover the academic team of Ursa-Net based at the University of Patras helped the author to compile an initial list of contacts in December 1991. This was used and expanded in the fieldwork in March - April 1992 as the interviewees nominated other members of the Greek GIS community (Assimakopoulos, 1993).

In December 1992 the author participated in the Greek ESRI Users' Conference in Athens and this list of contacts was further revised and updated for the purposes of the research in summer 1993. From June to August 1993 the participants in the first round of the research nominated additional members of the Greek GIS community who were interviewed either at the time or during the second round of the research in June 1994. Overall 60 people based at eight cities (Athens, Thessaloniki, Patras, Heraclion-Crete, Volos, Mytilini, Kos and Rodhos) throughout Greece were interviewed in some depth between 1992 and 1994. These individuals were usually the head and/or the senior GIS expert in teams who adopted and implemented GIS in government and utilities organisations, universities and research institutes, and private sector firms. More than two thirds of these interviewees participated in more than one round of field-research. It is worth also noting that some of the interviewees (i.e. academics, government officials) worked in different departments or laboratories of the same organisation and as a result participated in different GIS teams.

A key strand of the research strategy was to test the interpretation and analysis of the author against other people's experiences and knowledge of GIS developments in Greece. Therefore in the second round of the fieldwork in summer 1994 one key individual who worked for Marathon Data Systems until 1993 when he became the head of the technical department of Eratosthenis engineering consulting firm read the preliminary analysis of the findings to identify gaps and provided some useful comments and suggestions.

## 4 Social Constructs and Network Development

One of the main research objectives is to understand the structure of the emerging Greek GIS community. As a result a map of 51 teams and 95 linkages is put forward. The teams are small groups of individuals who adopted and implemented GIS innovations in government - university - private sector organisations throughout Greece, from the early 1980s to the early 1990s. Teams were chosen as units of analysis because in the large majority of organisations, not the whole organisation, but only a small group of individuals is responsible for GIS adoption and implementation. Moreover in many organisations, such as universities, several teams may be involved who usually work in different laboratories of the same department. The linkages often have multiple strands. They are either economic / contractual in nature (e.g. software vendor - government agency), or/and knowledge student - teacher relations, or/and social relations of friendship and support with respect to GIS adoption and implementation. The linkages map the functional interdependencies between these teams (see Figure 1).

It should be noted however that Figure 1 does not depict the multiple contents of GIS linkages between the 51 teams. As Alba (1981, 42) and others have pointed out this is a common limitation of social network research as the untangling of the different strands in multiplex relationships which convey not only information but also material resources and services is usually very difficult. Figure 1 also shows undirectional relations, tacitly assuming that all 95 linkages are reciprocal in nature. Mutuality or symmetry of linkages is not always the case between the various teams in terms of GIS adoption and implementation. Power relations are usually built because of the asymmetry of linkages with respect to the exchange of information and other resources (Callon, 1993; Law, 1991). However, Figure 1 does not consider the bidirectional nature of linkages because of the practical difficulties involved in estimating the intensity of such linkages. There is also no discussion of time with respect to the evolution of the patterns of linkages in Figure 1. This reflects the difficulties experienced by interviewees in studies such as this of recalling with any precision how they developed their linkages over time (Bernard et al, 1984). However, despite these limitations it is felt that Figure 1 gives a good indication of the overall structure of the Greek GIS community in the early 1990s.

Figure 1 groups the 51 teams in three main categories according to their institutional position: the boxes represent teams from central and local government and utility organisations, the circles represent teams from university laboratories and research institutes, and the diamonds represent teams from private sector firms including GIS vendors and consultants. It also shows the eight cities where these teams are based with black circles. Using different letters (A for ArcInfo, E for Erdas, Id for Idrisi, In for Intergraph, L for Laserscan, Mi for MapInfo, Mg for MapGrafix, P for Panterra, S for Star, S9 for System 9) Figure 1 also shows which GIS software package(s) was adopted and used by each team. The overall disciplinary background of each GIS team is also depicted in Figure 1 using different background shades and black or white numbers. Teams that share a surveying engineering background are represented by white numbers against a black background. Teams that share a spatial planning background are represented by black numbers against a white background. Teams that share "other" backgrounds are represented by black numbers against a grey background.

To illustrate the potential of social network analysis as a useful tool for formulating technology policy Figure 1 is treated as a graph. On the basis of Figure 1 a 51x51 GIS sociomatrix can be constructed that shows who is linked with whom in terms of GIS adoption and implementation in Greece in the early 1990s. Each row of this sociomatrix corresponds to one GIS team in Figure 1. Rows reflect what GIS linkages are initiated by each one of the 51 GIS teams and columns reflect what GIS linkages are received by each one of the 51 GIS teams. Subsequently the structural equivalence for the 51 GIS teams forming the Greek GIS community is calculated. Structural equivalence is measured with Euclidean distance using the UCINET IV social network analysis computer software. Moreover UCINET IV computes 2-dimensional scaling to visualise the Euclidian distances of these 51 GIS teams. Finally KRACKPLOT 3.1 writes a file that shows the 2-dimensional scaling of Euclidian distances, the team numbers and the key dimensions, institutional setting and disciplinary background of the 51 GIS teams forming the Greek GIS community.

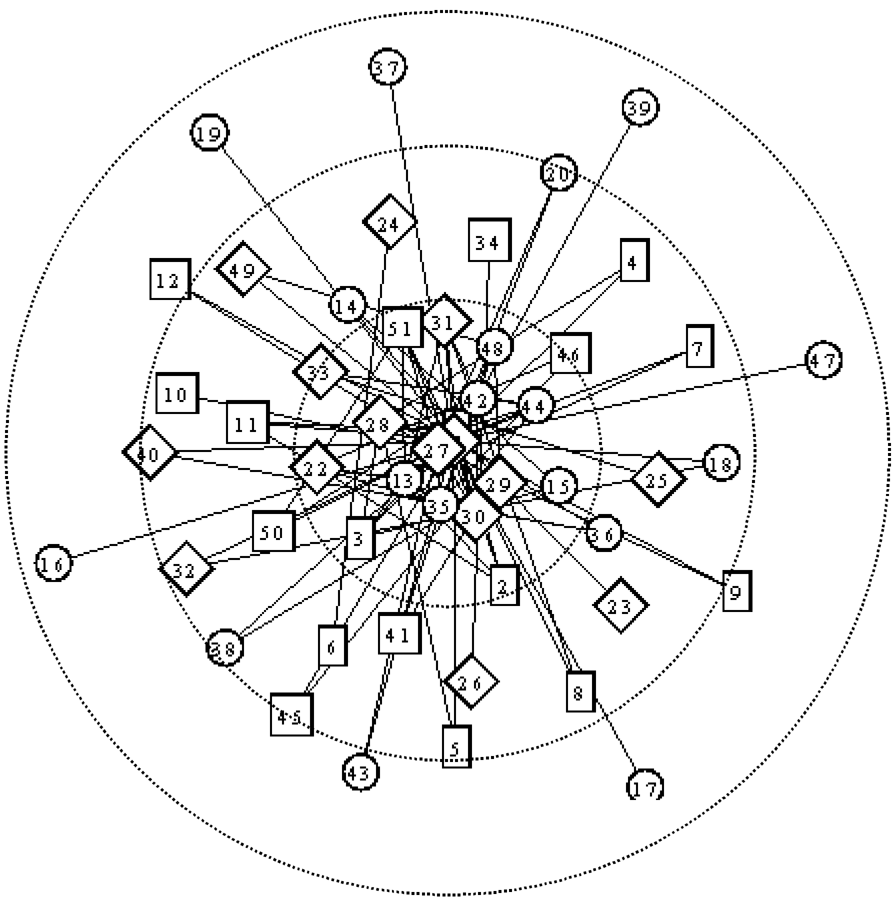
The purpose of the whole exercise is threefold. Firstly it explores two network models, (cohesion and structural equivalence) with respect to GIS diffusion in Greece. Secondly it gives insight into how social constructs such as institutional setting and disciplinary background influence the development of the Greek GIS community. And thirdly it shows the prominence or domination of particular actors and relevant social groups who participate in the early critical stages of development of the Greek GIS community.

*Figure 1 (to be inserted here)*

### *4.1 Institutional setting*

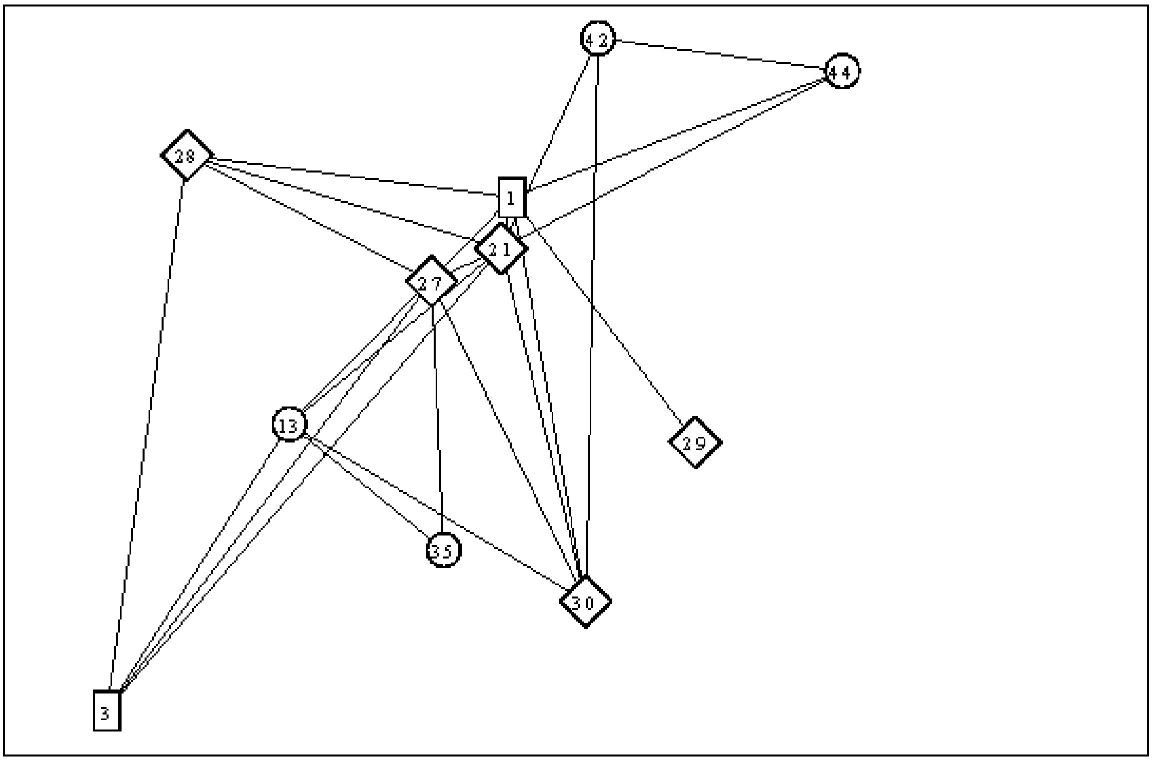
Graph 1 shows the positioning of the 51 teams according to the Euclidian distances between them. It also shows the direct connections between these 51 teams. The boxes represent teams from central and local government and utilities organisations. The circles represent teams from academia, and the diamonds represent teams from private sector companies including GIS software vendors and consultants. Teams that are closer together in Graph 1 have similar patterns of connections to the other teams that form the Greek GIS community in the ealry 1990s. The distance between them is the Euclidian distance (Burt, 1987) calculated according to the pattern of socio-economic linkages to and from all the other teams.

*Graph 1: Institutional groups of the 51 teams who form the Greek GIS community based on the Euclidian distances between them.*



Graph 2 shows in detail teams which are positioned in the centre of Graph 1. The Euclidian distances between them are so small that it is necessary to zoom in Graph 1 to separate them. As can be seen from Graph 2 a handful of teams including 21 (Marathon Data Systems, ArcInfo vendor), 27 (Eratosthenis engineering consulting firm) and 1 (Digital Cartography Department at the Hellenic Military Geographical Service) are located near the geometrical centre of Graph 1. Marathon Data Systems (team 21) was chosen as the centre of the inner, middle and outer circles of the Greek GIS community for three interrelated reasons. Firstly, it is the earliest adopter of commercial GIS software in Greece. Secondly, it has developed the highest number of direct linkages with other teams. Thirdly, it is positioned in the centre of Graphs 1 and 2, as a result of its Euclidian distance from the rest teams.

*Graph 2: Zooming in the core of the Greek GIS community.*



Subsequently the radius of the three circles was defined as 1/3, 2/3 and 3/3 of the distance between teams 21 and 16. As can be seen from Graph 1 the distance between teams 16 and 21 is the largest Euclidian distance between the teams in the centre and the periphery of the Greek GIS community. Graph 1 shows that there is a great deal of heterogeneity in terms of institutional backgrounds within the inner-circle and the whole of the Greek GIS community. Teams of the same shape are not clustered together but form a complicated pattern. It is worth also pointing out that the Euclidian distances in Graph 2 between teams from a broad range of institutional settings are small. It seems that members of public and private sector teams as well as academics can easily blur the boundaries between the different sectors of the Greek GIS community as they have similar patterns of connections in collaboration or competition for scarce resources. The 19 teams which belong in the inner circle come from a broad range of institutional settings: 1, 2 and 3 from central government, 46 and 51 from municipalities, 13, 15, 35, 42, 44 and 48 from academia, and 21, 22, 27, 28, 29, 30, 31 and 33 from private sector. Similar heterogeneity, although to a lesser extent, can be observed for the 23 teams of the middle circle, and the 9 teams of the outer circle.

Table 1 shows the percentage of teams in the inner, middle and outer circles of the Greek GIS community according to the main institutional groups. Private sector teams account for 42 percent of the inner circle because a handful of GIS vendors and engineering consulting firms provide connectedness to the whole of the Greek GIS community. In the second position are a handful of teams from academia who account for about a third (32 percent) of the inner circle. As might be expected academics, although they form the largest component of the Greek GIS community and have most of its external linkages, do not maintain many internal linkages unless it is for the development of specific GIS applications. This is also reflected in the composition of the outer circle in which there are no private firms but 78 percent comes from academia and the rest from government organisations. Government and utilities teams form the largest group in the middle circle accounting for almost half (48 percent) of it. The rest is divided between the private sector (30 percent) and academia (22 percent).

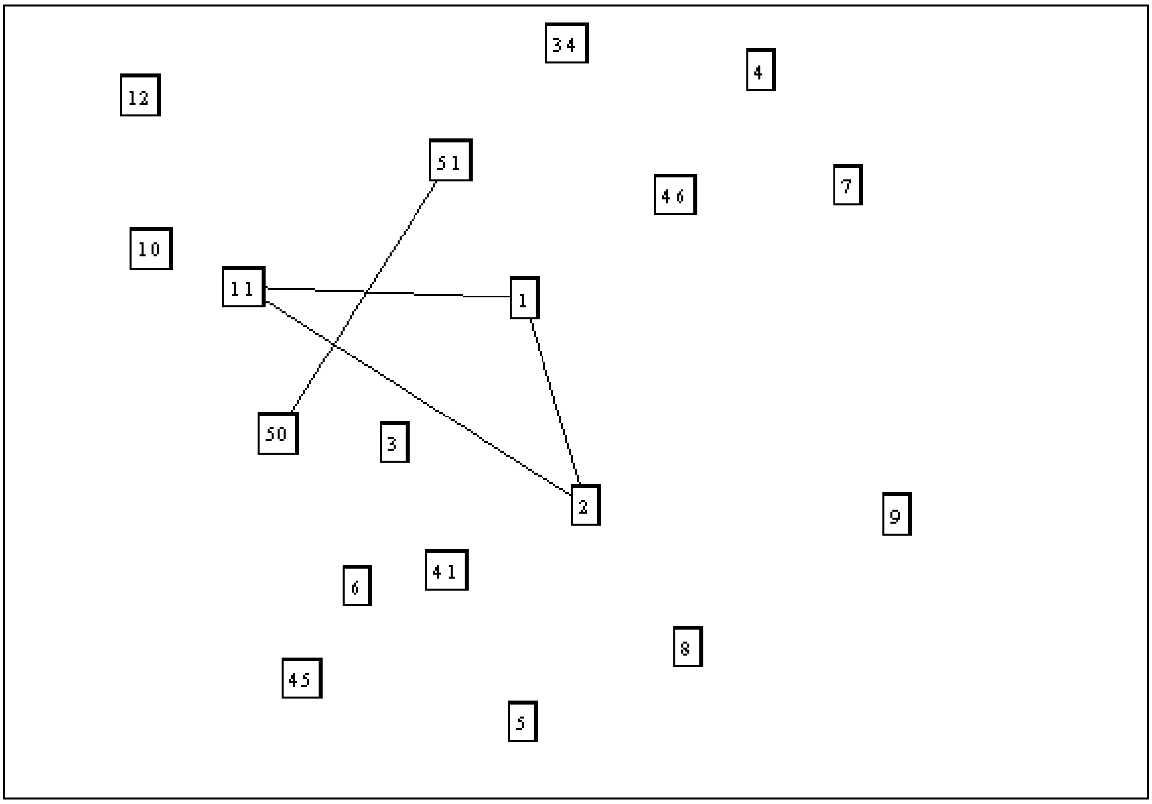
*Table 1: Percentage of teams in the inner, middle and outer circles of the Greek GIS community according to the main institutional groups.*

| **Percentage of Teams in the Inner, Middle, Outer Circle / Institutional Groups** | **Inner Circle** (19 teams) | **Middle Circle** (23 teams) | **Outer Circle** (9 teams) |
|---|---|---|---|
| **Government** (18 teams) | 26 | 48 | 22 |
| **Academia** (18 teams) | 32 | 22 | 78 |
| **Private Sector** (15 teams) | 42 | 30 | 0 |

To discuss in greater detail the positioning of 51 teams in Graph 1 according to the Euclidian distances between them, and the patterns of internal linkages within the various institutional groups a set of three graphs is put forward next which shows the Euclidian distances and the patterns of internal linkages within the government, academia and private sector.

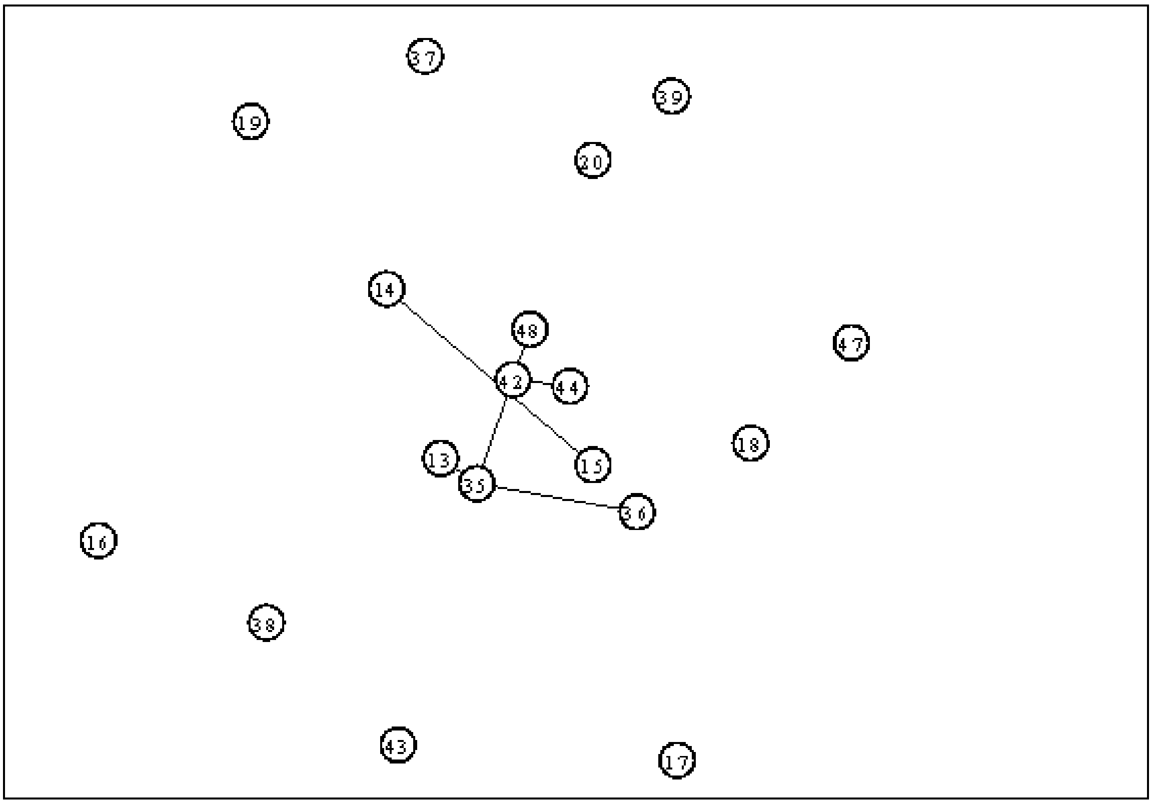
Graph 3 shows the teams who adopt and implement GIS within central and local government and utilities organisations. This group of teams is to a large extent unconnected. The two agencies under the Ministry of Defence (teams 1 and 2 at the Hellenic Military Geographical and Navy Hydrographic Services) maintain linkages between them and with the team 11 (Hellenic Telecommunications Organisation). Given their geographical proximity it is not surprising to find that teams 50 and 51 within the Technical Services of the Municipalities of Rodhos and Kos are linked with respect to GIS. The rest of the Greek public sector organisations are not connected although most of them sustain a number of GIS linkages with members of the two other institutional groups, private sector companies and university based laboratories.

*Graph 3: Teams who belong in central and local government and utilities organisations based on the Euclidian distances between them.*



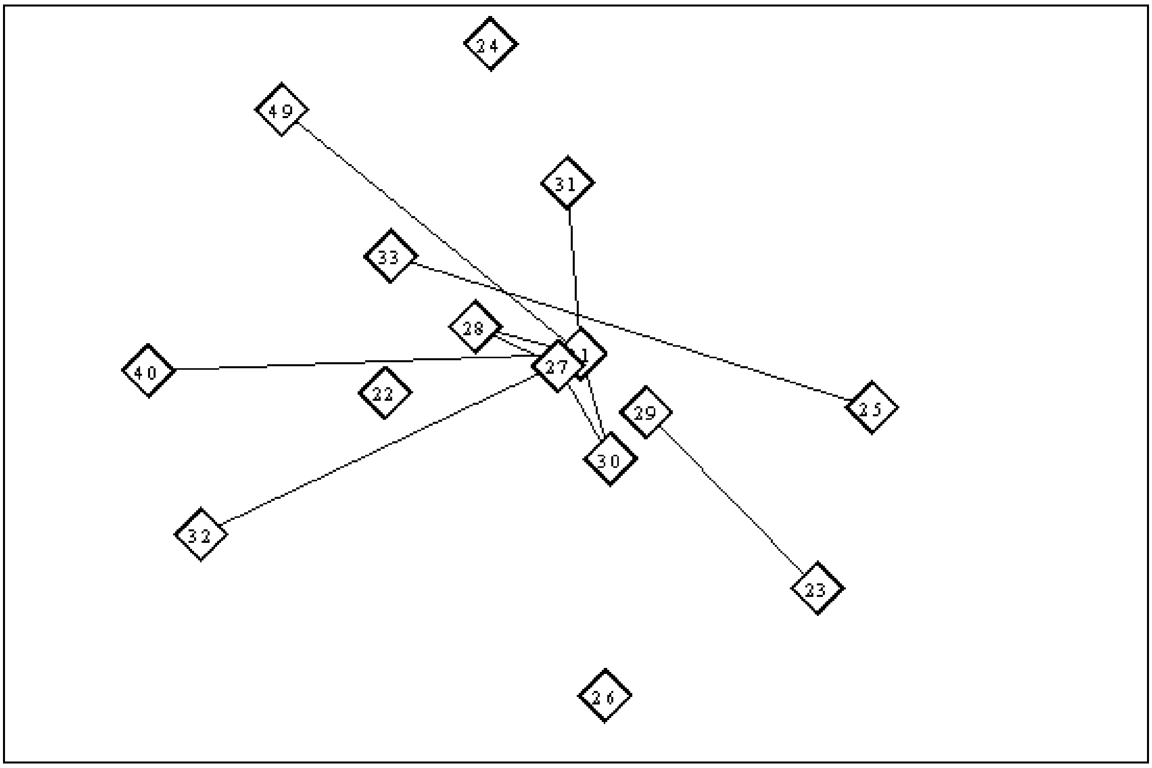

Graph 4 shows the positioning of academic teams based on the Euclidian distances between them and the patterns of internal linkages between them. The pattern of GIS linkages between academic teams is more dense than was the case for government teams. About half (8/18) of the academic teams that occupy positions in the inner circle of the Greek GIS community are interconnected. Teams form dyads based on common interests about specific types of GIS applications. For example, the teams (13, 35) from the Laboratories of Cartography at the National Technical University of Athens and Aristotle University of Thessaloniki are linked because they share a common interest in digital cartography and cadastral GIS applications. The same is the case for the teams (42, 44) from the Laboratories of Spatial Planning at the University of Patras and the Foundation of Research & Technology Hellas at Heraclion - Crete with respect to land-use planning.

*Graph 4: Academic teams based on the Euclidian distances between them.*




In contrast to government and academia Graph 5 shows that the majority of teams who belong to the private sector are interconnected. This is mainly due to the activities of the Greek ArcInfo vendor (team 21, Marathon Data Systems) who is the best linked team from the GIS software vendors with engineering consulting firms. Graph 5 shows that this team maintains linkages with teams: 27 - Eratosthenis, 28 - Geomatics, 30 - Terra and 31 - Gaia, because of various joint GIS projects throughout the country. In the middle circle of the Greek GIS community there is a small minority of GIS software vendors like Laserscan (team 24) and Star (team 26) which are isolates within the private sector because they have managed to sell their packages only to very few teams.

*Graph 5: Teams who belong in private sector firms based on the Euclidian distances between them.*




#### *4.2 Disciplinary Background*

Graph 6 shows the disciplinary backgrounds of the 51 teams who form the Greek GIS community based on the Euclidian distances between them. The positioning of teams in

Graph 6 is the same as in Graph 1 because the Euclidian distances between teams are calculated based on the same sociomatrix deduced from Figure 1. The boxes represent teams with a surveying engineering background. The circles represent teams with a spatial planning background based academically and professionally on architecture and civil engineering. And the diamonds represent teams which share such diverse disciplinary backgrounds as geography, electrical and computer engineering, mathematics, agriculture, forestry and environment.

*Graph 6: Disciplinary backgrounds of the 51 teams who form the Greek GIS community based on the Euclidian distances between them.*

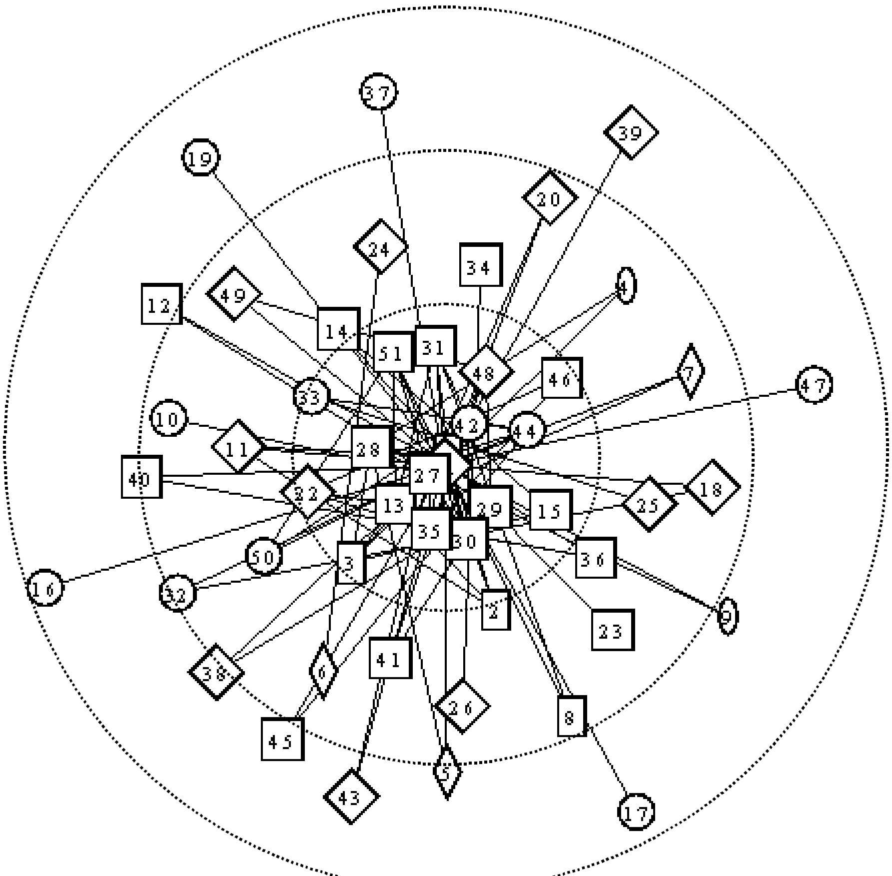



Table 2 shows the percentage of teams in the inner, middle and outer circles of the Greek GIS community according to these disciplinary groups. From this it can be seen that unlike the findings for institutional setting (see Graph 1 and Table 1), the inner circle of the Greek GIS community is rather homogeneous with about two thirds of the

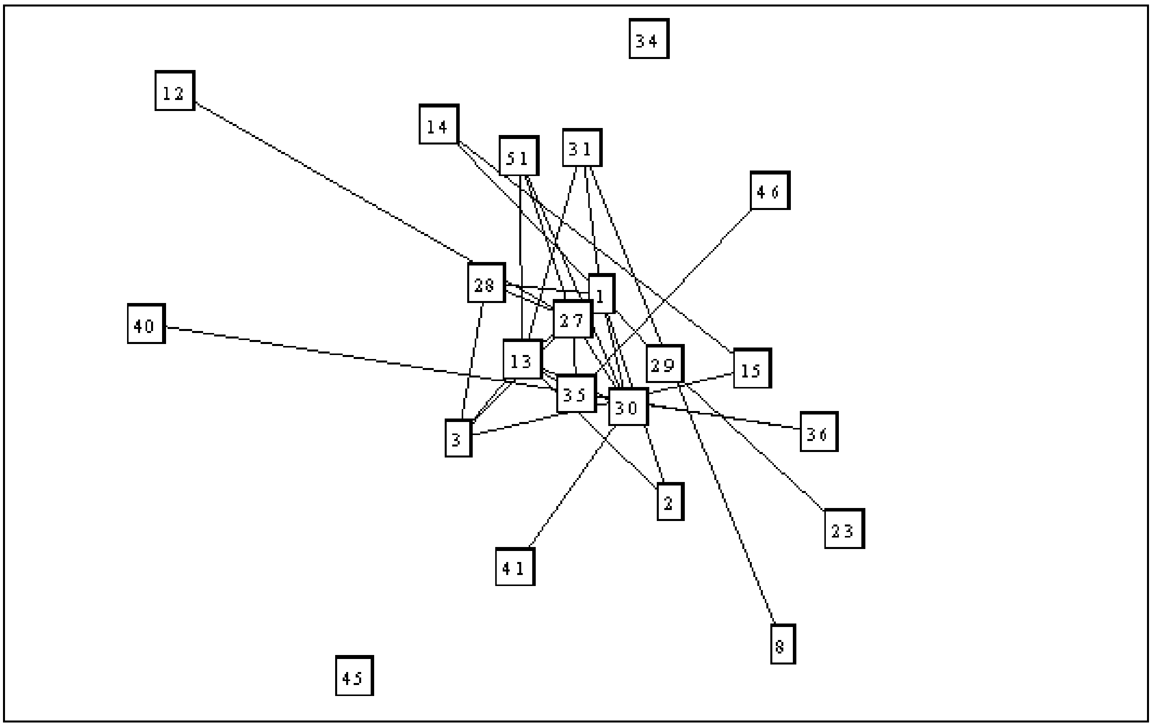
19 teams (or 68 percent) sharing a surveying engineering background. The other third is equally divided between the spatial planning and the other disciplinary groups. This is a significant finding with considerable implications for the future development of this GIS community. It shows that the group of teams with a surveying engineering background is the dominant relevant social group regarding GIS technology in the early 1990s, because the majority of the most central GIS teams in Greece share a surveying engineering background and maintain a strong web of affiliations with the surveying engineering tradition of practice. As can be also seen from Table 2 surveying engineers are the second largest group (35 percent) in the middle circle, and the third (11 percent) in the outer circle of the Greek GIS community. The spatial planners occupy two thirds (67 percent) of the outer circle, while the group of teams with one of the other backgrounds occupy almost half (48 percent) of the middle circle.

*Table 2: Percentage of teams in the inner, middle and outer circles of the Greek GIS community according to the main disciplinary groups.*

| **Percentage of Teams in the Inner, Middle, Outer Circle / Disciplinary Groups** | **Inner Circle (19 teams)** | **Middle Circle (23 teams)** | **Outer Circle (9 teams)** |
|---|---|---|---|
| **Survey Engineers** (22 teams) | 68 | 35 | 11 |
| **Spatial Planners** (13 teams) | 16 | 17 | 67 |
| **Others** (16 teams) | 16 | 48 | 22 |

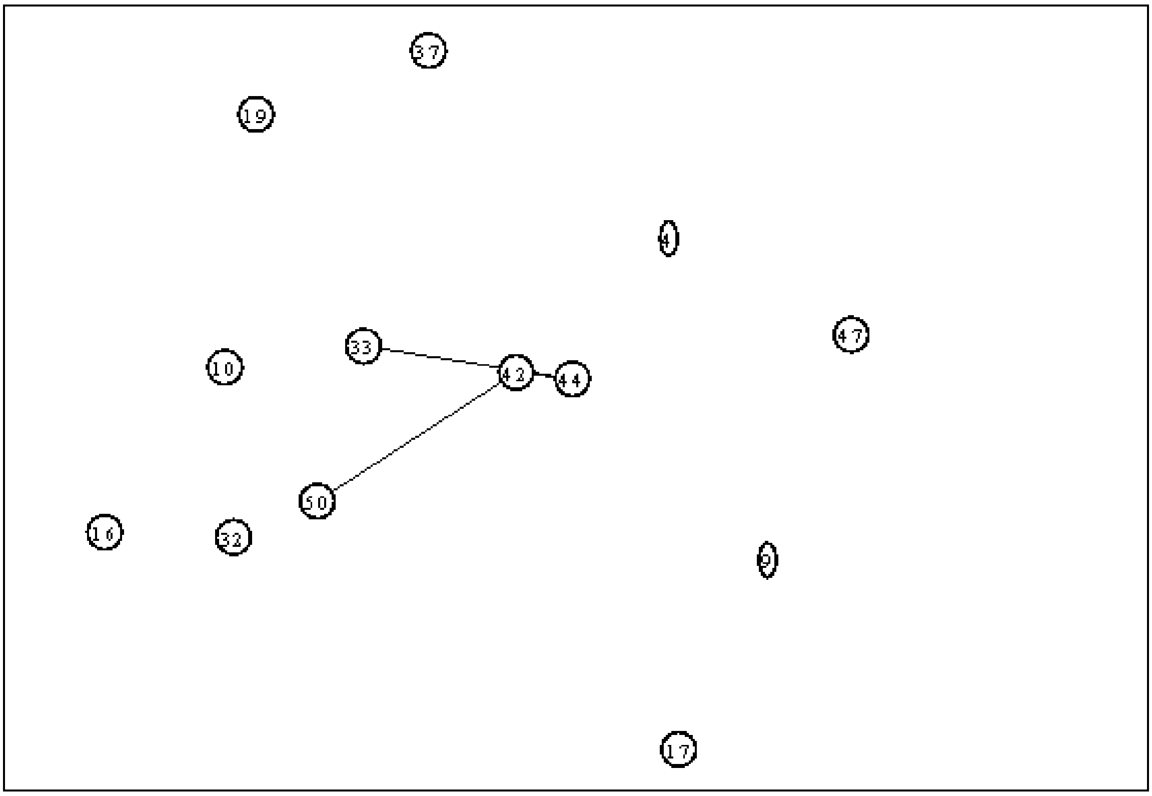
The next set of Graphs explores in more detail the patterns of direct linkages and the positioning of the 51 teams in Graph 6. Graph 7 shows the surveying engineering group of teams. Only 2 out of these 22 teams are unconnected with the rest. The vast majority of teams with a surveying engineering disciplinary background maintain at least one linkage with some other member of the surveying engineering tradition of practice. As can be also seen from Graph 6, the thirteen surveying engineering teams who shape a significant part of the inner circle of the Greek GIS community maintain a number of direct linkages between them. It can be argued therefore that this cohesive subgroup of surveying engineering teams has constructed a comparative advantage for surveying engineers in Greece.

*Graph 7: Teams who share a surveying engineering disciplinary background based on the Euclidian distances between them.*




Its members possess not only hardware, software, and digital topographic data but have also produced a shared body of knowledge and expertise related to GIS technology which fuels the further diffusion of GIS throughout Greece according to the surveying engineering tradition of practice. On the other hand as can be seen from Graph 8 more than two thirds of the teams who share a spatial planning disciplinary background are unconnected with each other and occupy positions in the outer circle of the Greek GIS community. Only two teams at the Laboratory of Spatial Planning at the University of Patras (team 42) and the Regional Planning Division at the Foundation for Research and Technology at Heraclion - Crete (team 44) are proximate and linked with each other. Apart from these two spatial planning teams only two other teams (33 and 50) are directly related to these academic teams.

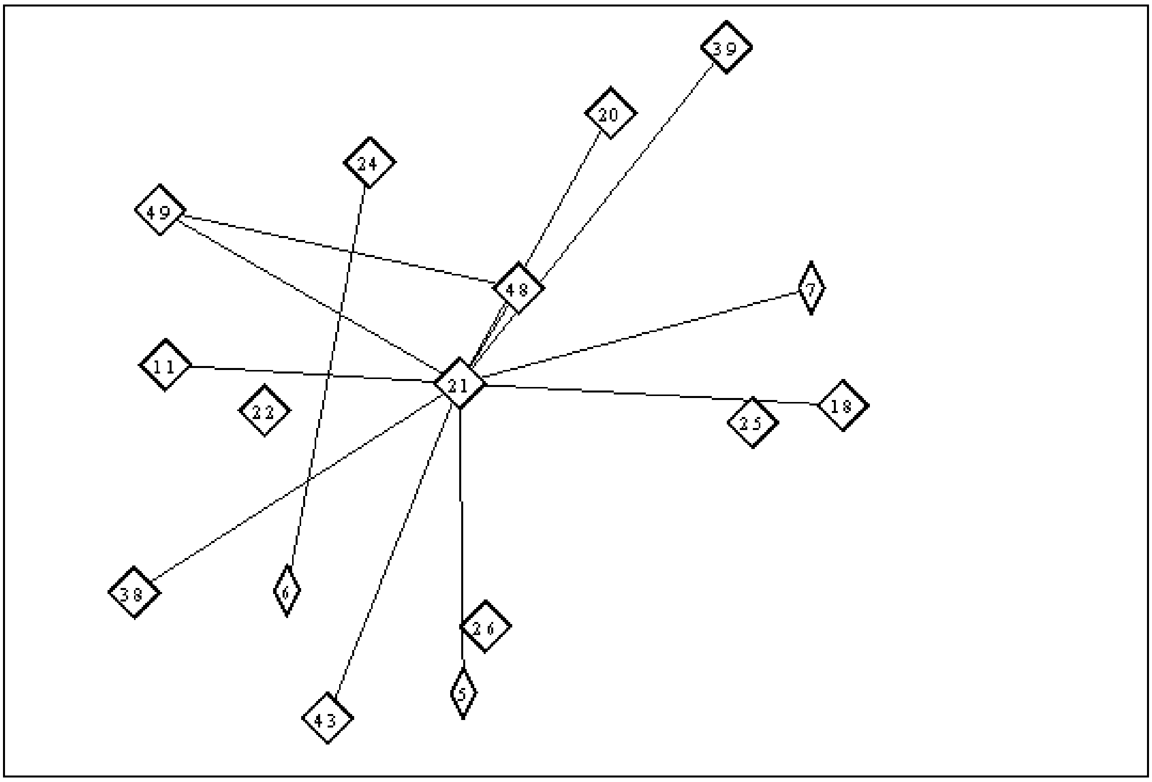
*Graph 8: Teams who share a spatial planning disciplinary background based on the Euclidian distances between them.*




Infocharta consulting firm (team 33) was set up by the head of team 44, while the head of the Technical Services (team 50) at the municipality of Rodhos has attended many of the Ursa-Net meetings set up by team 42.

Graph 9 shows the third group of teams that share one of the “other” disciplinary backgrounds related to GIS in Greece. As might be expected the Greek ESRI vendor (Marathon Data Systems, team 21) is the reference point for this group providing connectedness to most of its members. The only isolates within this group are other GIS software vendors, namely Intergraph Hellas (team 22), Omas-MapInfo (team 25) and Ambit-Star (team 26). Like the spatial planning group, only a small minority of the"other" teams (3 out of 16, Marathon Data Systems, Intergraph Hellas and the

*Graph 9: Teams who share the “other” disciplinary backgrounds based on the Euclidian distances between them.*




academic team based at the Department of Environmental Studies at the University of Aegean) belong to the inner circle of the Greek GIS community. The main reason for the lack of direct linkages among the teams of this heterogeneous social group is that they follow various traditions of practice related to GIS.

## 5 Evaluation

Based on a map of GIS teams and socio-economic linkages of the emerging Greek GIS community (see Figure 1) a GIS sociomatrix was analysed above using Ucinet IV and KrackPlot 3.01 social network analysis and visualisation computer softwares. A series of graphs (see Graphs 1 to 9) was produced based on 2-dimensional scaling of Euclidian distances to gain insights of the "deep" structure of the Greek GIS community, in terms of two social constructs, institutional setting and disciplinary background. Social network analysis allowed the rigourous definition of the core, or the inner-circle, of the Greek GIS community. This also made it possible to identify GIS actors (i.e. Greek ArcInfo vendor, team 21) and relevant social groups (i.e. surveying engineers) who take centre stage in the development of the Greek GIS community. As a result it was possible to discuss both the positioning of GIS actors according to structural equivalence and to comment on the patterns of direct GIS linkages within the various institutional and disciplinary groups who participate in the construction of the Greek GIS community in its early critical stages of development. In this sense they were explored both models of contagion of GIS innovations by structural equivalence and cohesion.

The findings according to both of these social network analysis models show that GIS teams who come from a broad range of settings can easily transcend institutional boundaries as they have developed similar patterns of connections with respect to GIS adoption and implementation. On the other hand teams who share a surveying engineering disciplinary background form the predominant relevant group of the emerging Greek GIS community. They not only occupy two thirds of the inner-circle but they are also better interconnected compared to any other disciplinary group of the Greek GIS community. As a result the technological tradition associated with the surveying engineers in Greece is becoming the dominant GIS technological tradition in the 1990s. If this hypothesis is true then a great part of GIS investment and the majority of GIS applications in Greece will continue to focus on cadastre, parcel management and tax assessment oriented projects, with the main emphasis on the issues of geometry, accuracy and digital topographic data production. The same network approach could be used in larger data sets, including not 50 actors at a national scale, but 500 actors at a European scale.

Usually the large number of actors involved in GIS diffusion research impedes the collection of reliable social and communication network data or the use of qualitative / ethnographic methods to study in-depth the social construction of technological systems throughout a whole country. The social network analysis methodology shows how the meaning of GIS technology is locally constructed within a whole country. It also provides a visual way to gain insights into the structure created by a large number of GIS system builders at a national scale across all sectors. Economic, knowledge and social relations in terms of GIS adoption and implementation usually transcend organisational boundaries and can be framed in GIS sociomatrices. Subsequently these GIS sociomatrices, even if they include hundreds of nodes and linkages, can be analysed for different social groups and the positioning of actors as well as the patterns of direct linkages between and among different groups can uncover the "deep" structure of an emerging GIS community in terms of different social constructs. If this exercise is repeated in more than one cycles then it is possible to study how the patterns of network linkages are hardened over time defining the nature of new technological systems like GIS throughout a whole country or a wider region.

As indicated in Assimakopoulos (1996, 149), from the late 1980s to the early 1990s the European Community / Union financial aid was the main factor which sustained the diffusion of GIS innovations in Greece as new technological systems (e.g. national cadastre, national environmental monitoring system) were externally induced in central government agencies. Fund allocation mechanisms which promote cooperation between different organisations can be linked with the technology policy aspects of social network research. Clearly the analysis of how various institutional and disciplinary groups interact would be useful in looking how technology policies develop. Perhaps it is time for social constructs such as institutional setting and disciplinary background to be taken into account in informing technology policy and strategy making at both the European and the national level.

Policy makers in European institutions like the European Commission want to take advantage of the huge diversity of experience across different European countries. In the generation of the necessary creative tension for greater cooperation at the European level, policy makers might need to know how they can diversify the heterogeneous GIS networks in Greece involving members of other technological communities from other European countries (e.g. not only surveying engineers from Germany or Austria, but also human geographers and town planners from the UK). So far, various actors from Greek university laboratories, private sector firms and government agencies maintain an outward perspective. As a result they could take advantage of such informed policies and forge linkages that facilitate collaboration and exchange of ideas among scientists and practitioners who come not only from different geographical areas but also from different relevant groups and technological communities.

In terms of theory building this research could be related to the debate of loosening the technology / society divide. As Latour (1991, 129) argues a theory of socio-technical change should conceptualise diffusion of innovations as a translation process in which different actors enrol differrent human and non-human elements in the formation of a socio-technical network which gradually defines a new idea. To make sense of this point using the analysis above, GIS teams, that belong to a broad range of institutinal settings but share the dominant surveying engineering tradition of practice, have adopted, implemented and used a great deal of hardware, software and data related to GIS in Greece. Equally in the early 1990s they have also attempted to translate GIS according to their interests shifting the emphasis of the debate in particular types of GIS applications (e.g. cadastre, parcel management, tax assessment) and specific GIS issues (e.g. geometry, accuracy in GIS databases, digital topographic data production). In this sense they enrol members of other social groups and technological communites related to geographic information handling and analysis in their agenda defining what GIS can (and can not) be used for within a whole country.

With this in mind two questions might be investigated for future research in the development of the Greek GIS community:

- in the early 2000s, do patterns of direct linkages within government, academia and private sector teams defining GIS technology in Greece remain similar to those discussed in section 4.1? and,

- have the GIS teams that share a surveying engineering background maintained their primacy of the inner-circle in this emerging technological community?

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