

Infrastructure in a GIS Context and Spatial Data Infrastructure

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The term "infrastructure" has been heavily used recently. At the beginning of 1992 the rupture of the tunnel and the subsequent floods in downtown Chicago brought heavy use of the term in many articles talking about the crumbling infrastructure. Then, in the national political discussion frequent reference was made to committing financial resources to rebuilding and maintaining our infrastructure. This enhanced exposure to the term prompted me to organize a panel session to examine how the word fits into the diverse realm of GIS.

I selected the panelists to get the thoughts of a range of people working in various aspects of GIS. The final group consisted of Charlie O'Conner, City of Chicago, responsible for maintaining many of the data bases and maps for the city; Elizabeth Cook, Illinois Natural History Survey, concerned with remote sensing data-bases; Bill Goran, Army Corps of Engineers CERL facility in Champaign, concerned with analyses of military bases around the world; and Nancy Tosta, U.S. Geological Survey in Reston, Virginia, responsible for coordinating GIS activities around the country.

The discussion began by exploring what is meant by the term

"infrastructure" in its traditional sense and whether the term has any special meaning in terms of GIS. Then the panelists were given an opportunity to add their thoughts. Finally, the discussion was thrown open to the audience. The session was well attended and the audience generated many questions and comments. The session went its hour and a half and would have gone longer were lunch not being served. This paper is an overview of the complete program.

Definitions and Dimensions of Infrastructure

The Random House Dictionary (Urdang, 1968) defines infrastructure as "the basic, underlying framework or features of something, especially of a technological kind, as the military installations, communication and transportation facilities, etc., of a country or organization." This definition is most consistent with the idea that infrastructure is bricks and mortar. It is not unusual to hear people in the media refer to infrastructure as "highways and railroads," but there are other dimensions to infrastructure. In *Spatial Data Needs: The Future of the National Mapping Program* (National Research Council, 1990) frequent reference is made to the information infrastructure. It appears that the term is introduced in the section, "Spatial Information and the Economy."

The two-way flow of spatial data . . . is a revolutionary concept and will require significantly altered conceptual and technical structures as

well as revised thinking on institutional and national economic issues. . . . If ours is to be an information-based economy that is competitive on a global basis, there is a critical need for a coordinated and efficient national information "infrastructure" to facilitate the sharing and communication of information resources. One component of this information must deal with where things are, that is, it must be a geographic information infrastructure, to support all manner of resource, transportation, planning, administration, marketing, and communication activities (p. 22).

The paper closes with the following statement: "The committee believes that geographic/spatial data at scales from local to global form an essential part of the national information infrastructure" (p. 50). Obviously, an information infrastructure is different from the bricks and mortar that everyone agrees is infrastructure.

Barbara Petchenik was the prime author of the National Academy study. Before her untimely death Petchenik (1991) had begun a paper entitled "The Infrastructure's Infrastructure." Her focus was on vehicle navigation systems, but this title fascinated me and I read more into these words than she had in mind. As if to support the direction my thinking was taking, a popular GIS magazine recently printed the following note (I paraphrase): a board that governs a Utility ruled that the GIS systems that the Util-

ity employs to manage its infrastructure can be considered part of the infrastructure of the Utility. The consequence of this is the Utility has a different method to cost out items that are considered to be infrastructure.

A couple of years ago, *Photogrammetric Engineering and Remote Sensing* ran a call for papers for a special issue devoted to the National Spatial Data Infrastructure (American Society for Photogrammetric Engineering and Remote Sensing, 1992). A few of the topics called for illustrate the pervasiveness of this term.

- Definitions of, and requirements for, a National Spatial Data Infrastructure
- The roles and responsibilities of the private sector and government agencies in construction of a National Spatial Data Infrastructure
- Benefits to local governments of a National Spatial Data Infrastructure
- Policies affecting a National Spatial Data Infrastructure
- Technological opportunities and constraints in developing and using a National Spatial Data Infrastructure
- Legal aspects and concerns regarding a National Spatial Data Infrastructure

As I reflected on the term, I realized that "infrastructure" is sometimes used to include a complex of tangibles and intangibles.

In discussions on the effects of the "green revolution" it was common to note that a place has to have an appropriate infrastructure to take advantage of the new fertilizers and seed. That infrastructure includes the ability to deliver water for irrigation and roads to get things to market—traditional parts of infrastructure—as well as markets nearby, banks to make loans, and a legal structure to secure loans and to support tenure to the land. Is it proper to consider some laws and institutions as part of the infrastructure?

Data networks are emerging as part of the infrastructure of GIS. The National Research and Education Network is the name assigned to the backbone of the national network built on the Internet.

Some people refer to the NREN as the digital equivalent of the interstate highway system. At other times the network is seen as the heart of the national information infrastructure. For many people around the country and abroad Internet is already a part of the infrastructure facilitating GIS activities. Given that data networks range from local area networks within a single building, to wide area networks that may extend across town connecting various agencies, to networks that link state agencies and firms, to the many gateways allowing the Internet to cover the nation and extend to many other countries what implications does this have for GIS communities?

Thus, we find references to geographic information being part of our infrastructure, GIS systems as part of an organization's infrastructure, and the highways, data

networks and pipelines that we map and include in our databases as part of our infrastructure. Is it appropriate to extend this further and argue that the trained personnel necessary to run and maintain our GIS systems are part of our infrastructure?

After developing this preface to the panel discussion I developed my own concept and working definition of infrastructure. In my mind infrastructure represents those things created and developed to help the country, region, organization, or firm be productive in its prime tasks. Things that are considered to be part of the infrastructure are created by a conscious effort, generally represent a considerable investment, and have potential utility over a considerable period of time. Natural resources such as clean air, good soils, gentle topography, and abundant groundwater are therefore not part of the infrastructure, but a good transportation network is. In an editorial reflecting on infrastructure problems in Chicago and our changing attitudes to investing in infrastructure, Haider (1992) makes the case for investing in "public infrastructure." If public infrastructure can be distinguished, is there then a private infrastructure? Is that infrastructure a part of the infrastructure of the region and the nation? If a region lacks appropriate buildings, major pieces of equipment, and a skilled workforce, it will be less productive than a region that has these attributes. Recall how our country was able to convert our power, personnel, and industrial capacity to a wartime footing at the beginning of World War II. In today's

terminology would that capacity have been considered part of our infrastructure?

Given these thoughts, I raised the following basic question before I turned the floor over to the other panelists and the audience: "How much of this discussion is predicated on the fact that it is now fashionable to use 'infrastructure' in our conversations. Put another way, is 'infrastructure' the buzz word of the early 1990s? Does it matter if the emphasis on infrastructure is a matter of fashion or a buzz word?"

Perspectives of the Panelists

Goran chose to focus on infrastructure in terms of digital geographic information and databases. He started the discussion by noting the recent reorganization of the Corps of Engineers Construction Engineering Research Laboratories into two new groups: the Environmental Containment Lab and the Infrastructure Lab. Thus, the role of infrastructure has been recognized by this part of the Corps. Hurricanes Andrew and Iniki recently brought home the need for an infrastructure to identify and distribute geographic data. In the processes of monitoring events and coordinating clean-up it proved very difficult to obtain necessary information.

Goran is a heavy user of the Internet and said that this large network offers the potential to solve many of these problems. He noted that we do not have all of the pieces in place to do the job right, even from the federal perspective alone. The concern is to have a method to identify appropriate data and get access to it in a

timely fashion. Certainly, there will be gaps in the data, and not all of it will be equally current and available for every place. The question is to find what is out there. From the data network perspective this might be thought of as a matter of indices and pathways.

Goran presented the idea of having a toolbox integrated into the data network to allow users to interactively query what is available. The queries might be based first on such spatial units as quads, administrative units, or natural units. Once a match is made the query could then focus on the subject matter and the currency of the data. Goran thinks this can be done even though various federal agencies are at different stages of data preparation and organization. Add in state and local agencies and nongovernmental organizations that hold relevant data and the task is sizable.

Goran went on to state that a number of questions need to be addressed. Developing file transfer protocols is already being worked on. He questioned that the Internet is robust enough to handle the potential traffic in geographic information. There will also be questions about limiting access to geographic information over the Internet. Although many people have access to the Internet, many do not. In the short run alternatives to the Internet will have to be provided, and there are viable alternatives. Goran finished by saying that he and his colleagues are addressing many of these issues now for the identification and distribution of defense department data.

Tosta started her comments by

showing her "party slide," portraying all the people and organizations that are interested in and have something to do with geographic information. In showing that mix she stated that informed and knowledgeable people are indeed part of the infrastructure. She then addressed the basic question of how to develop the communities of users so that people can find what they need and will have a mechanism to interchange the spatial information.

The Federal Geographic Data Committee (FGDC) operates at the federal level to get the agencies to know about each other and their common interests. Extending such functions to bring in local and state governments as well as the private sector adds to the task. Tosta noted that the committee has been holding town meetings and state gatherings to develop awareness among producers and users. Last year it held a public forum on the technical issues in data exchange. In May 1992 it had the first forum on metadata standards (Federal Geographic Data Committee, 1992). The theme of the National Geodata Policy Forum in May 1993 is to be the national spatial data infrastructure. There is a proposal to set up a computer bulletin board to facilitate the exchange of ideas and information on spatial geographic information.

The FGDC has stated its vision for the next year: everyone will be able to find data and be able to access it, assuming the data exists. Where data cannot be found, partnerships will be sought to develop ways to create the data. Having an organization that can facilitate the creation and dissemination of

needed data is a good example of the kind of infrastructure we need. Tosta cited the joint agreement between the U.S. Bureau of the Census and the U.S. Geological Survey for a common database for the 2000 census as an example of what can be done.

It is important to note the efforts to establish standards to facilitate the interchange of data. The 14 agencies on FGDC have signed off on some basic concepts, which might be thought of as standards. One such concept is to have a virtual clearinghouse for data. It is virtual in the sense that the clearinghouse would be at a single site, but with our information technologies in place many sites could function as a single unit. Metadata are data about data, another effort at developing functional standards (Nebert, 1992). As proposed, about one hundred pieces of information will be collected for each database as it is created, including such things as scale and areal coverage, the sources and lineage of the database, and when it was created and revised. As people employ the metadata standard for each database, it will become much easier for users to find appropriate data and to evaluate what is contained in the data. We in the GIS community will hear much more of this term.

Tosta argues that the resources which bring us together are part of our infrastructure, whether they be meetings such as *GIS in Illinois*, newsletters, names of colleagues on a rolladex, or e-mail across the Internet. That means this meeting and similar meetings are part of the infrastructure of GIS. As a closing shot she suggests it might

be better to use the term "Infostructure" for our information-based infrastructure.

Liz Cook built on what had been said earlier. She thinks that the desire to use infrastructure as we are now using it is part of the shift from an industrial society to an information society, where information, particularly digital information, is considered to be part of our economy. Although we may look to metadata and various indices to identify databases, she expressed concern about some of the political and legal issues that do not facilitate data sharing. The diverse state laws regulating data and information sharing constitute a significant issue that has to be addressed. She also expressed the opinion that the Internet is not yet a viable tool for the exchange of the remote sensing data she works with most of the time because these data are too voluminous.

Paying for all of this was another point Cook brought up. Across the country we have been having discussions about an increase in the gasoline tax to pay for the highway infrastructure. She has not heard an equivalent discussion about how we are to raise the funds to support an expanded national infrastructure for the exchange of digital geographic data, so much of which is in the public domain.

Charlie O'Conner harked back to 1975 when he attended meetings on land information systems, dealing with some of these same issues discussed by the earlier speakers. He recalled some of the buzz words that have been used over time: MOLDS—Modernization of Land Data Systems;

MPC—Multipurpose Cadastre; and now GIS—Geographic Information Systems.

O'Conner was involved in the development of O'Hare Field from the beginning. He noted that one of the most useful items was a composite utility drawing, with project numbers for each of the pieces written on the map. These numbers permitted people to know rather quickly where to go to find additional information. The indices and metadata discussed here seem to be the digital equivalent of that analog map. If it could be done then it should be able to be done now.

In his current position O'Conner could benefit from access to standardized data. He worked for years in engineering and surveying and now works in the planning department of the city of Chicago. He related how the planners get data from a great variety of places and want him to turn the data into maps. As he related the nature of much of the data, the need for standards became most apparent. Once again, a panelist revealed that the infrastructure is not in place to make his life easier.

Open Discussion Period

The discussion was then opened to the floor. There were a number of good comments and many ideas were brought forth. Warren Bingham of the Illinois Natural History Survey questioned our ability to limit access to digital data. He asked if all public data should be available for everyone. He cited the case of distributing information on the sites where an endangered species might be identified. If someone were to use the

information to harm the organizations, who would be responsible? So, while we build the infrastructure to identify data and provide access to the data, we should consider those situations where this may not be in the best interest of society. Bingham later brought up the fact that Illinois has legislated that citizens can gain access to all data held by a state agency, even if there are potential dangers in releasing the data.

Paper maps are part of our infrastructure, but much of the open discussion focused on digital data. A major concern with data in a digital format is keeping a historical record. Who will maintain data over time so users can go back and see what was known at a specific time? This was a major concern for a number of people. Many cited cases where current technology can no longer make use of digital data that was state of the art only a few years ago. Maintaining a history is important, and providing the tools to get at that history should be part of the infrastructure we build.

Considerable discussion was devoted to talking about network resources for identifying and exchanging geographic databases. Although many of the panelists use the Internet, only a small proportion of the audience had firsthand experience with it. The Internet is the name given to the large network of networks that employ the Internet protocol. NetILLINOIS is an effort to provide Internet access to all universities and colleges within the state, and in the process tie these units to public nodes and state networks. There are people working to ex-

tend the resources of the Internet to all reaches of the state and the country.

Finding information on a big network is still another concern. Wide Area Information Server (WAIS) was brought up during the discussion. This relatively new tool permits a user from his or her workstation to search all other servers running WAIS for data based on information requested. As hits are made on data one can refine the search to look for ever more specific data. The results from one search can be incorporated into the next search to extend or refine the precision of the search. WAIS is still under development, but it shows great promise for use in the distribution of geographic information.

The next step would be to adopt a metadata standard, create metadata files for large numbers of geographic databases, and post them on WAIS servers. Then, from a PC attached to the network a user will be able to search the world for data meeting various criteria by interacting with the WAIS search engine. This process will not give the person access to the data but should tell the person where such data exist and who to contact to get access to the data.

In spite of talk about future networking possibilities, there was the overriding concern of who will be able to get access to the networks. It was noted that many citizens now participate in commercial networks such as CompuServe and Prodigy as well as local freenet. For many homebound people these networks are a new way to get outside the house, and access is available 24 hours a day.

Many public schools are now getting links to the various networks. In general, if you have access to a telephone you can probably get on to a network. However, it will be some time before everyone can get access to the appropriate networks and have available the necessary tools to get to all of the spatial data they might want. Until that infrastructure is in place we still need to be concerned with finding and accessing appropriate geographic information by traditional means.

Closing Comments

The Internet, NetIllinois, WAIS, and metadata are parts of the emerging infrastructure that hold considerable promise for locating and accessing geographic information. Although these tools are at various levels of development, they are far enough along for a few people to use them for geographic tasks. The challenge is for all of us in the GIS community to keep our eyes and ears open for opportunities to learn more about these technologies and to try to inform people in our organizations about the possibilities.

Perhaps one way to reflect on what we mean by infrastructure in terms of GIS is to think of the ideal situation. In an ideal case a user would be able to find out how to get the information, determine what is available, access the data quickly, and have the tools needed to use the data in the format in which it exists. In most cases this is not possible today, for the infrastructure is not yet in place. To build that infrastructure will require more and better data, pathways to permit the interchange of data, policies and standards to let

the data be shared or sold, and knowledgeable people to make the system work and to keep it working. This is the infrastructure of current concern in the GIS community. It stands apart from but complements the bricks and mortar so often considered to be our infrastructure.

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The Cultural Map of Illinois: A New Kind of General Interest Map

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The Illinois Humanities Council has funded a two-year project to compile a unique map of Illinois featuring its rich cultural heritage. The Committee on Geographical Studies of the University of Chicago has received a \$36,000 grant to cover the compilation phase. The purpose of the project is to create a completely new kind of map for Illinois that will present geographically the full richness and variety of the state's heritage in a medium never attempted before. The project will offer an unprecedentedly wide and compelling humanities perspective to the general public through an interpretation of the cultural, historical, ethnic, and developmental patterns that have shaped the state and given it its present complex character.

The map, designed to complement the state highway map in size, will present a wide array of cultural and historical data covering the entire state. With colorful symbols, shading, and labeling, the map will display sites of historical significance; areas of ethnic settlement; physical features and landscape elements with cultural value; archaeological areas; architectural sites; and places with literary, musical, and visual arts associations recognized by local

communities—anything that helps define the local sense of place in a cartographic portrait of the state.

The Cultural Map of Illinois will differ fundamentally from *The Illinois Highway Map*, which is an aid to general travel, and the *Map Guide to Historical Places in Illinois*, which simply maps the locations of sites listed on the National Register of Historic Places (geographically a very uneven distribution). *The Cultural Map of Illinois* will be for browsing and reflection, to draw the visitor into the state, pique the curiosity, and provide an incentive to visit areas that are off the beaten track. It will be culturally inclusive and show as wide a range as possible of interesting cultural features and patterns for every part of the state. The map will also provide a foundation for cultural literacy for the citizens of Illinois. Neither of the existing maps even comes close to doing this. No state anywhere in America currently has such an innovative map, so this map is a bold departure in public humanities programming, intended to reach a vastly larger and more diverse audience than usual and to be of lasting value.

The project will involve intensive research in state and local history to determine which aspects of the state's heritage can be represented on the map. This will include considerable library and field work, compiling thematic information by individual community, county, and region from published sources in local history collections. The compilers expect to face two challenges. First, the map will need to reflect a balanced selection of cultural features, and firm criteria for inclusion will