FINAL REPORT

NCGIA RESEARCH INITIATIVE 4

USE AND VALUE OF GEOGRAPHIC INFORMATION

Harlan J. Onsrud and Hugh Calkins

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ABSTRACT

This report describes the results of NCGIA Research Initiative 4 on Use and Value of Geographic Information. It begins with a discussion of objectives and the process of developing a research agenda. The initiative was active during the period May 1989 through the summer of 1991, although the final wrap-up meeting was not held until April 1992. Since that time, research activities have continued and include activities within the original agenda as well as off-shoot activities contained within the research agenda of Initiative 9 on Institutions Sharing Geographic Information. This report describes each of the major areas of the research agenda and the research activities of the Center during and subsequent to the time period of the initiative. The report ends with an assessment of the initiative against five criteria.

BACKGROUND

The primary research objectives of Initiative 4 as expressed in the original center proposal to NSF were:

1. Identify primary and subsequent users of spatial information, and determine the value of such information;
2. Develop and test models of the decision-making process regarding land use, focusing on the role of geographic information;
3. Identify problems of dealing with risk and uncertainty associated with decision making; and
4. Evaluate the direct and indirect benefits of geographic information analysis and geographic information systems. (NCGIA 1988, pp. 61-62)

One of the challenges in organizing a specialist meeting is identifying a group of specialists who, as a group, can represent a broad perspective on the research area and yet can narrow in on priority knowledge needs. Beginning with a rather large group of potential specialists, a core planning committee selected and brought together a group of roughly thirty academics, government officials, and representatives of private firms along with NCGIA researchers for the Initiative 4 specialist meeting. The participants represented a variety of disciplines including geography, surveying engineering, sociology, economics, and law.

With the above objectives as a beginning point, the specialists discussed, evaluated, and prioritized research needs and developed an agenda for research on the use and value of geographic information. There was general consensus that much basic work had yet to be done to develop and test hypotheses about the use and value of geographic information. Through a series of large and small group meetings, characterized by open exchange and critique, the

participants arrived at a recommended research agenda for the general research community on the topics addressed by the initiative.

Among the research topics identified and discussed by the participants, three priority topics emerged:

1. Develop a taxonomy on the use and value of geographic information;
2. Investigate methods for assessing the value of using geographic information; and
3. Investigate the factors affecting the adoption and diffusion of geographic information technologies. (Onsrud, Calkins, and Obermeyer 1989, pp. 96-100)

NCGIA researchers developed a work plan that included activities addressing fundamental questions within all three of the priority areas. The overall objective of the work plan was to develop formalized integrated frameworks and tools for evaluating the use and value of geographic information. The general form of the research in developing these frameworks was to conduct, in an iterative manner, investigations into the actual use of geographic information in selected situations. The vehicles used were case studies, limited surveys, and broadly based surveys of geographic information users; both users and non-users of geographic information systems.

The range of research issues raised during the Initiative 4 specialist meeting is large and the methodologies enabling substantive knowledge advancements is complex and difficult for many of the areas. Although many important issues are in need of study, it has not been possible to cover all of them within the constraints of time and resources available. As a result, the closure of any initiative is not intended as a terminus of research but as a point to evaluate knowledge advancements and to provide impetus for further or alternative expansions by the rest of the research community.

The following sections discuss each of the priority research issues identified at the specialist meeting and the research progress achieved during the active period of the initiative. Topics discussed and explored at the specialist meeting and in subsequent research are of course colored according to the interests and specialized knowledge of the participating researchers. Although few NCGIA resources were devoted to this initiative after December 1990, derivative work has continued and been incorporated into Initiative 9 on Institutions Sharing Geographic Information.

PROGRESS ON THE RESEARCH AGENDA

At the Specialist Meeting, discussions progressed from identifying impediments to assessing the use and value of geographic information, to identifying those problems with assessing use and value that are researchable, and finally to identifying high priority researchable topics. It is important to understand that the areas addressed below are not the only areas relative to the use and value of geographic information where fruitful research topics may be discovered. Additional areas deemed important by the specialist meeting participants, some of which will require much longer time frames to accomplish, are reported in Onsrud, Calkins, and Obermeyer (1989). Rather, the broad topics addressed below were felt by the specialist meeting participants to be of high priority and more realistically pursued given present knowledge and research tools.

Taxonomy of Geographic Information Use

Understanding use is a prerequisite to effective design of GIS. The objective of taxonomy development is to provide frameworks or formalized structures for the study of the use of geographic information and for identifying the benefits of such use. Definitions for taxonomy (or taxonomies) have been summarized by Obermeyer (1989). Useful taxonomies classify objects on the basis of one or more characteristics (or attributes) of the object for the purpose of

identification and description in unambiguous terms. Taxonomies can be useful in the systematic study of objects provided the classifications allow each instance of the object under study to be observed and measured in a manner to facilitate comparison between observations and allow generalization of a set of observations to recognize significant patterns exhibited by the objects.

A taxonomy should reflect the purposes or objectives of the activity for which the taxonomy is created. In one instance the objective is to characterize the use of geographic information in decision-making. In another the objective is to identify and quantify the value, or benefits of the use of geographic information to one or more parties (preferably in a price-based form). In yet another, the objective is to systematically structure survey and case study efforts to facilitate later comparative analysis.

One taxonomy developed by the research is defined in terms of the set of questions for which answers are sought to further our understanding of the use of geographic information and the value (or benefits) derived from such use. Each question represents a single "view" of the use of geographic information. These "views" reflect not only what we would like to know at the present time, but also recognize the current state of development of systematic procedures for the use of geographic information (GIS) and the constraints imposed by the current level of development. The taxonomy represented through these questions is not representative of any complete taxonomy of geographic information use (or GIS). Other taxonomies (or views) designed for different objectives may be constructed (Obermeyer 1989) and would be valid for a broader understanding of the role of GIS and geographic information in a societal context. The "views" presented here are restricted to the purpose of the investigation and constrained by anticipated information availability from experts, users, and others currently involved with GIS.

The components of this illustrative taxonomy are based on three major questions reflecting what a potential user, manager, policy maker or other decision maker would typically want to know about the use of geographic information:

1. What successful uses are being made of geographic information?
2. How effective is the use of the geographic information?
3. What are the benefits attributable to the successful use of geographic information?

These questions are transformed into a more specific and relevant set of questions as follows:

What successful uses are being made of geographic information?

1. Who uses the geographic data or information?
2. What is the level of decision making of the user?
3. What is the purpose for using geographic information?
4. What are the steps in the decision making process where the information is used?
5. What are the application areas?

How effective is the use of the geographic information?

6. To whom do benefits accrue?
7. What is the level of need of the information?
8. What is the effect of the information and how is effectiveness measured?

What are the benefits attributable to the successful use of geographic information?

9. What are the Type 1 benefits of use of geographic information?
10. What are the Type 2 benefits of use of geographic information?
11. How are the benefits measured or identified?
12. What is the appropriate period for accrual of benefits?

What are the characteristics of the geographic data and spatial analysis?

13. What data are associated with successful use?
14. What geographical units are used?
15. How are the data represented?
16. What are the primary functional capabilities required in GIS to support uses?

17. What forms of spatial analysis are used or useful?
18. What is the form or format of the geographical product?
19. In what ways is the display of the geographic information useful?
20. What amount of geographic information is used?
21. What are the response time requirements?

What organizational factors affect the use?

22. How is the task of spatial data handling organized?
23. What types of organizations are using the geographic information?
24. What is the role of the organization in handling the geographic information?

This set of questions is then broken into further specific questions and sub-elements (Calkins and Obermeyer 1991).

Answers to the above described set of questions form an integrated initial taxonomy for the purpose of investigating the use and value of geographic information. That is, answers to a comprehensive set of standard questions may provide a rational and highly useful means of classifying geographic information uses and users.

In contrast to this approach to taxonomy development is an approach which draws from taxonomic work in the natural sciences and geographic theory for its foundations. Obermeyer argues that other taxonomies (or views) designed for different objectives may be constructed using this approach and would be valid for a broader understanding of the role of GIS and geographic information in a societal context. A preliminary taxonomy of geographic information and its uses has been developed from such foundations (Obermeyer 1989).

Neither of these approaches should be confused with taxonomies of "geographic information systems", whether those taxonomies focus on the task-orientation of particular systems (Dangermond 1983) or their system architectures (Bracken and White 1989). It has been argued that taxonomies of GIS typically focus on the state and direction of the technology and are useful in identifying information systems technology capabilities that have not yet been supplied in the existing suite of information system tools. Taxonomies of geographic information use, by contrast, focus more directly on end-users and their specific needs. Regardless, taxonomies of the uses of systems and of the systems themselves are obviously closely related.

A preliminary taxonomy of geographic information use developed by Obermeyer was presented at GIS/LIS '89. The different views and approaches to structuring a taxonomy of geographic information uses have been reported in Calkins and Obermeyer (1991). Leading into Research Initiative 9, Calkins and Weatherbee have extended their taxonomic framework to the more specific domain of spatial data sharing (Calkins and Weatherbe 1993).

The Use and Value of Geographic Information

A journal article in contemplation of the value research for the initiative was published by Dickinson and Calkins in 1988 in the *International Journal of Geographic Information Systems* with a comment piece following in a later volume. Foundation principals and ongoing work was also described in a paper at the GIS/LIS '89 meeting in Orlando and an annotated bibliography on the value of information was prepared and published by the NCGIA at about the same time (Dickinson 89b).

During the time period of this initiative and subsequent to it, numerous authors have explained the application of traditional cost/benefit analysis and extensions of it to purchase decisions regarding geographic information systems (e.g. Korte 1991, Steeger 1991, Poe, Bishop & Cochrane 1992, Smith & Tomlinson 1992, Moyer 1993, Donelan 1993). Others have reported in the GIS literature on methods for dealing with the problematic benefits-measuring issue raised

by Dickinson and Calkins (1988). For instance, Moyer and Niemann have analyzed benefits in terms of five primary categories of impact, namely; improved efficiency, responsiveness, integration, fairness and equity, and effectiveness (Moyer and Niemann 1991). Steeger has focused on "goal achievement valuation" and on an analytical method for assessing such values (Steeger 1991). Gillespie, in particular, has set forth a systematic and formalized approach for measuring and forecasting the benefits of GIS use. His approach first classifies an observable benefit as being either an efficiency benefit or an effectiveness benefit. Once classified, techniques for direct measurement of any benefit in the category are applied and strategies for inferring indirect benefits are suggested (Gillespie 1991). A digital benefits model that consists of separate equations for quantifying efficiency and effectiveness has also been derived. Its use requires a small number of objective and easily measured characteristics of the GIS application under consideration and the model has been tested for validity against numerous implemented systems (Gillespie 1992).

Contemporaneous with this related work, NCGIA research efforts began in this area with the recognition that a realistic determination of the value of geographic information could only be accomplished through a better understanding of the use of the information and the factors which influence the ability of decision-makers to use the information. The valuation of information principles from other disciplines are based on either establishing a monetary value for the information or defining benefits as "intangible," meaning an adequate measure cannot be defined and/or measured (Dickinson 1989a). Prior studies of the value of geographic information had identified benefits as tangible or intangible. The tangible benefits were identified mostly as direct cost or staff time savings while the intangible benefits were listed as better information, better planning and improved decision-making (Joint NORDIC Report 1987, Dickinson 1989a).

Significant benefits from the use of geographic information are contained within the intangible category. Calkins argued that the objective of attaching a monetary value to these types of benefits could best be reached through a better understanding of actual use patterns in decision-making contexts and identification of the factors facilitating or inhibiting such use. Thus the research plan for the Initiative first focused on the task of describing and understanding, in detail, the use of geographic information in decision-making.

Various methods for describing information use in a formalized model have been reviewed by Benwell, Sallis and Firns in a currently unpublished work. Their preliminary conclusion was that most popular methods for describing information flows have one or more drawbacks (such methods as flow charts, data flow diagrams, CPM or PERT diagrams, etc.). Benwell suggested that a variant of Petri nets (colored Petri nets) might be suitable for the purpose of modeling the use of geographic information. Formal modeling of use would then provide a framework to attach value measures to the geographic information (Benwell and Dickinson 1991). This notion was tested by Calkins and Dickinson using two in-depth case studies of GIS -the use of geographic information by the Washington State Department of Natural Resources (forestry application) and a local government geographic information system (Town of Amherst, New York) involving eight departments of town government (planning, building, assessment, recreation, engineering, highway, police and fire dispatch). In each of these case studies, attempts were made using the Petri net framework to model selected geographic information applications.

The application of the nets to complex systems proved to be extremely complex and detailed findings are reported in "Deriving a Method for Evaluating Use of Geographic Information in Decision Making" (Dickinson 1990a). In addition, substantive research contributions are being described by Calkins in an article reporting the initial results of I9 case studies. The research group at Buffalo has found that the current state of development of geographic information systems is not such that they could systematically measure use of geographic information by directly observing user transactions to a GIS before now. The GISs they have targeted for case

studies (i.e., those at least 5 or more years old) are still in the process of data conversion and, only now, are these systems beginning to experience significant levels of regular use.

Because the application of Petri nets to modeling the use of geographic information has proven to be extremely complex, continuing efforts in this activity are planned under I9 as part of the case studies into data sharing. Calkins and Weatherbe have begun a series of exploratory, in depth case studies looking into both data sharing and geographic information use and value (Orange County/City of Orlando, Florida; CAGIS, Cincinnati, Ohio; IMAGIS, Indianapolis, Indiana; and City of Milwaukee/Southeastern Wisconsin Regional Planning Commission, Milwaukee, Wisconsin). The research plan for these case studies anticipates asking each system to monitor utilization over a one year period with a subsequent evaluation of the use of the GIS and associated value of the information to users (decision-makers).

Taking another approach and focusing on a specific subset of geographic information, Gary Jeffress formulated a conceptual model for the use of land ownership information. The model initially derived from the assumptions that users of land information (whether ultimate use is by primary, secondary, or tertiary users) demand that information primarily for the purpose of reducing uncertainty in decision-making and that satisfying "demand" should be the focal component from an economic theory perspective in assessing the use and value of land ownership information. The intent of investigating existing theories of economics of information, information theory, risk analysis and cost-benefit analysis and exploring their relevance to land ownership information through model building was to aid structured analysis of the benefits that automation can be expected to have on the operations of recording and retrieving land ownership information. Data gathered from a world-wide survey of organizations currently recording and distributing land ownership information and data gathered on specific institutional users of land ownership information was used to support and define the limits of the model. The Ph.D. dissertation resulting from this research is titled "Land Ownership Information Use in Real Property Market Transactions" (Jeffress 1990). Research findings have also been reported in Jeffress (1991) and Jeffress and Holstein (1993).

Adoption and Diffusion of Geographic Information Technologies

Understanding technological change in the context of conceptual formalism and empirical generalizations as well as utilizing factors and processes of change to achieve desired goals of adoption and implementation are new areas of endeavor in the geographic information field. However, the principles of change, diffusion, innovation, utilization and social impact assessment have been studied by sociologists, management scientists, and others for many years.

Diffusion of innovations theory provides an approach for analyzing and formally modeling the factors and processes involved in acquiring, implementing, and utilizing geographic information innovations. Using this knowledge base, Onsrud and Pinto developed a series of theoretically focused empirical procedures for identifying critical and distinguishing characteristics in the diffusion process (Onsrud and Pinto 1991). Several tracer studies of adoption of GIS innovations in local government were carried out and a nationwide survey of local government GIS users was completed. Results were analyzed through regression analysis, structural equation modeling, and comparative analysis to identify the critical factors and processes for the class of users tested, to formulate a model of adoption success incorporating acquisition, implementation, and utilization components, and to test the efficacy of the theoretical framework in evaluating the use and value of geographic information innovations. Of the eleven factors identified through the factor analysis, only five were predictive of some form of adoption success. The most important factor across all three dependent measures was "utility" (Onsrud and Pinto 1993). However, when only the sample of U.S. local governments was evaluated, "benefits to extended users" arose as another significant predictor of success (Pinto and Onsrud 1993). Sub-elements

of the identified significant factors are explained in the respective research articles as well as interpretations and limitations of the findings.

Overall, the research program proposed and tested both content and process models of GIS adoption success and provided increased understanding of both the critical factors and specific action steps necessary to gain successful adoption of geographic information innovations within local governments. In addition to the models developed and the factors identified, an important benefit of this research was in making use of a large-scale empirical survey methodology to test the models of geographic information system adoption. Previously in the GIS research community there had been a dearth of theory-focused large-scale empirical testing.

Initial results of theoretical investigations were presented by Jeffress at GIS/LIS '89 and the paper by Onsrud and Pinto describing the applicability of diffusion of innovations theory to GIS was published in the *International Journal of GIS* . A follow up article incorporating various aspects of the specific findings of the tracer studies, the nationwide survey, and the interpretations of the results was published in the *URISA Journal.* Research reported by Pinto and Onsrud in *Use and Diffusion of Geographic Information Systems* (Klewer) focuses on the U.S. sub-sample and expands the analysis to address correlations between user characteristics and the dependent variable of GIS user satisfaction.

Extending from the diffusion of innovations work was a case study research project that set forth a method for testing technology transfer theories in GIS environments. The process was developed for GIS case studies with the intent to adhere to rigorous investigation methods following the nature of scientific cannons. The underlying assumption for this work was that for a technology transfer theory to be "scientific" it must be falsifiable, logically consistent, be at least as explanatory as any competing theory, and the theory, while falsifiable, must survive attempts at its falsification. A methodology was developed and illustrated that allowed testing against these fundamental criteria. In testing competing hypotheses by the methodology developed, the observer looks for "natural control" situations. The observer walks into the case study with a collection of hypotheses that might be capable of being tested. However, the observer does not pre-determine which explicit theories will be tested. It is the environment and the existence of "natural controls" in that environment that determines which theories, if any, are capable of being tested. The observer looks for identified changes in behavior or for continued behavior despite attempts at intervention that can only be explained by one or a small number of competing theories.

Investigators at other universities were invited to use the process to carry out a single case study to test a sample series of provided falsifiable hypotheses. B. Azad(M.I.T.), Z. Budic and D. Godschalk(UNC-Chapel Hill), S. Frank (Maine), and B. Bicking (Maine) all pursued use or partial use of the methodology in separate case studies. A background paper, instructions to potential participants, a list of thirty sample technology transfer hypotheses, and papers describing results of the Budic/Godschalk and Frank studies are included in an NCGIA Technical Report (Onsrud, Pinto, and Azad 1993.)

Expanding on the diffusion of innovations work and the initial case study work on testing technology transfer hypotheses is a cooperative case study effort with Bijan Azad, a Ph.D. student in Planning at M.I.T. In consultation with advisers at M.I.T. and Maine, he carried out a follow-up series of in-depth local government implementation case studies. Similar to Onsrud and Pinto, Azad began his work with a review and critique of current implementation research within the GIS field and focused on two major inter-related research shortcomings: (1) lack of adequate theory development and (2) the neglect of dependent variables. In seeking solutions, he developed a taxonomy of GIS effects as a basis for dependent variables development and, by example, applied his theory development models and proposed taxonomy to GIS implementation (Azad 1993a). Contemporaneous with this work, Azad focused on developing a meta-

framework for research that would provide theory building and testing "boundaries" for implementation research problems and would provide an organizing mechanism for thinking through the key dimensions of the GIS implementation process. The meta-framework arrived at consists of two principal dimensions (1) stages of implementation process and (2) elements of the organizational context for implementation (Azad 1993c).

With this background, Azad and Wiggins proposed an organizational technology transfer framework adapted from diffusion of innovations theory as an appropriate model for understanding and managing the non-technical issues in the application of geographic information system technology. Twelve detailed case studies were used in reviewing and refining the model and the model is then used to identify implementation process variables predictive of successful outcomes. "Change management" was identified through this process as a key umbrella concept (Azad and Wiggins 1993b). In conjunction with his case study work, Azad also has explore a conceptual framework that considers successful GIS technology implementation to be a function of the nature of the innovation, the appropriate alignment of organizational structure, and the existence or creation of an appropriate constellation of staffing roles (Azad 1993b). Azad's Ph.D. dissertation and subsequent articles will provide detailed reporting on the twelve case studies and the modeling outcomes.

A successful proposal for a NATO advanced research workshop on "Modeling Diffusion and Use of Geographic Information Technologies" was prepared by Harlan Onsrud (NCGIA) and Ian Masser (University of Sheffield) as co-directors with Lyna Wiggins (M.I.T.) and Nicos Polydorides (University of Patras-Athens, Greece). The workshop was held in April 1992 and drew together leading researchers in management information systems, organizational theory, and diffusion of innovations with GIS researchers from approximately fifteen countries. In addition to the Scientific Affairs Division of the North Atlantic Treaty Organization (NATO), support for the workshop was provided by the Regional Research Laboratories (U.K. Economic and Social Research Council), the Urban and Regional Spatial Analysis Network for Education and Training (URSA-NET: Greece, COMETT Program of the European Economic Community), and the National Center for Geographic Information and Analysis. The book produced in conjunction with the workshop, Diffusion and Use of Geographic Information Technologies (Masser and Onsrud, eds. 1993), includes 18 peer reviewed contributions and numerous commentaries for a total of 29 contributors.

It is noteworthy that the first major research specialist meeting to be hosted under the European GISDATA program will be on the "Diffusion of GIS in Europe." Funding for the four year GISDATA scientific program was approved by the General Assembly of the European Science Foundation in November 1992. The leaders of the initial specialist meeting have been substantially influenced by the research methods and results arising out of NCGIA Initiative 4 and the NATO workshop. Their specialist meeting process closely mirrors the specialist meeting process developed by NCGIA and a paper co-authored by U.S. researchers active in survey and case study research under Initiative 4 will be presented by Onsrud at their meeting.

ASSESSMENT

The previous section reviewed activities under Initiative 4 in each of the three priority areas defined through the specialist meeting process. This section provides a scientific assessment of the initiative, organized according to the five criteria for initiative assessments established by the NCGIA Board of Directors.

The specified goals of this research initiative going into the specialist meeting process were considerably altered by that process. The goals for the initiative as set forth in the 1988 NSF proposal were (1) identify primary and subsequent users of spatial information, and determine

the value of such information; (2) develop and test models of the decision-making process regarding land use, focusing on the role of geographic information; (3) identify problems of dealing with risk and uncertainty associated with decision making; and (4) evaluate the direct and indirect benefits of geographic information analysis and geographic information systems (NCGIA 1988, pp. 61-62). Although all of these topics were discussed at length though position papers and through oral discussions, the priority researchable topics emerging from the meeting were framed very differently. As mentioned previously, a substantial segment of the participants argued that, prior to pursuing some of the pre-specified goals, much basic work had yet to be done to develop and test hypotheses about the use and value of geographic information. Through this process emerged the three priority areas just discussed in the previous section.

For the agenda that arose, some parts received more attention than others, either because they were perceived to have higher priority or because there was more interest in them within the center. Unlike several of the other initiatives, there was very little research under way on the identified research priority areas within the GIS community outside the center prior to the center's involvement. The center's involvement in focusing on a subset of implementation and organizational theory issues has helped encourage research on such issues generally within the GIS community. We also note that the management information systems (MIS) academic community is becoming increasingly involved in research topics surrounding GIS design, implementation, and use (e.g. 27th International Conference on System Sciences, Minitrack on GIS, Maui, Hawaii, Jan 4-7, 1994).

How is the research agenda different from when the Research Initiative started?

The specialist meeting identified three priority areas of research: (1) develop a taxonomy on the use and value of geographic information; (2) investigate methods for assessing the value of using geographic information; and (3) investigate factors affecting the adoption and diffusion of geographic information technologies (Onsrud, Calkins, and Obermeyer 1989, pp. 96-100).

In the first area, the principal contribution of the initiative has been the offering of formalized taxonomies to characterize the use of geographic information in decision-making and to identify and quantify the benefits of the use of geographic information to one or more parties. This structuring is aiding the more systematic preparation of survey and case study efforts and this systematic treatment also makes comparisons among studies easier. The research has progressed from taxonomies for technological systems and architectures towards formalized integrated frameworks focused on end-users and their needs. The taxonomy research is being extended to more specific domains under Research Initiative 9.

In the second area, assessing the value of using geographic information, we began with a goal of effecting a means for quantifying the value of information generally so that the value of geographic information might thereby be determinable by drawing from that broader theory. Methods for valuing information developed in the economic and related literature were thoroughly reviewed. The conclusion was reached, lacking further theory development by the economic research community, that better means for quantifying the benefits of geographic information could best be achieved through better means for tracking the uses of such information. Various formalized methods for doing so were reviewed and the testing of one of the more promising methods was pursued. Through that effort, researchers at Buffalo found the present level of development (and therefore use) of geographic information systems was below a threshold that would permit the systematic measurement and evaluation of the use of geographic information by the formalized tracking methods attempted. In terms of a geographic information systems life cycle, they found that even GISs considered 'advanced' often were still in the process of data conversion. Thus, the goal of formally evaluating the use of geographic information in the case studies attempted could be implemented only through a series of long-

term, longitudinal approaches. Initial conditions and modeling attempts were documented and longitudinal work has been incorporated in active current work under Initiative 9.

The center's most significant contribution has been in the third area, applying diffusion of innovations theory and organizational theory to identify factors and steps predictive of successful use of geographic innovations. Structured methods for identifying critical implementation and use factors and processes have been developed for both case study and large-scale research environments. The methods have been applied and initial results achieved. Both inside and outside the center, researchers are following, testing, or critiquing the center's methods or results. The research agenda has moved from initial explorations of the applicability of diffusion of innovations theory and organizational theory in the GIS use domain to a cumulating scientific tradition.

What do we know now that is new?

The previous two sections addressed this question to some extent. The main points may be summarized as follows:

* how to systematically characterize the use of geographic information in decision-making through the use of taxonomic structures to aid survey and case study work

* how to apply formal models to better track the uses of geographic information

* how to better quantify the benefits of geographic information use

* how to identify through the use of formalized procedures factors and processes predictive of successful implementation or use of geographic information innovations

* how to apply the rules of scientific method and the requirements of natural science research models to GIS case study environments

This list is necessarily incomplete and addresses only the more obvious of the initiative outcomes. Specific results of individual studies are documented in the accompanying literature and typically need to be left embedded in the explanatory text to avoid their misinterpretation. However, at the risk of over simplification or misinterpretation, two examples of specific findings are as follows:

* From thirty-four factors derived from the organization theory, diffusion, and GIS literature and from a large-scale survey of GIS users in local governments, principal components factor analysis resulted in eleven independent factor groupings, and of these groupings five evidenced statistical significance in predicting "successful use" of GIS in local governments. Among the statistically significant factors were "utility," "ease of use," "experience with failure," "costs," and "proximity to others." When only the sample of U.S. local governments was considered, "benefits to extended users" arose as an additional significant predictor. Evaluation of stages or steps taken in the GIS acquisition process showed that the steps taken are relatively consistent in their chronological ordering and well defined (Pinto and Onsrud 1993).

* Survey and case study work under the initiative indicates that geographic information use is occurring on a broad front including uses for: 1) cartographic display; 2) routine geographic queries; 3) map analysis; and 4) spatial modeling. Currently, the highest utilization is the query function, which is accounting for as much as 90 % of GIS use. While the benefits from query applications (value) are rather low-level, they do constitute a "base level" of utilization generally sufficient to justify the implementation of GIS.

> Observations indicate that as each GIS matures we can expect a greater level of value to be realized through higher-order applications (map analysis and spatial modeling) (Calkins and Weatherbe 1993).

Many findings of a similar nature are contained in the various articles reporting the results of the case study and survey work and should be directly consulted.

What recommendations does NCGIA have in this area?

Numerous maxims have been suggested regarding what allows individuals and organizations to acquire, implement, and successfully employ GIS. The problem for researchers and practitioners is that many of these maxims either contradict each other or are so situation specific as to be non-generalizable to a larger population. Identifying determinants of successful use of geographic information is one of the primary research streams that should continue to be extended.

Relative to the behavior of individuals, important generalizations have been verified through empirical studies in other fields relating to the impact of individual characteristics on the adoption and diffusion process. These have served as valuable starting points for understanding the diffusion of GIS technology but their applicability and limits within GIS environments needs to be further evidenced through formal methods of confirmation or falsification. Open questions also suggest that useful insights could be provided by investigating the stages at which opinion leadership is most critical; as distinguished from determining the overall amount of involvement by opinion leaders. In addition to this temporal or process concern, the roles and impacts of innovators, change agents, champions, opinion leaders, and adopters should be reexamined in the context of the hybrid centralized/decentralized model offered by geographic information technology transfer environments.

Understanding organizational adoption of innovations is a primary research need. Many studies have attempted to extend the theory of individual adoption to organizations while others have focused on distinguishing among characteristics of organizations to explain their degree of innovativeness. Organization size, complexity, resource base, decision-making structure, characteristics of personnel, and similar broad attributes have frequently been examined to explain adoption characteristics (Greer 1981). Explanations suggested for inconsistencies in the results include lack of adequate theoretical base (Azad 1993a), failure to measure variables consistently (Onsrud and Pinto 1991, 1993), failure to relate the characteristics of innovations being adopted to characteristics of adopting organizations (Greer 1981), failure to consider the management state of the organization (Kraemer et.al. 1989), and failure to consider elements of the organizational context and leverage levels of individuals in the organization (Azad 1993c). An additional idea that should be probed by research on organizational adoption of geographic information technologies is that the ability to adopt or the extent of adoption is closely related to the amount of change required in the organization's structure. Specific to GIS, Rogers suggests particular scrutiny should be focused on the factors or characteristics of "re-invention," "complexity," and the changing nature of the technology (Rogers 1993).

Another shortcoming of current research is the lack of development of supportable methodologies for collecting and evaluating post-adoption utilization information. Research in other fields has frequently presumed that acquisition and use of a technological capability was synonymous with implementation success without an evaluation of the overall extent of use and without identification of the functional levels in the organizational structure of that use. Presuming that meaningful assessment information may be acquired for a particular class of users, the role which that assessment information could play in future decisions by other individuals and organizations to adopt the innovation also needs investigation.

Much of the current research on adoption and implementation of GIS is retrospective, unreflective, and fails to fall into the category of rigorous research with testable hypotheses. The weakness of the continued use of retrospective research on GIS implementation is highly significant. Geographic information systems are general purpose tools which are likely to be highly useable by new classes of potential users over time as increased capabilities are added to the systems through technological advances. Much could be learned from prospective studies as new classes of users learn about the potential application of these tools to their fields. Prospective observations could provide new insights on (1) how the problems and needs of users are communicated to system designers, (2) the extent to which geographic information technologies are adapted by the social class rather than by system designers, (3) the key communication linkages which are used by the social class over time and particularly during the critical mass stage when the rate of adoption accelerates, and (4) the ultimate consequences to the social class involved.

Another frequent weakness of technology transfer research in the past which must be avoided in the GIS field has been overdependence on variance research. In variance research, covariances are determined among the set of variables being evaluated. That is, rather than adopt a "process" outlook in which the adoption process is presumed to follow well recognized stages, much of the current research is predicated on developing "content" models of diffusion. Content models develop a large list of all the different variables that can impact on the adoption decision. However, through traditional variance analysis the time dependency of the variables on each other is indeterminable. Although variance analysis is appropriate for certain research (e.g. determining personal characteristics of adopters), process research methods are more appropriate for gaining understanding of a series of decision stages or events that occur over time (Onsrud and Pinto 1993, Azad 1993c).

An additional research need that must be considered involves the distinction between centralized and decentralized models of diffusion. Most studies of the diffusion of technological innovation assume a centralized model, yet the database development needs of GIS (i.e. a significant portion of the investment in the innovation) are typically being met through decentralized communication and decision making processes. Decentralized diffusion has the advantage that the innovation diffused is likely to fit more closely with needs of local users when the innovation eventually achieves its ultimate evolved form (Rogers 1983). However, one drawback of decentralized diffusion is that, for innovations involving a high level of technical expertise in their use, it is possible for "bad innovations" to diffuse through the system due to lack of quality control (e.g. inappropriate selection of base layers of data or quality of data for anticipated users). The development and promotion of meetings of users with similar applications is one method being used by some GIS hardware/software vendors to lessen the danger of such diffusion and to provide a coordinating mechanism for users for evaluating the appropriateness of new methods and adaptations of the technology to their class of needs. Consideration should be given to evaluating the postulated efficacy of this method and exploring supplemental or alternative methods.

One final research need relative to diffusion, implementation and use research is the development of a suite of systematic and rigorous methodologies for accurately assessing the diffusion, utilization, and impact of geographic information innovations. Particularly lacking in the GIS literature are evaluations using quantitative research methods. Within this research needs context, Azad urges far more attention to dependent variables (Azad 1993a). Development of systematic and rigorous methodologies does not necessarily require a separate research thrust. In the process of designing research plans to probe use and value questions, GIS researchers may overcome this shortcoming by being aware of the alternative research methods available, selecting methods which are appropriate to eliciting the forms of information desired, and understanding the strengths and limitations of each research methodology. Thus, the

appropriateness of various methodologies may be tested and honed with each investigation, resulting in an accumulation of knowledge over time.

Much of the focus in Research Initiative 4 has been on use behavior, factors and processes internal to organizations. There is a need to extend evaluations into the domains of inter-organizational use and sharing of geographic information. Research Initiative 9 on "Institutions Sharing Geographic Information" has developed a research needs agenda in this area making it unnecessary for us to relist them here (Onsrud and Rushton 1992).

Another general area of research needs relates to the interaction of geographic information systems and law. It became apparent in investigating impediments to the use of geographic information under Initiative 4 that the legal system's inability to keep up with technological changes and, as a result, the unknown legal situation relative to many use and sharing issues is substantially impeding the effective use of the technology. Several papers written by initiative researchers during the time period of the initiative that address a range of these legal issues are attached in a separate listing. Indepth research on the impact of law and information policy on the use of geographic information and research on how geographic information systems will impact society are very substantial research needs.

What has NCGIA learned about the Initiative process and how might the operation of future Initiatives be improved?

In regard to the specialist meeting process, we probably learned more about how *not* to run a specialist meeting than we did from any of the other first initiatives. Individuals selected to lead the initiative established an agenda, set the process in motion, and then backed out so that others were forced to step in and pull the pieces back together. Participant selection had strong political overtones and a significant proportion of individuals attending had little or no scholarly stake in the process; resulting in little inclination to contribute to advancing the agenda after the meeting. Finally, unreasonable performance expectations were raised during the specialist meeting process. Because of the rough and tumble process the Initiative 4 specialist meeting experienced and the problems that arose as a result, a comprehensive and well-reasoned process was developed for carrying out the next initiative dealing with social and institutional issues.

Initiative 9 began with selection of a core planning group with representation from six universities. This group prepared a background paper laying out the issues to be addressed at the specialist meeting and developed a process for selecting meeting participants that was based on visible evidence of scholarly input and commitment to contribute. A public call for papers was issued accompanied by the jointly prepared foundation paper and participants were selected through the refereeing of submitted paper proposals by the core planning group. Thirty papers were accepted for presentation at the meeting and all papers were refereed by other participants prior to the specialist meeting. At the meeting speakers were limited to ten-minute presentations of paper "highlights." Two or three presentations were made in each session followed by a short discussion period. Upon completion of these presentations and discussions, specialists were assigned to small focus groups, asked to review the material from the discussions, and requested to prepare a list of major incentives and impediments to the sharing of geographic information. The lists were reported back in a plenary session. Through consideration of these lists and reflection, participants were then each asked to suggest a subset of important researchable issues which could be addressed in greater depth through a working group. From this larger body of topics, a small number of research topics were selected for detailed consideration by focus groups. This specialist meeting process resulted in better prepared participants, more substantive discussions at the meeting, and better research products flowing from the meeting. The essential elements of the process have now been adopted generally for NCGIA research initiatives (See the NSF renewal proposal supplement).

In regard to research carried out under the initiative, we learned that research into the social, economic and institutional impacts of the use of geographic information in decision-making (through actually examining operational GISs) is generally a longer term activity than experienced under other research initiatives and must be planned accordingly. If a substantial number of individuals within the GIS community are not already carrying out research on the range of topics covered by the initiative, the time spent in exploring foundation principles also must be greater.

In addition, means had be found to interest and motivate individuals in the broader research community to become involved and initiate work in the area. One device that worked well was to develop a methodological approach for carrying out research , offer a set of hypotheses for testing, and then invite others to jointly publish research with us. For the "open invitation" case study project previously discussed in this report, approximately twenty researchers from academic programs around the country requested written copies of the foundation materials and an unknown number acquired the materials from anonymous ftp, approximately ten signed statements of intent to participate in the project, and of that number four resulted in full case study write ups (all Ph. D. students). Even though only a small number of researchers were able to move their case study projects to completion within the time frame allowed, the "open invitation" process motivated a significant number of GIS researchers to explore behavioral and organizational issues they probably would not have explored otherwise and the process exposed them to a formal framework for addressing case study work.

What contribution has the initiative made to GIS education?

The initiative is at least in part responsible for spurring interest in formalized case study and survey approaches in evaluating use and implementation issues, which has resulted in sessions at conferences and chapters in books. As a result of their involvement in Initiative 4 and subsequent work, Obermeyer and Pinto produced books addressing issues arising from or directly related to initiative topics (Obermeyer and Pinto 1993 expctd. , Pinto 1994 expctd). Many GIS researchers were first exposed to diffusion of innovations and technology transfer theories through the products of this initiative. The primary book reporting results from the initiative , *Use and Diffusion of Geographic information Technologies* (Masser and Onsrud, eds.), obviously had an affect on educating European scientists to the need for further research in the area, as their first ESF specialist meeting will be on this topic.

As with other research initiatives, one area of educational impact has been the pursuit of graduate theses. Completed Ph. D. theses include "Deriving a method for evaluating the use of geographic information in decision making" (H. Dickinson) and "Land Ownership Information Use in Real Property Market Transactions" (G. Jeffress). Case study and survey methodology materials generated from the research initiative have now been incorporated into the graduate course in research methodology at the University of Maine.

ANNOTATED LIST OF NCGIA PUBLICATIONS FROM INITIATIVE 4

The following section includes the references and abstracts to the papers resulting from Initiative 4 to date. Although legal issues are not included in the three priority use and value research areas identified through the specialist meeting process, legal issues directly affect the use and value of geographic information. Therefore, articles on legal issues produced by Initiative 4 investigators during the time period of the initiative are appended in a separate list. Additional references cited in the text are listed in a separate section at the end - some of these are by authors who contributed to the specialist meeting and may have been stimulated or influenced by it in their own research. Authors affiliated with the Center (i.e. receiving some form of compensation for research expenses) are listed in bold.

Azad, B. (1993a) Theory and Measurement in GIS Implementation Research: Critique and Proposals. *Proceedings, Third International Conference of Computers in Urban Planning and Management* (Atlanta). In press.

There have been many calls for more rigorous research on implementation of geographic information systems in recent years. However, the progress towards such research has been slow. The critique in this paper suggests that this slow pace is the result of our failure to adequately deal with two major inter-related research issues: (1) little or no theory development and (2) the neglect of dependent variables. The critique addresses the following points: why theory is important, the existing theory gaps in research, the prevailing models of theory development and criteria for relevance in theory development; symptoms of dependent variables neglect, and a proposed taxonomy of GIS effects as a basis for dependent variables development; and an example, applying the theory development models and the proposed taxonomy to GIS implementation.

Azad, B. (1993b) The Critical Choices of Organizational Structure and Staffing Roles in Implementation of GIS. *Proceedings, GIS/LIS '93* (Minneapolis). In press.

The implementation of geographic information systems is explored through a case study that focuses on the steps taken to develop and implement a successful, parcel-based mapping system by a city/county jurisdiction in the midwestern U.S. The issues of the case are analyzed using a conceptual framework that considers successful GIS technology implementation to be a function of: the nature of the GIS technology innovation, the appropriate configuration of organizational structure, and the existence of a constellation of critical staffing roles. Implications for human resource management are discussed as well, which is a neglected topic in GIS implementation research.

Azad, B. (1993c) Organizational and Institutional Aspects of GIS implementation: A Meta-Framework for Research. Under review by IJGIS.

GIS implementation research is in need of theory development and testing. However, theory development and testing are in most cases only viable as an incremental process of building on existing theories and modifying them where they appear inadequate, namely, a cumulative scientific tradition. This paper addresses the following concerns: (1) development a comprehensive model of GIS implementation; (2) inclusion of the elements of the organizational context in a comprehensive manner; and (3) viewing GIS implementation from a stage (process) model perspective. First, the principal threads in the existing body of GIS implementation research are highlighted. Then elements of a meta-framework of research are discussed. The purpose of a meta-framework is to provide "boundaries" for the research problem in theory-building and testing and as an organizing mechanism for thinking through the key dimensions of the GIS implementation process. It consists of two principal dimensions: (1) stages of implementation process (as diffusion of

Innovation), and (2) elements of the organizational context for implementation, i.e. task, structure, people, technology, and external environment. Details of an example research use of the meta-framework are discussed. The paper concludes by pointing out several remaining tasks beyond the development of the meta-framework.

Azad, B. and L. Wiggins (1993a) Institutional issues in the Transfer of GIS Technology to Organizations: The People Gone Missing. *Key Address and Distributed Paper, First Sharjah Conference on Geographic Information Systems and Applications* (Sharjah, United Arab Emirates)

A technology transfer framework is proposed as an appropriate model for understanding the application of geographic information system (GIS) technology in organizational context. This framework regards outcomes of attempts to introduce computer based GIS tools into ongoing governmental work as a function of three effects: features of the new technology; characteristics of the organizational context; and properties of the implementation process. Initial steps taken in the development and refinement of the model are discussed. How the model might be used to identify implementation process variables predictive of successful outcomes is also presented.

Azad, B. and L. Wiggins (1993b) Organizational Aspects of GIS Technology Transfer: Preliminary Results from a Dozen Cases. *Proceedings, URISA* '93 (Atlanta) In press.

An organizational technology transfer framework, adapted from diffusion of innovations theory, is proposed as an appropriate model for understanding and managing the non-technical issues in the application of geographic information system technology. This framework regards outcomes of attempts to introduce computer-based GIS tools into ongoing governmental work as a function of three key sources of effect; features of the new technology; characteristics of the organizational context; and properties of the implementation process. Among them, the implementation process itself (that is, the steps taken to embed a new tool in an extant setting including 1. flexible plans, 2. organizational actions, and 3. commitment to change) is most closely linked to organizational and institutional dynamics. Preliminary research results based on twelve case studies are reviewed to corroborate and refine the model in relation to GIS-based work, using it to identify implementation process variables predictive of successful outcomes. Positive "change management" is identified as the key umbrella concept.

Beard K. (1989) Designing GIS to Control the Misuse of Spatial Information. *Proceedings, URISA '89* (Boston) 4: 245-255.

Commonly recognized map errors include those associated with data collection (source error) and the processing of data for map compilation (process error). Another error component, use error, is defined and added to the topology. This paper argues that without attention to use error, large investments to reduce source and process error may be wasted. Traditional representation of spatial information on paper maps has limited our ability to control this form of error in any significant way. While the misuse of maps cannot be entirely avoided, computer technology offers a possibility for limiting the opportunities for misuse. This idea is explored by examining ways in which maps are misused, and from this exploration, formulating geographic information system design strategies that may counteractthe potential for misusing spatial information.

Benwell, G. and **H. J. Dickinson** (1991) Software Requirements for Petri Nets in the Behavioral Analysis of Spatial Information. *New Zealand Surveyor* 33: 64-79

This paper introduces the concept of petri nets, shows their relevance to behavioral analysis, and stresses the importance of using rigorous modeling tools in developing geographic information systems. The application of Petri Nets is developed with simple examples and a more extensive example is presented to highlight the rigor of the Petri Net approach.

Calkins, H. (1991) GIS and Public Policy. In: D.Maguire, D. Rhind and M. Goodchild (eds.), *Geographical Information Systems: Principles and Applications*, Longman Publishing Co. 2: 233-245

A rational approach to policy decisions (as opposed to incrementalism) is assumed in order to facilitate understanding of how GIS can be used in public policy decsion making. In the GIS context, public policy making is supported by policy analysis based on the application of scientific or systematic methods. Such an approach leads to an idealized view of the public policy decision-making process, which is acknowledged to exist only rarely. It never has been and never will be possible to make policy analysis a purely rational, coldly objective, scientific aid to decision making that will neatly lay bare the solution to every problem to which it is applied. This chapter focuses on the potential for GIS to play a significant role in "real world" public policy analysis as it supports public decision making.

Calkins, H. and **N. J. Obermeyer** (1991) A taxonomy for surveying the use and value of geographic information. *International Journal of Geographic Information Systems* 5(3): 341-351.

Understanding the use and value of geographic information in decision-making has been identified as crucial to further development of geographic information systems and related spatial analysis techniques. Research into the use of geographic information will be through surveys and case studies. A taxonomy for investigating the use of geographic information and its associated value are needed to structure the survey and case study efforts. This article presents an initial attempt at such a taxonomy. The survey methodology to be supported will be mostly telephone and/or mail questionnaires, and this has influenced the structure of the taxonomy. The goal of this paper is to create a taxonomy suitable for survey use that will enhance our understanding of the use and value of geographic information in decision-making.

Dickinson, H.J. (1989a) Techniques for establishing the value of geographic information and geographic information systems. *Technical Papers, GIS/LIS '89* (Orlando, FL) 2: 412-420.

Many agencies are looking toward implementing a GIS to support geographic information analysis and decision making. Since GIS implementations often require large expenditures of time and money, economic justifications for such projects are often required. This paper discusses the popular use of cost-benefit analysis for such justifications. Difficulties arise when attempting to perform a cost-benefit analysis empirically due to the problems of establishing the value of geographic information. This paper also identifies a number of methods from economic and information science literature which may be used to empirically establish the value of geographic information and its analysis.

Dickinson, H.J. (1989b) Selective Bibliography: The Value of Information. *Technical Report 89-8*, National Center for Geographic Information and Analysis, Santa Barbara, CA .

This paper was prepared in conjunction with Initiative 4 to aid research on economic issues. It includes references to articles, papers, reports, and book chapters.

Dickinson, H.J. (1990a) Deriving a method for evaluating the use of geographic information in decision making. Ph. D. thesis, Department of Geography, State University of New York - Buffalo. Published as *Technical Report 90-3*, National Center for Geographic Information and Analysis, Santa Barbara, CA.

The research presented in this dissertation involves establishing the value of geographic information and its analysis in decision making. Methods used in economics, management science, and information science to establish the value of information are explored. The conclusion is reached that prior to establishing value, it is first necessary to improve understanding of how geographic information is actually used. However, to support empirical observations of use there is need for a more structured format than descriptive case studies. A modeling technique capable of revealing where geographic information is critical in a decision-making process and the costs and benefits associated with that use is discussed. Specific characteristics of complex decision-making tasks are used as criteria in examining the applicability of various techniques and petri nets are chosen for further investigation. The use of petri nets to attach and measure costs and benefits along each step of the process is presented at a conceptual level.

Dickinson, H.J. (1990b) Justification and Evaluation Strategies for GIS Implementations. Distributed papers, ESRI User Conference (Palm Springs, CA).

The appropriate method to be used for evaluating the benefits of GIS use depends on the purpose of the economic evaluation. Initially, a preimplementation justification is performed to compare the system's expected benefits to its expected costs. If the benefits outweigh the costs, the expenditure is justified. Evaluation can also occur after the system has been implemented. At this time, use and performance of the GIS are evaluated to provide direction for enhancements to the implementation. Different uses of the GIS also require various methods for establishing benefits. This paper discusses different types of benefits that may be expected from a GIS implementation and various methods to be used in economic evaluations.

Dickinson, H.J. and H.W. Calkins (1988) The economic evaluation of implementing a GIS *International Journal of Geographic Information Systems* 4(2): 307-327.

Implementation of geographic information systems (GIS) involves a substantial commitment of resources by the sponsoring agency. Economic evaluation of the proposed GIS is an important step in the implementation process. This article discusses the traditional benefit cost analysis and suggests alternative approaches which may prove useful in situations where the benefit cost model may not be appropriate. A case study of an actual implementation of a GIS which illustrates the approaches discussed is also presented.

Epstein, E. and **T. Duchesneau** (1989) The impact of information science on conflict. *Proceedings, URISA '89* (Boston, MA) 4: 305-309.

Geographic and land information system technology is often adopted and used for the efficient generation and distribution of traditional spatial information products and services. These actions are predictable given the responsibilities and burdens on public officials and

private citizens who make growth and resource management decisions. These decisions are often contentious, with the controversy extending to the data and information used in the decision-making. These perceptions are are developed by the parties to the growth and resource management struggles, and provide important direction for system designers and builders.

Frank, A. U. (1989) The geographic information system and its use for valuation. *Property Tax Journal* 8:85-98.

In order to evaluate and assess real estate property information properly, it is necessary to describe the property. The major part of this information is necessarily space-related, that is, related to the land it describes. Geographic Information Systems (GIS's) are computerized systems to manage large amounts of spatial information and could therefore be valuable tools for assessors. The uses of GIS may be classified as planning or operational; these uses have very different requirements for the quality of the data in the system. The two primary architectures for GIS, file and database oriented, can be linked to these use classes. Systems for valuation purposes should be database oriented.

Frank, A.U. (1991) Acquiring a Digital Base Map: A Theoretical Investigation into a Form of Sharing Data, *Journal of Urban and Regional Information Systems* 4(1): 10-23.

The idea of sharing data and distributing the cost of collecting and maintaining geographic databases is central to the development of GIS and spatial information systems in general. Increasingly we are seeing companies that collect high quality spatial data sets and offer them to others that have a similar need. This paper investigates potential problems that can occur when organizations exchange data. These problems all center around finding precise definitions to the meaning of a set of data set and its quality. The closer the provider and acquirer are in their business and the task for which they use the data, the easier it is to share. A number of typical forms of organization for the sharing of data are described. In the last section, we concentrate on the problem of updating an acquired data set.

Frank, A. U., **M.J. Egenhoffer**, and **W. Kuhn** (1991) A Perspective on GIS Technology in the Nineties, Photogrammetric Engineering and Remote Sensing 57(11): 1431-1436

Information technology is a rapidly changing field and its innovative ideas and accomplishments will affect the design and use of future GIS. Experience shows that the development rate of new computer hardware tends to be underestimated; however, expectations about improved software systems are usually higher than what industry can deliver. Considering these circumstances, possible changes in GIS technology and its use are assessed. Specific challenges from the user perspective are addressed in three areas: data quality and how it is communicated to the user, user interfaces designed from the user perspective, and cost-benefit analysis of geographic information. These point to current research that is expected to influence the GIS community toward the end of the decade.

Hintz, R.J. and **H.J. Onsrud** (1990) Upgrading real property boundary information in a GIS. *Journal of Urban and Regional Information Systems* 2:2-10.

One difficult issue facing geographic information system (GIS) developers in the U.S. today is the current inability to create spatially accurate, legally supportive and operationally efficient land ownership data bases. Solutions in providing strong legal foundations for GIS are not simple. This paper describes technology for establishing a measurement based management system at the local government level. Sophisticated surveying computations, least squares analysis, statistical techniques, and blunder detection methods have now been largely automated. Tools which were available previously to only

highly specialized surveying experts are now potentially useable by surveying technicians. Through use of these powerful tools, maintenance over time is readily achievable for cadastral measurements in a GIS database.

Jeffress, G. (1990) Land Ownership Information Use in Real Property Market Transactions. PhD Dissertation, Department of Surveying Engineering, University of Maine.

Dissertation investigates the use and value of land ownership information and develops a conceptual model for evaluating the use of land ownership information. Theories and methods of economics of information, information theory, risk analysis, and cost-benefit analysis are reviewed and the conceptual model developed is used to analyze the benefits that automation can be expected to have on the operations and recording and retrieving of land ownership information.

Jeffress, G. (1991) An international survey of land record costs, revenues, and some characteristics. *Proceedings, URISA 91* (San Francisco) 1: 90-101.

This paper describes a survey carried out in 1989 to assess the amount of business conducted by land records agencies throughout the world. The survey provides insights into the nature of the real property transaction recording business worldwide and indicates that, even though the deeds registry systems in the U.S. are considered archaic by many, some of the least expensive costs of land ownership transfer occur in jurisdictions within the United States.

Jeffress, G. and **H.J. Onsrud** (1989) Does LIS/GIS Have a Role in Economic Growth? *Technical Papers, ASPRS/ACSM Annual Convention* (Baltimore, MD) 4: 285-292.

Much has already been documented on the conceptual models, efficiencies and technical aspects of LIS/GIS; little has been said of the economic consequences of LIS/GIS information. This paper looks at the concept of economic growth and the problems of understanding and quantifying the benefits of LIS/GIS information. The benefit/costs of this information is discussed along with the concept of how LIS/GIS information products contribute to economic growth. Two different cases of benefit/cost study of spatially related information products are discussed.

Jeffress, G. and D.C. Conway (1989) GIS Innovation Diffusion. *Technical Papers, GIS/LIS '89* (Orlando, FL) 2: 430-437.

This paper looks at the introductory process and diffusion of GIS technology. How do organizations choose to invest in GIS? What factors prevent the introduction of GIS innovation within organizations? The investment and commitment to introduce GIS technology can be expensive. Aspects of the decision process which lead to investment in GIS will bepresented and discussed.

Jeffress, G., R. Hintz and **H. Onsrud** (1990) An automated measurement management system: a useful tool for surveyors and digital cadastral data base managers. *The Australian Surveyor* 35:19-28.

The increased use of digital data recorders by the surveying profession is connaturally linked to the creation of digital cadastral data bases (DCDB). The management of digital measurements, whether made in the field or on a digitizing tablet, is fundamental to the production of the spatial information contained in both survey plans and digital maps. This paper describes the application of a measurement based management system for use by the surveyor and or the manager of a DCDB. Sophisticated survey computations, least squares

analysis, constraints by variance, statistical techniques, and blunder detection have now been conveniently packaged into an automated tool box.

Note: This paper was awarded the R.D. Steele Prize for 1990 (cash award) by the Council of the Institution of Surveyors, Australia, Inc.

Jeffress, G. and L. Holstein (1993) An International Survey of Real Property Transaction Costs and Some Characteristics. *Journal of Urban and Regional Information Systems* 5(1): 53-66.

This expands upon previously reported work and describes a survey carried out in 1989 to assess the amount of business conducted by land records agencies throughout the world. The survey gives some insights into the nature of the real property transaction recording business. The survey indicates that among the least expensive costs of land ownership transfer to users occur in jurisdictions within the United States which are based on deeds registration. The survey also suggests that land records modernization need not be subsidized by government.

Masser, Ian and **H.J. Onsrud**, eds. (1993) *Use and Diffusion of Geographic Information Technologies*. NATO Advanced Science Institutes Series, Kluwer Academic Publishers, Dordrecht, Netherlands, 349pp.

This book is a collection of 20 papers reporting results from studies on the use and diffusion of geographic information technologies in numerous countries. The book includes contributions by individuals from several academic disciplines (geography, business, planning, communications, engineering) with research interests in technology diffusion, management information systems, and geographic information systems. Individuals affiliated with the NCGIA contributing chapters or section introductions include Onsrud, Pinto, Rushton, and Wiggins.

Obermeyer, N.J. (1989) A systematic approach to the taxonomy of geographic information use. *Technical Papers, GIS/LIS 1989*, (Orlando, FL) 2: 421-429.

This paper represents an effort to lay groundwork for the development of a taxonomy of the use of geographic information. Beginning with a discussion of some of the pitfalls of taxonomy development, the author proposes a framework for the taxonomy of geographic information use. An iterative process is suggested that would seek the input of geographic information experts and survey users of geographic information to achieve consensus on an appropriate taxonomy.

Obermeyer, N.J. (1990) Sharing geographic information across organizational boundaries: an organizational-managerial perspective. *Technical Papers, State of Indiana GIS Conference*, (n.l.) 132-141.

One of the frequently mentioned problems in geographic information systems is the need for information and data bases that may be housed in several organizations. This paper explores the organizational and managerial roots of difficulties in sharing data bases. The paper identifies three means by which alliances may be formed and information may be shared: appeals to professionalism, coercion, and bargaining. A theory is proposed on the relative power of the participants to predict which of these three strategies will be used.

Obermeyer, N. J. (1990) Bureaucratic factors in the adoption of GIS by public organizations: preliminary evidence from public administrators and planners. *Computers, Environment and Urban Systems*. 14:261-271

In this paper, the author argues that because of organizational reliance on "standard operating procedures" on the one hand, and professional training and socialization on the other, public organizations tend to favor the status quo, while public administrators screen out the geographical components of professional tasks and rely on nongeographic information systems. This argument is based on a theoretical understanding of bureaucracy, organizational decision-making, and the search for information used by organizations in the decision-making process. Support for this argument is based on a preliminary study of the use of geographic information by public administrators and planners, as evidenced by the presence o maps, within the professional publications of the American Society for Public Administration and the American Planning Association and the American Institute of Certified Planners.

Obermeyer, N.J. (1990) Bureaucrats, clients and geography. Research Paper No. 216, University of Chicago Geography Research Papers, 135 pgs.

This study explores the relationship between public organizations, their clients, and policy decisions relating to the location of major facilities. Most research on the geographical siting of facilities assumes that decision-makers are guided by rational and predictable factors, whereas work on organizational behavior points to the importance of seemingly irrational influences, especially noneconomic constraints, on decision making. In examining one such constraint-the influence of client groups on a national regulatory agency-this study seeks a better understanding of a varied nature of administrative decision-making.

Obermeyer, N.J., **M.K. Beard** and D.W. Leboutillier (1993) The diffusion of GIS among AAG members. Distributed at 1993 Annual Meeting of the Association of American Geographers, Atlanta, GA, April.

GISs are becoming more widespread in the applications. Originally valued as an important tool in natural resources management and analysis, GIS is gaining acceptance in planning, archeology and socio-economic analyses as well. Not surprising, geographers with a variety of interests are using GIS nowadays. This paper examines the diffusion of GIS among members of the AAG, using historical data on the growth of membership in the AAG's GIS Specialty Group. (The authors are preparing this presentation for submission as an article to *The Professional Geographer.)*

Obermeyer, N. and **J. K. Pinto** *Managing GIS (*New York: Guilford Press) Publication expected in 1993.

This book provides a theoretical framework for the discussion of problems related to the implementation of GIS in both the public and private sectors. The book places GIS within the context of organizational information systems, explains how it can be used as a strategic tool, and how it can aid in the managerial decision making process. Among the topics covered are: institutional impediments to the implementation of GIS; strategic planning of GIS; the diffusion of GIS; benefit/cost analyses; problems of assuring the qualifications of GIS professionals; and GIS in a democratic society.

Onsrud, H. (1989) Understanding the uses and assessing the value of geographic information. *Technical Papers, GIS/LIS'89* (Orlando, FL) 2: 404-411.

This article describes a process for identifying and addressing critical use and value research issues. The process was derived from discussions which took place at a specialist

meeting hosted by the National Center for Geographic Information and Analysis. Also described are two initial research thrusts currently being carried out utilizing the process.

Onsrud, H., **H.W. Calkins** and **N.J. Obermeyer** (1989) Use and Value of Geographic Information: Initiative Four Specialist Meeting Summary Report. *Technical Paper 89-6*, National Center for Geographic Information and Analysis, Santa Barbara, CA.

This summary contains introductory material and findings from the specialist meeting.

Onsrud, H., **H.W. Calkins** and **N.J. Obermeyer.** (1989) Use and Value of Geographic Information: Initiative Four Specialist Meeting Report and Proceeding. *Technical Paper 89-7,* National Center for Geographic Information and Analysis, Santa Barbara, CA.

This document contains a complete report on the specialist meeting and includes background material, position papers by participants, discussions and findings.

Onsrud, H.J. and **J.K. Pinto** (1991) Diffusion of Geographic Information Innovations *International Journal of Geographic Information Systems*. 5(4): 447-467.

Appropriate diffusion of geographic information technologies is hampered by lack of systematic research on factors and processes affecting diffusion, utilization, and impact assessment of the technologies and by a variety of conceptual and methodological problems. Diffusion of innovation principles developed in other fields, in combination with methods developed within the field of management information systems (MIS), provide an important beginning for improved understanding. This paper focuses on knowledge gaps which might be addressed within the geographic information field by diffusion of innovations analysis techniques and research methodologies.

Onsrud, H.J., J.K. Pinto and **B. Azad** (1992) Case Study Research Methods for Geographic Information Systems. *Journal of Urban and Regional Information Systems*. 4(1): 32-44.

Although they are perhaps the most commonly-used and popular research methods, case studies and other qualitative forms of social science research have long been criticized for their lack of generalizability to the larger population and lack of sampling controls. These criticisms may be aptly addressed and solutions constructed by evaluating the rules of scientific method within case research environments. By using more logically consistent, rigorous, and systematic approaches, some of the shortcomings of case study methods may be overcome. This article draws from the management information systems (MIS) and organization behavior (OB) literature to make some suggestions on how to conduct and evaluate GIS case study research. It reviews the requirements of natural science research models, particularly as described by Lee (1989), and provides examples of how the substance of those requirements may be met in the context of GIS case studies.

Onsrud, H.J. and **J.K. Pinto** (1993) Evaluating Correlates of GIS Adoption Success and the Decision Process of GIS Acquisition. *Journal of Urban and Regional Information Systems* 5(1): 18-39.

The intent of this research was to gather initial information on specific interpersonal, organizational, and institutional variables that affect an organization's decisions to acquire, implement, and use GIS. We selected local governments as an appropriate social system of interest for this initial investigation. One goal was to explore whether factors determined as critical to the adoption of innovations in other fields were also deemed significant by adopters in the GIS field. Another was to examine whether factors important in the

acquisition of GIS are also predictive of the success of use of GIS within an organization over time. A further goal was to develop various means for evaluating the process of adoption. A final goal was to demonstrate the application of quantitative methods within the framework of a logically consistent progression of methods for investigating GIS adoption variables.

Onsrud H.J., J.K. Pinto and **B. Azad, eds.** (1993) Testing Technology Transfer Hypotheses in GIS Environments Using a Case Study Approach. *Technical Report 903-X* National Center for Geographic Information and Analysis, Santa Barbara, CA. (The contributed papers to this volume are not listed separately in this bibliography.)

Most case work seen to date in the GIS community has been directed at deriving theory or, alternatively, consists of case histories of GIS implementation experiences. The intent of this research effort was to spur work in which pre-derived theory would drive the direction the case study work would take and to use case study methods as a means of testing theory. This report gathers together (1) an original foundation paper used as the basis for the case study research project, (2) a call for participation in the project, (3) a listing of thirty hypotheses for which "natural control" conditions were sought in each case study, and (4) final reports from two of the case studies. The two cases selected for inclusion in this report were chosen because the first by Steven Frank most closely adhered to the methodology presented in the foundation paper and the second by Zorica Budic and David Godschalk, while using a modified approach, provided the most insightful and constuctive criticism of the methodology suggested.

Pinto, J.K. *Caught in the Machinery: Human Factors in Successful GIS Introduction* (New York: Guilford Press) Under review - publication expected in 1994.

This book offers a systematic approach to managing the behavioral issues important to the successful acquisition and introduction of a new GIS in an organization. The focus is behavioral because the preponderance of research in the area of new system implementation points to the preeminent importance of addressing human issues, rather than purely technical aspects related to the introduction, if GIS is to be successfully implemented. A number of critical issues in GIS implementation are examined including: a thorough understanding of what constitutes implementation "success," the role of politics in the implementation process, leadership, team building, and a variety of other behavior issues all aimed at improving the likelihood of new system success.

Pinto, J.K. and **H.J. Onsrud** (1993) Correlating Adoption Factors and Adopter Characteristics with Successful Use of Geographic Information Systems. In I.Masser and Onsrud (eds.) *Use and Diffusion of Geographic Information Technologies*. Klewer: 165-194.

This paper reports on the gathering of information on specific interpersonal, organizational, and institutional variables that affect an organization's decision to acquire, implement, and useGIS. The research reported explores whether factors determined as critical in other fields were also deemed significant by adopters in the field of GIS in U.S. local governments. Another goal was to examine whether factors important in the acquisition of GIS are also predictive of the success of use of GIS within an organization over time. The research investigates correlations between characteristics of users and their satisfaction with GIS. Finally, the paper demonstrates the application of quantitative methods for investigating GIS adoption variables.

PUBLICATIONS ON LEGAL ISSUES RELATED TO USE AND VALUE

Dansby, B. and **H. Onsrud** (1989) Geographic Information Systems - a map for the future. *Probate and Property*, Section of Real Property, Probate, and Trust Law, American Bar Association. 2(7): 20-27.

As members of the real estate conveyancing community, lawyers have an important role to play in developing standards and practices needed to improve land records. To be of most use, the data collected by local governments needs to be referenced to individual land parcels. The information on individual parcel boundaries in a GIS, referred to as the cadastral layer, forms a bridge between legal ownership rights in land and the physical location of those rights on the earth. Thus, the cadastral layer is often referred to as the legal foundation for any widely useful GIS.Parcel boundaries, and therefore the cadastral layer, are legally defined by the conveyancing layer, are legally defined by the conveyancing documents recorded in connection with real estate transactions. Because of the primitive state of conveyancing records systems in almost all jurisdictions in the U.S., the GIS currently being implemented are at risk of having inadequate cadastral foundations.

Moreno, R.J. and **H.J. Onsrud** (1990) Legally Supportable Cadastral Information System. *Proceedings, ACSM/ASPRS Conference* (Denver, CO) 1: 275-279.

Research has begun towards the development of an automated land information system that will support spatial integrity to the extent that surveying measurements allow and will survive most legal challenges to the quantitative and qualitative validity of the cadastral information contained in the system. This paper describes three levels of applications in which a legally supportable cadastral information system (LSCIS) could be particularly useful. Properties necessary for a useful LSCIS, a brief overview of research developments, and a planned research project are outlined.

Onsrud, H. (1989) The land tenure system of the United States. *Forum: Zeitschrift des Bunds der Offentlich BestelltenVermessungsingenieure.* 1: 23-28.

The purpose of this paper is to briefly describe the land conveyancing system used in the United States of America. In addition to its operational aspects, several shortcomings of the system are described. Although the U.S. conveyancing system at first observation appears to be far inferior to the land registration system used in the Federal Republic of Germany, the U.S. system supports certain policies, which are considered important within the U.S. social framework. It is submitted that recent technological advances in the storage and retrieval of land records may be moving U.S. jurisdictions towards a conveyancing system, which will have the same overall effect as a land registration system.

Onsrud, H. and B. Dansby (1989) Geographic Information Systems and the Legal Community. *ACSM Bulletin*. 30-36.

As members of the real estate conveyancing community, lawyers have an important role to play in developing standards and practices needed to improve land records. Society is placing unprecedented demands on government and the private sector to provide land information and analysis of that information. The legal community is being called upon to supply the critical component of spatially accurate, legally supportive ownership information. A GIS that includes deeds or title records will be beneficial to lawyers and the conveyancing community. Such a system has the potential of remote access to title documents, remote filing of title documents and computer-assisted title examinations.

Onsrud, H. (1989) Legal and liability issues in publicly accessible land information systems. *Technical Papers, GIS/LIS'89* (Orlando, FL) 1: 295-300.

LIS now being used do not visually communicate to the user the likely accuracy of the data, the original source of the data, nor much else about the entities displayed. The user is able to "zoom in" precisely on any entity on the screen and receives the false impression that this precision also represents high precision on the ground. The result is that citizens are likely to rely on derived data from the LIS in situations where they should not, and that damages will result. If a database is used by anyone other than those operating it, there will always be liability exposure. No LIS will ever by complete for all conceivable purposes of the system nor will the accuracy of data meet the required needs of all potential users. To ensure the greatest use of publicly maintained LIS at the local level, the database manager, those delivering data to the system, and users of the system should all be protected from the consequences of misuse and errors in the system.

Onsrud, H. J. (1990) Liability concerns for surveyors contributing data to public land information systems. *ACSM Bulletin*. 20-24.

This paper focuses on current practices and rule of law which individuals contributing data to a publicly accessible land information system or using data or products from such a system should be aware of.

Onsrud, H.J. and R.J. Hintz(1991) Evidentiary Admissability and Reliability of Automated Field Recorder Data. *Surveying and Land Information Systems*. (51)1: 23-28.

In modern surveying practice, field notes written on paper are being replaced by digital data stored in electronic field recorders. Potential errors associated with electronic field recorders include input, hardware, software, and perception errors. Because of these potential errors and because digital data is often easy to alter with little or no trace of alteration, the legal reliability of data from electronic recorders has been questioned. To introduce a series of issues in regard to assuring the competency of data from automated field recorders, typical procedures a surveying or engineering business might use in collecting and processing data from a field recorder and a dispute arising from those procedures are presented.

Onsrud, H.J. (1991) Evidentiary admissability and reliability of products generated from GIS. *Technical Papers, ASPRS/ACSM Annual Convention* (Baltimore, MD) 1: 197-201.

In modern cartographic and surveying practice, maps and plats traditionally maintained as paper documents are now being maintained in digital form in computerized files. Potential errors associated with geographic information systems and other computerized spatial handling systems include input, hardware, software, and perception errors. Because of these potential errors and because digital data is relatively easy to alter with little or no trace, the legal reliability and stability of data from computerized land information systems have become important issues for users and potential users of such systems. General rules for the admissibility of computer generated evidence in court are discussed within a framework of relevancy, authentication, and hearsay considerations.

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Steeger, W.A. (1991) A Framework to Value Information Systems. *Journal of Urban and Regional Information Systems* 3(1): 33-42.

PUBLICATIONS ON EDUCATIONAL ISSUES BY I4 RESEARCHERS - do not include these!!!!!!!!!!!

Obermeyer, N.J. (1993) The right person for the job. *GIS/LIS '93* in press

There has been a plethora of case studies in the GIS community describing various approaches to teaching GIS. This paper attempts to bring some understanding of these studies and to present them in the context of the real needs of employers of GIS professionals. Beginning with a literature review of case studies on GIS training, this paper goes on to discuss the needs of GIS employers, including vendors, municipalities, and academia. This paper raises questions about the balance of our education programs between teaching GIS skills and the substantive knowledge require for professional positions. While it is clear that many of the leading programs in GIS maintain this balance, it is less clear that such balance exists across the board. This has major implications for current concerns about how we, as a professional community, might assure the competency of GIS professionals.

Obermeyer, N.J. (1993) Certifying GIS Professionals: Challenges and Alternatives. *URISA Journal,* 1: in press (Originally published in*URISA 1992 Annual Conference Proceedings, Vol. III,* pp. 176-187.)

Recently, state legislatures in California and Georgia, working at the request of Surveyors, considered whether or not to adopt legislation that would require certification for GIS professionals. The legislation in Georgia became law. The GIS community had suggested certification previously as one way to address a perceived need to assure the qualifications of GIS professionals. Certification involves the development of an approved program of training for individuals wishing to enter the field; the final rite of passage is typically an examination. Similar certification procedures are well established in medicine, law, planning and surveying. The development of a certification process for GIS professionals will not be a simple task, nor is it necessarily desirable. Many problems must be resolved before certification can become a reality. This paper examines relevant issues in certification, taking cues from the experiences of other certification processes in an effort to provide insight into the task that lays ahead if, indeed, we choose this option. This paper also explores alternatives to certification, including accreditation and maintaining the status quo, and makes a case for accreditation as an alternative to certification.

Note: This paper was awarded the1992 Horwood Critique Prize by the Urban and Regional Information Systems Association (URISA).

Obermeyer, N.J. (1993) Issues and examples in GIS education: introduction. *Computers, Environment and Urban Systems.* 17:45-47

Education in GIS has become an increasingly important issue in recent years. Spurred by the rapid proliferation of GIS adopters and the concomitant need for professionals to implement these systems, the GIS community has developed a variety of approaches to education. This group of five papers explores a variety of approaches to or issues in education and training in GIS and reflects experiences in the U.S., Canada, and Australia.

Obermeyer, N.J. (1993) Certification and accreditation in GIS: prospects and pitfalls. Computers, Environment and Urban Systems, 17: 91-102.

The rapid proliferation of GIS adopters has raised concerns within the GIS community about assuring the competency of GIS professionals. The strategy most commonly suggested as a means to achieve this objective is certification, which involves specialized training of individuals who are ultimately tested on what they have been taught. This paper discusses certification and accreditation as alternatives to the status quo, raises questions that the GIS community as a whole must consider before making a decision, and recommends that we begin to address this issue by asking the question, "How can the GIS community best assure the competency of its professionals?" rather than beginning with the assumption that certification is the only means to this end. Since the goal of this paper is to stimulate discussion on how we can best assure the competency of GIS professionals, it deliberately avoids making any recommendations about which strategy the GIS community should follow, suggesting instead the community formally consider this topic to achieve a resolution.

N.J. Obermeyer (1993) GIS and Public Policy. Workshop presented at the Third Indiana GIS Conference, Indianapolis, IN, March 1993.

This workshop provides and overview of issues related to the implementation of GIS in the public sector. Among the topics covered are institutional impediments to the adoption of GIS, benefit/cost analyses, accreditation and certification, and the potential for GIS in a democracy.

N.J. Obermeyer (1993) Introduction to GIS. Presentation to courses in two separate departments at Indiana State University: (1) Principles in Environmental Health II (1/26/93) and (2) Computers and Management Information Systems (4/21/93).

This presentation provides a basic introduction to geographic information systems and their uses. The presentation described GISs, discussed implementation of the technology, and suggested specific ways that GISs might be used in the disciplines and professions represented by the courses in which the presentation was made.

N.J. Obermeyer - organizer (1992) Geographic information systems in the public sector, panel for the American Society for Public Administration National Conference, April 11-15, 1992, Chicago Hilton and Towers.

This panel provides information on the implementation of a recent technological innovation (GIS) in the public sector, and promotes the appropriate integration of GIS into the public administration community. Panelists included Stephen Ventura ("Implementation of a GIS in Wisconsin"), Steven P. French ("GIS as a Tool in Planning" - Lyna Wiggins, co-author), and Dennis McDonald ("The City-Wide Infrastructure Management System of Chicago").