**National Center for Geographic Information and Analysis**

# *Measuring and Representing Accessibility in the Information Age*

A Specialist Meeting of NCGIA's Project Varenius

Geographies of the Information Society

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**Asilomar Conference Center, Pacific Grove, California**

**Research Conference Report**

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## THE ASILOMAR CONFERENCE

### Background

The origins for a meeting on measuring and representing accessibility in the information age are rooted in the conference on Spatial Technologies, Geographic Information and the City, which met in Baltimore in September 1996. One of the concerns of that conference was to identify changes in accessibility brought about through spatial technologies, defined "as the complex of transportation, communication, and information technologies that together modify spatial relations". An outcome of discussions in Baltimore was the specification of research priorities, including the need to differentiate accessibility levels among a broad range of social groupings, the need to study disparities in electronic accessibility, and the need to investigate new measures and means of representing accessibility to capture the effects of information technologies, along with those of more traditional means of spatial interaction.

In 1997, the Varenius Panel on Geographies of the Information Society designated accessibility as a theme for a specialist meeting. The subsequent appointment of the Steering Committee resulted in a statement of conceptualization (below) and a Call for Participation (Appendix I).

The specialist meeting at Asilomar was structured around a set of 15 research papers, circulated on conference Web sites (http://www.ncgia.ucsb.edu/varenius/access/ and http://www.artsci.washington.edu/varenius/) well in advance of the meeting. This permitted an agenda built around thematic discussion of key issues as opposed to formal presentation of papers. In plenary sessions, authors established how their research advanced conference goals. These plenary sessions were structured around three primary themes regarding (1) the conceptualization and measurement of accessibility, (2) the visualization and representation of information space within Geographic Information Systems (GIS), and (3) the social issues that should inform the measurement and representation of accessibility. Plenary sessions were followed by small-group breakout discussions for in-depth examination of research questions and approaches. Reports back to the plenary sessions from breakout groups helped to integrate discussions among the three primary conference themes. The final day of the conference focused on the preparation of final group reports (contained later in this document) and on plans for advancing the status of accessibility research.

### Conceptualization

Concepts of potential and realized interaction and accessibility are central to geographic theory and models. Current models are based, however, on physical notions of distance and connectivity that are insufficient for understanding new forms of structures and behaviors characterizing an information age. Accessibility and spatial interaction in the traditional physical sense remain important, but information technologies are dramatically modifying and expanding the scope of these core geographical concepts. Through technological, structural but also social developments, an increasing range of transactions takes place in virtual space, or in some new hybrid space combining the physical with the virtual. Of importance also is the influence of new forms of communication on the use of and investment in traditional transportation infrastructure. Moreover, just as space can be fragmented so too can time, as activity rhythms in one place become increasingly synchronized with those in distant places. Geographic information science and technology, themselves products of this new information age, potentially have a major role to play in helping reconceptualize, measure, represent, monitor, and plan for the new emergent geographies.

Accessibility, both *within* and *to* communications and transportation networks, is the central concept in the geographic definition of opportunity. Since humans communicate continually as a part of knowledge building and social interaction, gaining access to a computer is equivalent to changing one’s accessibility within the broader flux of society. Since the information age has not made the information society ubiquitous, it is essential that geographical and planning models incorporate measures that reflect restructuring of geographical space and space-time differentials in accessibility to virtual networks. Models of how institutional and other contingencies influence who has access to whom, what, when, and where, via physical and especially via virtual contact, are also required for assessment of policy approaches to reduce inequalities in opportunities for social and economic interaction. Analytical measures and computerized visualizations of accessibility are needed to reflect hardware and software availability, inadequacies of education and training, cultural factors, and differential relevance of the Internet to everyday life. Such measures and representations of accessibility will contribute insights and reference points for judging efforts to mitigate the perpetuation of 'information poverty' for certain places and social groups.

This specialist meeting examined how geographic information science can assist research into the geographies of the information age. By helping to reconceptualize accessibility through appropriate representations of accessibility opportunity and inequality, this Varenius initiative explored expanded models of space (and time) that encompass both the physical and the virtual.

**Questions and Goals**

Some of the **key questions** considered were:

1. What are the information age counterparts to the accessibility and potential surfaces developed for interaction in physical space?
2. What space-time topologies need to be developed to accommodate both the physical and virtual worlds?

3. How do emerging conceptions of virtual space map onto traditional conceptions of geographic space and how do we handle their interfaces analytically?
4. How can interactions and accessibility gradients within these new hybrid spaces (and space-times) be represented and visualized within GIS?
5. How useful are traditional spatial interaction and urban computable general equilibrium models for the analysis of the new forms of accessibility? How should they be altered?
6. What are the technical and societal impediments to network access in different social domains, particularly for geographic information?
7. What representations can highlight patterns of lack of access independently of the lack of interaction?

The **goals** of plenary and small-group sessions were:

1. to identify and demonstrate conceptual and analytical approaches for accessibility research in the information age,
2. to review and demonstrate possible contributions for GIS in representing geographies of the information society,
3. to formulate an agenda for continuing research and research proposals to be assisted in part by Varenius seed grants,
4. to establish a communications network of accessibility researchers, and
5. to organize reports and publications from papers and discussions.

## GROUP REPORTS

The following group reports represent the main findings and research questions that arose from discussions at Asilomar. Group leaders were requested to summarize the principal contributions of participants in the three conference paper sessions, and to report on the breakout-group discussions that followed each session. The task of the breakout groups was to identify the major issues that confront researchers and to suggest questions that might guide a future agenda for accessibility research. The group reports, refinements of those presented to the final session of the conference, attest to the importance of accessibility issues to society, to the need for broad scientific and public discourse, and to the requirement for technical research that is informed through social understanding.

### Group I—prepared by Helen Couclelis and Arthur Getis

### Conceptualizing and Measuring Accessibility in Physical (Geographical) and Virtual Worlds (Space)

### Background

The study of accessibility in geography has a distinguished history dating back to Ravenstein's work over a century ago. In the late 1940s to the 1960s, scholars such as Zipf, Stewart, Warntz, and Wilson theorized about the way individuals and aggregates of individuals respond to the constraints of cost, time, and effort to access work, shopping, recreation, and other spatially distributed opportunities. Since that time accessibility has been closely related to but also distinguished from such key geographic concepts as mobility, movement, nearness, and the friction of distance. Different forms of spatial interaction models have been successfully used to study accessibility at the aggregate level, while the study of individual movements in space-time has provided insights into the personal significance of accessibility. These kinds of models have proved extremely useful not only for understanding how people are spatially related to their economic and social

activities, but also for the help they gave urban planners in designing transportation systems and land uses that satisfy general accessibility needs.

Recent societal developments require us to rethink the concept of accessibility at all scales. In technologically advanced societies, there is mounting evidence that urban areas are being restructured and that many kinds of social relations are being re-shaped in light of new communications and information technologies. Moreover, the nature of accessibility itself appears to be changing, as increasingly goods and services can be accessed by individuals or groups without recourse to physical movement. It would appear that mobility, nearness, and the friction of distance no longer are a necessary part of the definition of accessibility; or rather, that accessibility in physical space is now being complemented by accessibility in virtual space, defying familiar principles of distance, nearness, or spatial interaction. Given appropriate operational definitions of accessibility, geographic information science can play a leading role in helping us understand, explain, and if possible, predict the actual and potential effects of the new technologies on the spatial organization of society. For this particular conference sub-theme, the participants sought to explore and discuss the new concepts of accessibility that are emerging in virtual as well as in physical spaces, and the new measures that are called for in light of the widespread socio-spatial developments characterizing the information age.

**Session Outline**

This part of the meeting on conceptualizing and measuring accessibility was led by **Helen Couclelis** and **Arthur Getis**, and began with a brief presentation of the following four papers:

**Pip Forer and Otto Huisman** presented "Space, Time and Sequencing: Substitution at the Physical/Virtual Interface," in which they considered the substitution of virtual for physical access to daily activities within a university student population. The paper extended Hägerstrand’s space-time activity prisms in several new ways, demonstrating that the methodology is in principle applicable to both physical and virtual spaces, and that the analysis can be attractively visualized in the context of GIS.

**Eric Heikkila**, in his "The Fuzzy Logic of Accessibility," emphasized that fuzzy sets together with Tiebout’s theory of clubs can shed light on the complex associations of individuals in space as they try to maximize benefits given the available spatially distributed opportunities. Fuzzy clubs allow us to think of membership in self-selected groups as a matter of degree rather than total commitment. In a spatial context, this translates into degrees of accessibility for different kinds of people, places, and functions.

**Lauren M. Scott**, in her paper "Evaluating Intra-Metropolitan Accessibility in the Information Age: Operational Issues, Objectives, and Implementation," discussed several issues associated with operationalizing aggregate-level measures of accessibility. She then defined accessibility in terms of "levels of service", that is, how well a given location serves surrounding populations in some particular domain (e.g., employment opportunities), and showed how that notion could be implemented.

In "Transportation, Telecommunications, and the Changing Geography of Opportunity," **Qing Shen** demonstrated a new accessibility measure that incorporates location, transportation, and telecommunications into an integrated representation of spatial relationships. That measure is capable of identifying the varying degrees of the effects of telecommuting on spatial, social, and employment accessibility.

**Discussion**

The discussion sessions that followed elaborated on the main ideas presented in the four papers Participants addressed specific concepts and measures of accessibility, GIS technology, and the social usefulness of the concepts and measures of accessibility. It became clear, however, that three recurring themes were generated from the papers and the discussions: 1) general issues surrounding the definitions, concepts, and measures of accessibility 2) the distinction between individual and aggregate accessibility, and 3) changing spatial relations of the information age requiring new approaches to the study of accessibility.

**Issues Surrounding the Definitions, Concepts, and Measures of Accessibility**

The following questions were proposed by the session leaders ahead of time to stimulate discussion:

- To what extent do we need new concepts and measures rather than adaptations of existing concepts and measures of accessibility?
- Are there criteria that might help us to choose between/among different measurement approaches?
- Is there a useful operational difference between access and accessibility (e.g., between realized and potential contact)?
- What theoretical criteria might guide prediction or explanation in the area of accessibility?
- How can GIS functions and operations and GIS-based formalisms (e.g. map algebra, geo-algebra) be used to represent and measure accessibility? How can other promising formalisms (e.g. local statistics, fuzzy set theory) be incorporated into GIS?

Participants considered these questions but the discussion moved well beyond these. The issues that were discussed have for the most part been already raised in traditional accessibility research, e.g. the issue of potential vs. revealed accessibility, of structure vs. agency, of the demand vs. the supply view of accessibility. However, the societal and technological developments of the information age tend to add new dimensions to the old dilemmas.

It is important that accessibility be defined clearly. Problems of definition limit the effectiveness of accessibility measures and inhibit their successful application in planning. However, it is also recognized that the correct definition largely depends

on the scope and context of the investigation: it is unlikely that any particular definition will satisfy all research and planning needs. Thus a first task would be to survey the main types of situations within which the question of accessibility arises and clarify the meanings and role of the term within these contexts. Several new problem contexts arise in the information age, e.g.: differential access (by geographic location or socioeconomic group) to the technologies allowing virtual access; access within “cyberspace”; the possibility to substitute virtual for physical access; the comparative quality of the access experience in case of substitution; and so on.

Participants also agreed that in general accessibility should be viewed as a time-space phenomenon. Scheduling of activities is not only a spatially constrained process but also one that is strongly time dependent. While the idea is not new, it has new implications at an age when virtually instant access to some opportunities frees up time (and the potential for access) to others. The scheduling of activities may no longer be constrained by the spatial logic of multi-purpose trips, or the temporal constraints of business hours (“authority constraints”). New temporal constraints come into play as we access people and places across the globe - and so on. The paper by two of the participants (Forer and Huisman) showed that the traditional Hägerstrand time-geography framework can be extended to take into account some of these novel situations; it is unclear whether it can be adapted to all of them.

Among more recently formulated concepts, a particularly useful one appears to be that of proximal space. Proximal space integrates the attributes of a place along with the attributes of locations in the vicinity (physical or functional) of that place. This concept thus embodies both site and situational characteristics of places. For example, a site may provide good bus service to a set of other locations that together constitute its proximal space from the point of view of mobility through public transportation; or it may provide the means to connect to the Internet, and users communicate with specific addresses that together help form the virtual proximal space for these users at that particular location. The issue of accessibility in physical versus functional space is another major point raised in the group’s discussions. It will be briefly addressed later.

From this it becomes clear that there is a need for new concepts or at least adaptations of existing concepts and measures of accessibility. From the standpoint of social relevance, many of the ideas expressed in the conference focused on the new technologies in connection with employment. With significant numbers of people turning to telecommuting, models must include some sort of measure of proximal activity spaces indicating what is reachable (physically, virtually, or both) from a person at a given location. A model that distinguishes those that have telecommunications capabilities from those who do not might better approach the realism needed for adequate understanding and planning. A measure devised by a participant (Shen) takes into account the varying levels of composite accessibility for community residents The weighted measure shows that the higher the percentage of a zone’s residents who have access to advanced spatial technologies, the higher the zone’s general accessibility will be. Another such model is based on

the Hansen-type spatial interaction approach to accessibility measures. It is founded on measures of spatial opportunities and impediments (Scott). In terms of access to jobs, the $G_i^*$ local statistic (devised by Getis and Ord), when used as a model allows for a modern recreation of the Hansen approach. Among other outcomes, the model finds job-rich and job-poor areas, and naturally leads to a hypothetical transportation solution to the often-studied spatial mismatch phenomenon. The extension of such models to opportunities in virtual and hybrid (physical and virtual combined) spaces appears promising.

**The Distinction between Individual Accessibility and Aggregate Accessibility**

Participants recognized that disaggregate and aggregate level measures serve different functions. They allow us to address different types of issues. General questions that were considered were as follows:

- What are the strengths and weaknesses of aggregate versus disaggregate measures?
- Can we develop measures that will transcend/bridge the various scales of analysis?
- Do multi-level measures provide a richer understanding of accessibility? How?
- In moving from the individual to aggregates of individuals, what new types of activity surfaces are being created?

A recurrent theme in our discussions was the problem of scale. This is expressed as either the micro/macro problem or the individual-based versus aggregate measure problem. Disaggregate and aggregate level measures serve different functions; each allows for different types of questions. The behavioral, decision-making strengths of the micro approach are often undermined by the unavailability of individual data. The aggregate approach, while fulfilling analytical requirements (more manageable sample sizes) is by its nature limited to the study of planning problems dealing with group behavior and averages. The age-old question of the appropriate spatial resolution continues to be debated. The debate is complicated by the apparent spacelessness (and scale-lessness) of many of the newer telecommunications and information technologies. Multi-scale or scale-free approaches to analysis do not necessarily do justice to the complex effects of the new technologies on accessibility and human interaction.

The papers presented in this session provide some promising clues. Helping us through the quandary of the modifiable areal unit problem may be the time-space approach. The approach would be to focus on modeling individual accessibility into operational lifelines and Hägerstrand prisms (Forer and Huisman), and then generalize these into aggregate patterns of accessibility. Perhaps the idea of fuzzy club memberships will bridge the gap between individual responses and responses of the club to accessibility. In addition, the advantage of fuzzy theory is that spatial and non-spatial response functions can be handled within the modeling structure of

fuzzy set mathematics (Heikkila). Moreover, such techniques as neural net (not explicitly discussed at the meeting) hold promise as multi-scale analyzers.

The micro/macro problem in complex systems reaches beyond the issues of aggregation and scale. A very important related aspect is that of emergent behavior. As an example, it is well known that the individual increase in accessibility afforded by widespread automobile ownership in North American cities resulted in urban structures characterized by low overall accessibility scores. What corresponding emergent phenomena will be observed in the city of the information age is anybody's guess. Further, focusing solely on how best to aggregate individual choices and paths in space-time may lose sight of the fact that these choices and paths themselves are to a large extent socially constructed (more simply put, enabled and constrained by aggregate behavior). Finally, we should not lose from sight that a large part of urban structure may be explained not by the accessibility needs of individuals but by their distancing needs, as they strive to avoid the vicinity of less desirable groups, land uses or environments. While these centrifugal tendencies have always been present, the technological and organizational possibilities of the information age may greatly amplify these phenomena.

**Changing Spatial Relations**

There was consensus that we need to move beyond physical proximity in our representations of accessibility in order to understand how old and new kinds of spatial relations come together in post-industrial landscapes. Some key questions suggest themselves:

- How are the traditional spatial relations studied in socioeconomic geography responding to new conditions of access to goods, services and information?
- What new kinds of relations are replacing, complementing, or otherwise affecting traditional spatial relations?
- What other spatial and non-spatial relations become especially important in the information age?

At the root of many of the spatial changes taking place in the post-industrial city is the increasing dissociation between places and functions: activities are becoming increasingly person-based rather than place-based, so that where you are is less and less a reliable indication of what you may be doing. The assumption of a strong structural correspondence between spatial and functional relations, on which much of traditional socioeconomic geography is based, can no longer be taken for granted. Novel concepts were proposed by participants to deal with these changes: places as networks; the extensible individual (Adams); "wormholes" in functional space, like tunnels in space-time allowing instant access to activities at physically distant places; "real virtualities" as well as virtual realities, recreating at a place the feel or function of processes taking place elsewhere.

Participants agreed that some of the most exciting areas in accessibility research are to be found at the intersection of physical and functional spaces—where the socioeconomic relations in functional space "touch ground", and where the spatial

relations still constrain the functional. Studying that intersection will be a considerable challenge, because functional space has potentially many more dimensions than physical (geographic) space.

Many kinds of questions may be raised in that context. What is the practical relevance of defining and measuring accessibility where spatial relations no longer necessarily correspond to the most important functional relations? How is the quality of interaction affected for different kinds of functions when the spatial interaction is by-passed? What interactions must remain spatial and thus continue affecting spatial structure the old-fashioned way? What are the social costs and benefits of vastly increased opportunities of interaction within the functional/physical continuum, and how does that structure of opportunities vary over space and time?

**Research Objectives**

To advance geographic information science in this domain the focus should be on a generalized notion of accessibility as *process* taking place in physical, virtual, or hybrid spaces. The challenge will be to find consistent conceptualizations of accessibility that bring into focus the dynamic interconnectedness of physical and virtual accessibility. In this context some more specific questions suggest themselves:

**Project Questions for Geographic Information Science**

- How is accessibility modeled as process in a GIS environment?
- What computational process models may be developed to explore accessibility in complex, data-rich environments?
- What axioms may be formulated towards a general theory of accessibility in physical and other spaces? What kinds of theorems might be developed from axiomatic statements, and what new metrics of accessibility?
- What statistics can be used to measure and test hypotheses using data that express physical and virtual accessibilities? Are new kinds of statistics needed?
- What kinds of data are needed for the study of generalized notions of accessibility such as those discussed at this meeting? Who will collect, maintain, and distribute that data, and what new practical, technical, and legal issues may arise?
- How can geographic information science assist planning efforts in areas relating to accessibility, such as sustainable transportation, energy use, pollution control, public service provision, social equity, and the demand for access by different segments of the population?

**Group II—prepared by Harvey J. Miller and Michael Batty**

## Visualizing and Representing Information Space within Geographic Information Science (GIS)

### Background

The focus of this session was on new information spaces of both a virtual and material kind, associated with rapidly developing communications networks particularly the Internet and specific individual behaviors in real geographic space. Simply understanding such spaces based on their measurement was a major aim of this session but following measurement, their representation using visual software and their analysis using new kinds of simulation processes was also part of the central focus. Similarly to the entire meeting, accessibility was taken as the starting point. In the various presentations and the discussion that followed, the rather normative association of accessibility with its focus on physical proximity was subject to considerable scrutiny. The argument shifted to notions of adaptability and sustainability as being possible organizing concepts on which the measurement of new information spaces might be based.

The key arguments of the six presentations concentrated on mapping and visualizing new information spaces, adapting to information spaces, the role of accessibility in defining distance within and between such spaces, and the role of the internet in contrast to other less “visible”, less “accessible” networks. The four breakout groups were focused generally round these four themes although there was considerable fluidity in the discussion that followed. All groups dealt with mapping and visualization as well as the significance of traditional notions of accessibility to the emerging digital world at local to global scales. There was some basic questioning of whether or not accessibility—meaning overall nearness of propinquity with respect to a field of activity locations such as shopping centers or residential locations—was of any significance whatsoever in the new digital world. This was followed by some skepticism as to whether mapping virtual spaces with distance as some kind of underpinning concept was ever like to yield any insights. In particular, even if such mapping were likely to be useful, mapping Internet hubs and host computers was unlikely to reveal, at least directly, changes to the power relations which structure geographic space. In short, the spatial/geographical metaphor may not be the most appropriate especially as the flow of communications on most networks does not correlate with geographical space nor are they organized according to any traditional measures of distance. Nevertheless the most compelling arguments were those that sought to connect e-space with material space, in other words, connecting the virtual with the real. There is little if any research to date on these connections. There is a burgeoning traditional of measuring the internet but little on connecting such network spaces to other networks and spaces that exists in the material realm.

The notion of identifying new centers and new location of significance in both the virtual and material worlds was identified as being one of the most important tasks for future research. Of equal importance to measuring flows is research into the content of such flows and into the processes that mediate these flows. Increasingly

markets are being structured in real time across electronic networks and this poses a level of complexity on the real world that makes traditional approaches untenable. Moreover, it suggests that the main focus of geographical research into such questions is not one of the exploring the virtual world per se but of exploring the interface between the virtual and the real. This interface is where the real complexity of modern life is to be found.

It was judged important to develop clear notions of the demand for and supply of information particularly in relation to highly diverse networks where there are already very clear distinctions in terms of usage. What is available and what is required for what purposes are very different notions that must be identified, not only in relation to new information spaces but how these spaces map onto existing physical spaces. These may be articulated at various scales from social networks to global markets. The issues of the fundamental differences between information transmitted electronically and that through face to face contact came up time and again.

Another theme that weaves its way through all of the discussion emanating from this session involves the development of tools and protocols to enable efficient navigation through information space. This more instrumental viewpoint suggests that good geographical metaphors grounded in good theory about the information society should be at the basis of navigation tools that link behavior to purpose. Much visualization work is concerned with the development of better tools. These tools are being developed and tempered by the various institutional structures that require them. At the same time, we are beginning to learn more about new information spaces using the very tools designed for using these spaces in a routine fashion. As we develop tools to explore these new spaces, these tools are being used in routine way to navigate them. At the same time, the existence of these tools modifies these spaces. This is a kind of relativism that is rarely highlighted in the material world.

Questions as to the quality of information accessible in the virtual world were also central to the discussion. Good and bad information spaces were contrasted with good and bad information within these spaces with no one-to-one correspondence between each. The transitory nature of the digital world was also a feature of the debate. This highlighted the difference between a material world where information spaces are usually structured in terms of built form which has a life span which ensures some permanence in contrast to virtual information spaces that can appear and disappear overnight. This focus on temporality was an issue which served to test the limits of our discussion reinforcing the long standing idea that time geography and accessibility in time as well as or rather than space was of much more significance here that we had hitherto thought.

Lastly, the cliché of the digital world—that networks enable people to interact with “anyone”, “anywhere”, at “any time” and in “any place”—illustrates our crude vision of the emerging digital world. In this meeting, our focus was much more considered with an emphasis on how humans interact with one another in space and time, adapting to access the “right amount” and the “right” information in the “right time” and in the “right place”.

We attempted to cull all these deliberations into a plan for future research based on (i) what do we know and what do we have; (ii) what are the appropriate future research directions, and; (iii) what are the appropriate research questions? We will deal with these in turn. Although our discussions ranged far and wide, we re-emphasized our initial themes in developing ideas for the future.

## I. What Do We Know about Visualizing and Representing Information Space?

We conclude that a thorough review of our starting point is required. This might be accomplished through research projects but it is more likely to come from the current generation of researchers coming to the similar conclusions as these and spontaneously developing such reviews and statements. There are five issues here:

**Representing Networks.** This includes reviewing different ways of coding and identifying networks based on extensions of graph theoretic measures, methods of sampling and so on.

**Conceptualizing Activity Spaces and Accessibility Measures**. These are relevant to the virtual world but developed to date largely for spatial issues in the real world

**Cataloguing Market Data.** This includes reviewing methods for counting and observing network flows and new concentrations of information in real and virtual space

**Exploring the Role of Geographic Information Science in Mapping.** This focuses on assessing how far existing methods of GIS are useful for mapping new information spaces

**Exploring the Role of Scientific Visualization in Measuring and Mapping**. This requires reviewing how new methods of visualization for spatial and non-spatial data in spaces with many dimensions might be used to chart new information spaces

## II. Research Directions

**Researching the Flow and Cost of Information**. How can flows be identified and linked to the emergence of new spaces which in turn map onto existing market, social, and institutional processes.

**Tools of Cybernavigation.** The development of new tools for both exploring and moving through information spaces that are based on insights into the emergence of such spaces, the interface between activity in real and virtual worlds and developments in human-computer interaction.

**Mapping Activity Spaces.** This requires exploring ways in which existing approaches within time geography can be informed and extended by network paradigms, network flow data, and scientific visualization.

**Visualization of Connections between Virtual and Real/Material Geographies**. This can provide insights into how information spaces are connected to real spaces through augmenting existing measures of accessibility and the development of new ones

### III. Research Questions and Projects

**1. Need for a Major Data Initiative.** There is an urgent need for a major initiative in the collection of network data and its subsequent analysis with respect to the search for new information spaces. These initiatives could take many forms and we list four here:

- An Internet Census: A Data Archive for the Internet
- Definition of Private Networks
- The Collection of Behavioral Data associated with all Kinds of Networks
- The Role of Time Sampling in the Use of Networks

**2. Evaluation of Existing Tools and the Development of New Tools for a Geographic Science Relevant to the Information Society**. This should focus in particular on principles and tools in contemporary cartography and scientific visualization

**3. Theoretical Generalization of Distance and Space from the Real to the Virtual.** Theories, models and visualization of accessibility in real, virtual and hybrid spaces requires a generalization of geographic distance in terms of formal, logical and computational terms

## Group III—prepared by Mark Wilson

### Societal Issues Informing the Measurement and Representation of Accessibility in the Information Age

### Background

Societal Issues formed one of the three elements of the Varenius workshop on Measuring and Representing Accessibility in the Information Age. The workshop addressed many elements of access to, and use of, information technologies, and workshop themes crossed many of the papers and sessions used to organize the meeting. The central core running through the session was how to revisit the well-developed theoretical foundation established for accessibility in transportation geography, and to advance this foundation to understand the impact of electronic media such as computers, the Internet, and Geographic Information Systems.

While not a unique charge in the overall meeting, the Societal Issues group focused on the social context in which information technologies are used and developed. Implicit in this component of the meeting was an awareness of the need to understand how society and technology meet and interact. In fact, the political, economic, and social dimensions of information technology use may well represent

a far more complex and controversial arena for IT development than the technical barriers' scientists confront when advancing information technologies. This report summarizes the common themes of the Societal Issues session, which were access and equity, rights, the role of time, and ownership and control.

**Session Outline**

The Societal Issues component of the meeting was led by **Mark Wilson** and **Eric Sheppard**, and comprised the following five papers.

**Susan Hanson**'s paper, "Reconceptualizing Accessibility,"explored how spatial technologies affected equity. In particular, this paper went beyond issues of physical access to information technologies, to address the social importance of information flows and their form. Susan Hanson called for an understanding of how new technologies intersect with existing social relations, and the role of information technologies compared to face-to-face relationships and other networks currently used for interaction.

**Andrew Harvey** and **Paul Macnab** investigate the role of time in an immediate system of electronic interaction. Their paper, "Who’s Up? Global Interpersonal Temporal Accessibility," suggests that time remains one of the key challenges to interaction now that distance can be overcome electronically. Using a case study of Canada and its six time zones, the constraints of interaction are clearly defined by temporal coincidence, and the limited windows of real time communication possible at any one time.

In "Qualitative GIS: To Mediate, Not Dominate," **Robert Mugerauer** considers the possibility of alternative spatial configurations to capture qualitative elements of space. In particular, to harness the power of Geographic Information Systems to allow different groups and interests to define their own visions of space and location. Mugerauer calls for empowerment though the ability to use GIS by each group or interest to define its own world.

**Sylvie Occelli**, "Revisiting the Concept of Accessibility: Some Comments and Research Questions," concentrated on the urban context for information technology and accessibility. Occelli called for an extension of our concept of accessibility to include a temporal dimension, and for access to be seen as a resource for urban populations. The commonly used concepts of accessibility are seen as being surpassed by increasingly complex urban societies that deserve more sophisticated conceptualizations of accessibility.

This does not mean that the conventional notions of accessibility no longer apply. It simply reflects the fact that accessibility is an intrinsically manifold notion, encompassing several definitions that can co-exist and not be reducible to each other.

In "Loss of Legal Access to Geographic Information: Measuring Losses or Developing Responses?" **Harlan Onsrud** chronicles how the legal context for rights of access to information are changing in the United States. In particular, Onsrud is concerned about the erosion of access to public information sources for citizens. The

diminishment of legal access comes from a series of legislative changes that are often buried deep within legislative bills. The rights to access public information gained in the past are slowly being lost as "publishers and government agencies use the threat of digital technology as an opportunity to limit the rights of citizens to access information."

**Discussion**

Discussion of the Societal Issues component was organized around three themes, equity issues, rights, and time. These three foci were chosen as they represent important elements that shape, and are shaped by, the social context in which information technologies are used. This section recaps the major points made for each of the discussion points.

**Equity**

Equity issues were seen in several ways: 1) the relationship between information technologies and social networks; 2) in terms of the type of interaction (relationship, mode, and purpose); and 3) the impact of information technologies on identity, social capital formation and use, and political efficacy. The core points of the discussion were:

- The need to understand how people gather and acquire knowledge, and how they evaluate and act on that knowledge.
- The need to understand how social networks are developed and how information technologies shape, and are shaped by, social forces and relationships.
- How do information technologies affect the relationship between access and power?
- How do inequalities change over time, and how do information technologies affect the rate and direction of change
- Do information technologies remove locational disadvantages or reinforce them?

**Rights**

The discussion of rights recognized a broader domain for the role of ethics in electronic interaction and access. Issues of right to access and use of technology and information was seen as based in political and social context, and part of the choices societies make for utilitarian or communitarian systems. The core issues and questions raised were:

- Should we advocate the use of GIS for non-technical representations such as traditional and cosmological world views?
- The power of information technologies needs to be addressed in historical context. Of note was the role of information technologies in encouraging heterogeneity and diversity, and concern about the ability of IT and GIS to

force homogenization and undermine diversity. Does IT require a common language that produces a common mindset?

- Three important issues for IT use are: 1) representational issues; 2) legislative issues; and 3) language/dialect and user community issues.
- How can geographers respond to the historical trend towards cultural uniformity?
- Concern raised about growing legal restrictions on access to information, and the shift of access to public information away from government to value adding private interests.
- Is there a right to electronically represent one's group and how would such rights be formulated and implemented?
- Does one electronic medium imply one frame of thought and one reality?
- Is the World Wide Web embedded in a dynamic of control that shapes all communication in it?
- Rights involves several elements: 1) right to speak; 2) should there also exist a right to be heard?; 3) right to information access, and the shifting to private information from public information sources and control; 4) is there a right to receive a response from decision makers?; and 5) what are the ethics of having decision-makers "lurk" but not respond to critical web forums.
- Restriction of access to information may help or hurt people. There is a need to balance needs for access and privacy, and to be aware of the information "haves" and "have nots."
- Data can be envisioned as infrastructure, and the rival/non-rival distinction used for public goods can also be applied to information goods.

**Time**

The time dimension cuts across many of the papers presented, although it was specifically addressed as one of the discussion groups for Societal Issues.

The principal assumptions to be made about time in an IT context are:

- Time is the currency of the new economy, and it is a limited finite resource
- Time use is constrained in multiple ways
- The societal increase in types of activities (both virtual and real) subjects the individual and institutions to allocation decisions.
- The importance of measuring and representing accessibility is to permit individuals and institutions to extract greater value from time.
- There are many ways to think about time; as distance, space, location, and duration.

- One question raised concerns whether time is the right conceptualization; are we really interested in process and the understanding of events separated in time?

**Future Directions**

Discussions of the Societal Issues associated with access to information technologies resulted in the identification of many research issues and questions. Directions for research can be divided into three groups: 1) basic questions; 2) description of IT systems; and 3) understanding processes of IT development and use.

**Basic Questions**

Among basic questions deserving attention are:

- What is the value and use of access, in particular, how useful is access to information technologies and for whom?
- What are the priorities and opportunity costs associated with improving access to information technologies?
- How do people acquire and gather knowledge to construct their awareness of accessibility spaces and opportunities?

**Description**

The growth and scale of information technology systems requires significant analysis just to map and identify how IT systems work:

- What are the physical systems that allow IT networks to operate, and how do they affect access?
- Who owns and controls IT networks, such as individuals, for profit and nonprofit corporations, government, and countries?
- What are the interests and voices that are heard about IT control, and whose voices are not heard?
- Recognition of the need for case studies of both good and bad practice for information access and use.

**Processes**

The underlying theme of this research direction is how the social, economic, and political institutions in different places and time shape access to and use of information technologies:

- How do different types of institutions set agendas for information use and control?
- How do the sets of institutions in different locations interact to shape IT use?
- How does decision making proceed in the establishment of an information infrastructure? And, how does this process vary across time and space?

- Does using information technologies, such as the Internet, require or generate different forms of social capital?
- How do people construct their social networks and how does this relate to accessibility?
- What are the relationships between accessibility and power?

## ABSTRACTS OF PAPERS

The abstracts presented in this report were revised by the authors to reflect discussions that took place at the Asilomar Conference. Authors were requested to prepare final abstracts that establish linkages among the papers and that build on the formal and informal debates of the conference proceedings.

**Group I**

- **Eric J. Heikkila,** Accessibility and Membership in “Fuzzy Clubs”
- **Pip Forer** and **Otto Huisman,** Space, Time and Sequencing: Substitution at the Physical / Virtual Interface
- **Lauren Scott,** Evaluating Intra-Metropolitan Accessibility in the Information Age: Operational Issues, Objectives, and Implementation
- **Qing Shen,** A Pragmatic Approach to Defining Spatial Relationships in the Information Society

**Group II**

- **Paul C. Adams,** Application of a CAD-based Accessibility Model
- **Martin Dodge,** Accessibility to Information within the Internet: How Can it be Measured and Mapped?
- **Mei-Po Kwan**, Conceptualizing and Measuring Individual Accessibility to Information Resources on the Internet
- **Mitchell L. Moss** and **Anthony M. Townsend,** The Role of the Real City in Cyberspace: Understanding Regional Variations in Internet Accessibility and Utilization
- **Shane Murnion,** Cyber-spatial Analysis: Modelling Web Server Information Flows
- **Daniel Z. Sui,** Spatial-temporal Patterns of Accessing the Internet: A Multi-scale (holographic) Perspective

**Group III**

- **Susan Hanson,** Reconceptualizing Accessibility
- **Andrew Harvey** and **Paul Macnab,** Who’s Up? Global Interpersonal Temporal Accessibility
- **Robert Mugerauer,** Qualitative GIS: To Mediate, Not Dominate
- **Sylvie Occelli,** Revisiting the Concept of Accessibility: Some Comments and Research Questions
- **Harlan Onsrud,** The Rise of Digital Libraries and the Fall of Public Rights in Geographic Data

## Accessibility and Membership in "Fuzzy Clubs"

**Eric J. Heikkila**

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My paper will argue that the mathematics of fuzzy set theory can operationalize the concept of accessibility in a way that encompasses both its geographic and virtual dimensions. As discussed below, fuzzy set theory is a branch of mathematics introduced by Zadeh (1965) that recognizes degrees of memberships in sets that we shall call "clubs", in reference to a branch of the public goods literature. Club theory argues that individuals voluntarily form groups or clusters in order to derive tangible or intangible benefits through mutual association. Cornes and Sandler (1986) summarize this literature well, tracing its antecedents through Buchanan (1965) and Tiebout (1956).

The proposition I will advance builds on recent papers by Roger Bolton, myself, and others:

- Bolton (1997) establishes a compelling correspondence between *places* and *networks*, arguing that, "Recent theory on communications networks, from microeconomics, geography, and sociology, has relevance to planning, because one can model a well-functioning local community, especially one with a strong sense of place, as a network of social interactions."
- Heikkila (1996), in turn, demonstrates empirically that municipalities (or "places") within complex urban settings such as Los Angeles can be usefully understood as "clubs". ANOVA tests for sixteen broadly based socioeconomic indicators reveals that a "club-like" clustering within municipal boundaries explains a substantial proportion of the overall spatial variation in those indicators.
- Richardson *et al* (1990) and Heikkila *et al* (1988), in their empirical studies of residential land values in Los Angeles group their explanatory variables in three sets, corresponding to (i) property characteristics, (ii) neighborhood attributes, and (iii) geographic accessibility. The first two components account for ninety percent of the overall spatial variance in land values.

Taken together, these ideas and findings suggest that traditional notions of spatial accessibility are misplaced. Geographic location within an urban area appears to be secondary to considerations of "club membership", where those "clubs" may or may not be geographically defined and where club membership need not be binary. Membership in a club indicates an *association* with that club. In a geographic sense, *proximity* is an essential measure of the strength or degree of association. In a transactional sense, *interaction* is an alternative measure of association. In a socio-political sense, *influence* is another.

What is called for, then, is a more *general theory of membership association* that encompasses geographic proximity, transactions-based interactions, socio-political

influence and other dimensions of association. From this perspective, the relevant question is not so much how to adapt geocentric concepts such as spatial interaction and accessibility to a virtual context. Instead, we may be better advised to ask whether membership association can be defined in a sufficiently robust way that it may be extended to encompass both geographic and virtual domains.

Fuzzy set theory may be a logical place to begin this inquiry. Introduced by Zadeh (1965), fuzzy set theory allows for degrees of membership in so-called fuzzy sets, where degree of membership is defined by a membership function. According to John (1996), "For any set A the function $m_A$ indicates the degree of membership that x, of the universal set X, belongs to set A, and is usually expressed as a number between 0 and 1:

$m_A(x)$: X --> [0,1] "

Consider, for example, how this concept may apply to the traditional geographic concept of an urban rent gradient. Instead of conceiving of a particular parcel of land as being "accessible" to the central business district, we may instead think of that parcel as having a certain degree of membership (as defined by $m_A$) in the CBD "fuzzy node". By an extension of the same line of reasoning, the entire urban space can be conceived of as the union of a set of overlapping fuzzy urban nodes. Like clubs, these nodes need not be geographic in nature.

It would appear that fuzzy set theory has considerable potential for integrating geographic, social, virtual, and other elements of accessibility or association. Fuzzy set theory provides an array of logical operators that can be used to define the union and intersection of fuzzy sets. Geographic space is not lost in this formulation, however, it is operational primarily within the confines of the membership function, $m_A$. From this perspective the advent of communication technologies may alter the membership structure of certain fuzzy nodes or clubs, but not in a way that impacts the logical or analytical foundations by which we may understand the relationships between clubs. It is this perspective that I would like to pursue for the *Varenius* project.

**References**

**Bolton, Roger (1997)** “Place” as “Network”: Applications of Network Theory to Local Communities; paper submitted for *Volume in Honor of T.R. Lakshmanan*; Department of Economics, Williams College, Williamstown, MA 01267; December.

**Buchanan, J. M. (1965)** An Economic Theory of Clubs, *Economica*, vol. 32, 1-14.

**Cornes and Sandler (1986)** *The Theory of Externalities, Public Goods, and Club Goods*; Cambridge University Press.

**Heikkila, Eric J. (1996)** Are Municipalities Tieboutian Clubs?; Regional Science and Urban Economics, vol. 26, 203-226.

**Heikkila, Eric J. et al (1988)** What Happened to the CBD-Distance Gradient? Land Values in a Polycentric City; *Environment and Planning A*, vol. 21, 221-232.

**John, Robert I. (1995)** Fuzzy Inferencing Systems: Problems and Some Solutions; *CMS Working Paper No. 62*; School of Computing Science, De Montfort University, The Gateway, Leicester, LE1 9BH, U.K.

**Richardson, Harry W. et al (1990)** Residential Property Values, the CBD and Multiple Nodes: Further Analysis; *Environment and Planning A*, vol. 22, 829-833

**Tiebout, Charles (1956)** A Pure Theory of Local Expenditures, *Journal of Political Economy*, vol. 64, 416-24.

**Zadeh, L.A. (1965)** Fuzzy Sets, *Information and Control*, vol. 8, 338-353.

## Space, Time and Sequencing: Substitution at the Physical / Virtual Interface

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This paper considers the issues of accessibility and human activity scheduling in the context of space-adjusting technologies. It proposes some concepts for implementing an enhanced view of access and activity, and attempts an application of these in the domain of the geography of tertiary learning. We report on work that models student daily life choices and which seeks to identify new university structures that might offer the best provision of 'accessibility' to a geographically widespread student body. The paper concludes by reviewing the concepts of Time Geography, sequencing and substitution in the light of our experience with them in the domain of tertiary education.

It is widely accepted that accessibility is a complex and difficult concept to make operational. Traditional quantitative measures have treated accessibility as a purely spatial phenomenon, based upon simplistic assumptions of distance, with limited cognizance of either a temporal dimension or process. Time and activities were consistently neglected in these models of accessibility potential and spatial interaction, for a variety of conceptual and computational reasons. However, refined models have emerged, based upon more realistic measures of spatial separation and interaction, including topological or network travel time, and cost.

Although not conceived of as an accessibility measure by Hägerstrand, the field of Time Geography which grew from his seminal work on life-lines has nevertheless contributed to a wider appreciation of “real” access. Time geographic studies stress the importance of the temporal dimension by explicitly incorporating time in their models of process, and so in any calculation of accessibility and spatial opportunity. From this perspective, human activities can be seen as sequences of social, economic, and recreational events, each of which has a duration, and occupies a given location in time and space. The range of locations available for these

activities is subject to a set of constraints that reflect timing and mobility and these choices in turn impose limitations on participation in other activities. The ability to overcome these constraints is very much the essence of effective accessibility.

It has been argued that the strengths of Time Geography were not realized in the 1970s due to an inability to scale the concepts into substantial applications in the real world (Hanson 1998, Huisman and Forer 1998), and to implement better conceptions of 'space' as a separator in socio-spatial process. We now witness advances in geographic information technologies and spatial modelling packages which are seizing new opportunities and contributing to a growing volume of literature that applies core concepts of time-geography to specific research problems (Miller 1991; 1998, Kwan 1998). Both new application areas and enhanced concepts are features of these developments.

This paper accepts that there is a need to extend these studies into an improved language of access and interaction, and draws on and reports the authors' earlier work on a discrete cellular implementation of Hägerstrand”s geometric conceptualization of space and time. It also accepts that a major overlooked issue in a complete Time Geography has been the substitution effect of 'virtual' for 'real' meetings or access to functions. In the 1970s substitution principally reflected the use of the (synchronous) telephone making a face to face meeting unnecessary. A growing range of technologies has become available for use, allowing growing substitution and impact of real geographies (Janelle 1995). Currently, advances in (synchronous and asynchronous) telecommunications make the potential for substitution far more pervasive (Harvey and Macnab 1998). This poses new problems in defining the interaction of individual time geographies and structures. In particular, it requires us to consider in greater depth the activity issues of *discretionary sequencing* and *physical/virtual substitution.*

This paper develops preliminary operational concepts in these areas, which are demonstrated for a specific domain. The chosen domain is the geography of tertiary learning, which is selected for two reasons. Firstly, the student life experience is an excellent context in which to develop and test concepts. It is structured by numerous 'markers' in terms of lecture timetables and such, and so is both clearly defined and well documented. Secondly, it is an area of potentially high physical/virtual substitution. Emerging virtual technologies in education are able to bring about changes that are both complex and inevitable in the delivery of tertiary education. These changes are leading to greater diversity in tertiary learning options, and are likely to induce significant structural changes in tertiary education delivery. The ability to describe and understand these changes has important practical applications in the context of tertiary learning delivery, as well as more general implications for the geography of tertiary education.

Specifically in this paper, the concepts of accessibility, sequencing and substitution are investigated operationally for students at a metropolitan university under an existing and a hypothetical 'virtual' delivery scenario. The timing of lectures and the accessibility of campus sites dominates the activity patterns in students' lives, and initial accessibility measures are generated for a sample of 100 university students using actual timetables and constraints for Auckland, New Zealand. A second set of

measures is then developed based upon the likely impacts of new information technologies, substitution and potential rescheduling. It is shown that substitution of physical for virtual learning activities allows the modification of spatial and temporal constraints and has significant impacts on the effective accessibility of students to places and vice versa.

**Keywords:** Time Geography, accessibility, activity scheduling, sequencing, substitution.

**References**

**Hanson, S.** 1998. Reconceptualizing Accessibility. *Paper presented at the Varenius meeting on Measuring and Representing Accessibility in the Information Age*. 19-22nd November 1998 (Asilomar, California).

**Harvey, A.S. and Macnab P.** 1998. Who's Up? Global Interpersonal Temporal Accessibility. *Paper presented at the Varenius meeting on Measuring and Representing Accessibility in the Information Age*. 19-22nd November 1998 (Asilomar, California).

**Huisman, O. and P.C. Forer**. 1998. Computational Agents and Urban Life-spaces: A preliminary investigation of the time-geography of student life-styles. *Proceedings 3rd International GeoComputation Conference*. 17-19th September (Bristol, UK). CD-ROM/Hypertext 23 pages.

**Janelle, D.G**. (1995). Metropolitan Expansion, Telecommuting and Transportation. In Hanson, S. *The Geography of Urban Transportation, 2nd Ed.* Guilford Press, pp. 407-434.

**Kwan, M.** 1998b. Representing and Measuring Hybrid-Accessibility in Space-time Using GIS: A multi-scale extension of the individual space-time path. *Paper presented at the Varenius meeting on Measuring and Representing Accessibility in the Information Age*. 19-22nd November 1998 (Asilomar, California).

**Miller, H.J**. 1991. Modelling accessibility using space-time prism concepts within geographical information systems. *International Journal of Geographical Information Systems* 5: 287-301.

**Miller, H.J.** *Forthcoming*. Measuring Space-time Accessibility Benefits Within Transportation Networks: Basic theory and computational procedures. *International Journal of Geographical Information Systems*.

## Evaluating Intra-Metropolitan Accessibility in the Information Age: Operational Issues, Objectives, and Implementation

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Broad urban restructuring processes—globalization, suburbanization, economic restructuring, and rapid developments in telecommunications and transportation technologies—have had dramatic impacts on the urban landscape, fundamentally altering the spatial and organizational composition of where we work and live. How have these broad spatial processes impacted intra-metropolitan accessibility? Notions about intra-metropolitan accessibility provide the basis for a variety of urban policy and transportation planning decisions; they represent key components in urban economic theory relating to land use and urban development; they serve as a common focus for geographic research concerned with economic growth, transportation patterns and infrastructure, metropolitan form, urban efficiency, and social equity. Despite the centrality of these ideas to urban research agendas, accessibility remains a difficult construct to both define and operationalize. The challenges become more pronounced in the "information age" where access to urban activities and spatial opportunities is no longer necessarily constrained by physical space, but increasingly takes place via electronic telecommunications (see Chen; Forer and Huisman; and Harvey and Macnab in this volume).

This paper addresses the Varenius call for participation in the specialist meeting on "Measuring and Representing Accessibility in the Information Age" by presenting an analytical framework for evaluating intra-metropolitan accessibility within the context of broad urban restructuring processes. This analytical framework is implemented within a GIS environment and is structured around (1) a "level of service" definition of accessibility, (2) the Couclelis proximal space theoretical construct, and (3) the Getis/Ord $G_i^*$ spatial statistic. The analytical framework is applied to 1990 employment data in the Greater Los Angeles region in order to demonstrate its effectiveness and potential for addressing a wide variety of empirical research questions, for contributing to urban theory, and for evaluating urban and transportation planning strategies.

This research focuses on employment opportunities because employment represents a fundamental component of urban accessibility and has been directly impacted by broad processes of globalization, suburbanization, economic restructuring, and technological developments. The framework is applied to the Greater Los Angeles study area because restructuring processes here have thoroughly altered the social and economic geography of the region; Los Angeles, in fact, has been referred to as *the* prototypical example of urban restructuring. Accessibility is defined in terms of "level of service" rather than opportunity counts or magnitude, because the "level of service" definition has practical application for urban and transportation planning policy. The Couclelis proximal space construct is adopted to represent a variety of spatial and non-spatial relationships between jobs and resident workers; this construct provides an elegant solution for bridging the theoretical concepts of absolute space with relative space, and site with situation, offering tremendous flexibility and potential for modeling complex origin/destination relationships. Finally, the Getis/Ord $G_i^*$ spatial statistic is utilized because it affords a number of advantages over traditional measures of intra-metropolitan accessibility.

The analytical framework outlined in this research has been structured with the following definitional, representational, and methodological criteria in mind:

1. An effective definition for accessibility will encompass three essential elements: (a) the distribution, magnitude, quality, and character of employment opportunities in both space and time; (b) the integrity and effectiveness of urban transportation and information networks; and (c) the ability and desire of people or firms to overcome spatial and/or temporal constraints.
2. An effective model of accessibility will allow flexible representation of the spatial relationships within an urban activity system, reflecting the notion that accessibility has multiple dimensions, is a process of space, time, and technology, operates over multiple spatial scales, and is influenced both by local and by non-local events/phenomena.
3. An effective measure of accessibility will present robust results and provide application for urban and transportation planning policy.

From this perspective, accessibility is considered a multi-dimensional attribute (see Hanson in this volume) of the proximal spaces defined for any given urban activity system. It is multi-dimensional because the concept of accessibility comprises both structural and functional components, encompassing both potential accessibility and realized accessibility.

Structural components of accessibility are investigated in the first two empirical analyses, emphasizing spatial distributions of jobs and workers within the context of the transportation infrastructure connecting them. The proximal space relationships used in these analyses include physical distance and estimated travel time costs. Extended application of these analyses includes addressing jobs/housing balance, spatial/skills mismatch, and journey-to-work commute planning issues.

Functional components of accessibility, on the other hand, comprise a variety of attributes associated with different groups of individuals (their resources, aptitudes, constraints, preferences, ingenuity, etc.) which lead to different patterns of realized accessibility. Realized accessibility is expressed through observed travel behavior. A third set of analyses presented in this paper focuses on these functional components of accessibility by modeling the proximal space construct using estimated *functional* travel times. Extended application of this set of analyses includes testing how well variations in income, race/ethnicity, gender, or occupational categories explain sensitivity/insensitivity to the structural constraints of accessibility imposed by urban spatial structure. Conclusions outline future research directions.

**Keywords:** Accessibility, Getis/Ord Gi* statistic, Proximal Space, GIS, Los Angeles

## A Pragmatic Approach to Defining Spatial Relationships in the Information Society

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Accessibility is a key concept for defining the strength and extensiveness of spatial relationships among people, places, and activities. However, virtually all existing accessibility measures incorporate only transportation without considering other means of spatial interaction. It is obvious that these measures are unable to depict the full range of spatial relationships in contemporary society, where digital information and communications technologies are deployed on a massive scale. Therefore, in order to understand the technologically reconfigured geography and to plan our cities and regions, we need new analytical frameworks that integrate location, transportation, and telecommunications into a unified representation of spatial relationships. What I present at this meeting is an approach to conceptualizing and operationalizing this type of analytical frameworks.

The starting point of this approach is to reconceptualize geographic space by identifying its three components: the physical space (*space 1*), the hybrid space (*space 2*), and the cyberspace (*space 3*).

The next step is to reconceptualize spatial relationships by reexamining accessibility. The development of digital information and communications technologies has been accompanied by a gradual shift of activities (opportunities) from the physical space to the hybrid space and to the cyberspace. It has also been accompanied by the emergence of two distinctive classes of people (opportunity seekers)—those who have access to these advanced technologies and those who do not have such access. Furthermore, the large-scale deployment of information technologies has generated major effects on people's travel behavior, as manifested by changes in the frequency and duration of different types of trips.

The third step is to restructure accessibility measures. To make these measures operational, determinants of accessibility—opportunities, opportunity seekers, and impedance or cost of access—must be defined explicitly. Opportunities consist of the following three categories:

- f O—opportunities that exist in *space 3*, and therefore are accessed through telecommunications
- l O—opportunities that exist in *space 2*, and therefore can be accessed through either transportation or communications
- (1-f -l )O—opportunities that exist in *space 1*, and therefore are accessed through transportation only

Opportunity seekers consist of two broad categories:

- d P—seekers who have telecommunications capabilities, and therefore can access all three categories of opportunities
- (1-d )P—seekers who do not have telecommunications capabilities, and therefore can access only two categories of opportunities (those in *space 1* and *space 2*)

A great challenge is to specify an impedance function for opportunity seekers who use telecommunications as a means of access. Instead of attempting to quantify the impedance directly, my approach is to measure it indirectly by examining the partial substitution effect of telecommunications. A critical assumption underlying this approach is that seekers who can use telecommunications capabilities to access opportunities in *space 2* and *space 3* still make trips, although at a lower frequency. This assumption is made on the basis of empirical studies of telecommuting, which indicate that telecommuters reduce, but do not eliminate, commuting trips (Mokhtarian, 1990; US DOT, 1993). Therefore, the following relationship can be established for telecommuters:

$$t_{ij}^{cv} = s\,(1 / t)\,t_{ij}^{v} \quad (1)$$

$t_{ij}^{cv}$ is perceived average daily travel time from location i to location j for telecommuters;

t is the interval (number of working days) between two round-trips;

$t_{ij}^{v}$ is the travel time from i to j by mode v;

s is a parameter that converts actual average daily travel time to perceived average daily travel time.

The main elements of the restructured accessibility measure are generally expressed by the following two equations:

- Accessibility for seekers who do not have telecommunications

$$A_i^{v} = A_i^{v(1)} + A_i^{v(2)} \quad (2)$$

- Accessibility for seekers who have telecommunications

$$A_i^{cv} = A_i^{v(1)} + A_i^{cv(2)} + A_i^{cv(3)} \quad (3)$$

$A_i^{v(1)}$ is accessibility to opportunities in space 1 using transportation;

$A_i^{v(2)}$ is accessibility to opportunities in space 2 using transportation;

$A_i^{cv(2)}$ is accessibility to opportunities in space 2 using telecommunications;

$A_i^{cv(3)}$ is accessibility to opportunities in space 3 using telecommunications.

In the context of commuting and telecommuting, equation (2) and equation (3) can be made operational by incorporating the relationship described in equation (1). As I demonstrate elsewhere, the resulting accessibility measures can serve as a tool for understanding some important aspects of the changing geography of the information society (Shen, forthcoming).

There are several issues yet to be addressed, and these point to possible directions for future research. First, I have characterized my approach as "pragmatic" mainly because it is based on indirect measurement of impedance of interaction in cyberspace. It has so far ignored time or cost differentials within cyberspace. Some participants of the meeting showed that, at least at the global level, time or cost differentials within cyberspace can be quite significant. It seems important to be able to include such differentials in the measurement of accessibility.

Second, while the approach is operational in the context of commuting and telecommuting, it is not clear whether this approach is operational in other contexts. Many human activities take a composite form, that is, they involve both transportation and telecommunications. These two elements are related in a variety of ways, which raise the question of whether they can always be represented by a discrete classification of activity spaces and means of access.

Finally, the operational form of my analytical framework is currently a set of gravity-type accessibility measures that indicates the potentials for spatial interactions but does not indicate the economic benefits and costs of such potentials. To provide behavioral interpretations of spatial relationships, it will be important for future research to examine people's time and monetary budgets and tradeoffs in choosing work, residence, and means of access.

**References**

**Mokhtarian, P. L.,** 1990, A typology of relationships between telecommunications and transportation. *Transportation Research A*, Vol. 24, 231-242.

**Shen, Q**., forthcoming, Transportation, telecommunications, and the changing geography of opportunity. *Urban Geography*.

**US DOT**, 1993, *Transportation Implications of Telecommuting*. Washington, DC: US Government Printing Office.

## Application of a Cad-Based Accessibility Model

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Geographical understanding of communications and transportation usually proceeds macroscopically, from the vantage point of a remote and detached observer. Total minutes of telephone communication between a set of countries, presented as a network map, would be one form such knowledge might take. Frequency of flights between a set of cities would be another. While the macroscopic perspective provides a good sense of the overall degree of interaction between places and how such interaction varies spatially, it obscures the way communication and

transportation are incorporated in people’s lives in real places. Much that is of interest from a cultural geography or social geography viewpoint is lost in the process of aggregation.

Time geography’s seminal question "where are the people in regional science" (Hägerstrand 1970) is as relevant as its subsequent focus on activity and authority patterns in time and space. The question "where" must be answered through a focus on individual lives. This focus can address either the objective or the subjective characteristics of accessibility. Objective characteristics include total minutes a person spends communicating through various channels, the mean duration of such communications, his or her physical movements through space, and the substitution effects of communication on a particular transportation routine. Subjective characteristics include the sense of place (or virtual place) engendered by certain media, the reciprocal feeling of being lost or "out of place," the strategies by which people navigate through "cyberspace," the cognitive image or mental map of virtual space, and the use of what might be called virtual landmarks. In short, micro-scale analysis of accessibility includes both subjective and objective characteristics related to individual uses of communication, as a complement to macro-scale analyses that examine communication systems in their entirety and society in aggregate.

Distanciated activities surround the physical nucleus of the human body like the branches of a tree or the "pseudopods" of an amoebae (Adams 1995). Technologically-constructed extensions through space (e.g. telephone conversations) are no less constitutive of social structure than the interactions of co-present individuals. A fax, a phone call, a letter, a memo, a video image, or a broadcast voice can all affect consumption, direct business activities, pursue a romantic encounter, reinforce or challenge political values, provide a connection to the past or future, or build community. Furthermore, mediated interactions cannot be understood simply by inference from macro-scale patterns. Much that is evident at this scale, such as the primacy of certain urban hubs in routing information from place to place, disappears at the individual scale. Much that is evident at the micro-scale, such as the rhythm of alternation between different communication media, the construction of non-place communities, and the cognitive "carry-over" from physical space to virtual space, is invisible at the macro-scale. Thus, analysis and mapping of accessibility must take into account both the micro and macro scales, and both subjective and objective concerns. In short, topics relevant to accessibility occupy four intersections: macro-scale objective concerns, macro-scale subjective concerns, micro-scale objective concerns, and macro-scale subjective concerns.

The study in this paper applies two "lenses" to understand the micro-scale, objective characteristics of accessibility. Both lenses are directed towards the lives of five people who live in the Albany, NY metropolitan area. First, a narrative lens provides a general "feel" of their different lifestyles. These lifestyles range from a quiet retirement schedule to a busy schedule coordinating several professional positions. All five schedules include both work and leisure, with distinctive contrasts and complementarities between the two spheres of activity. Also included in this narrative are intersections of the five life-paths, encounters and communications

between the individuals. Through these intersections five daily routines are integrated as a social network.

Second, a "map" of these daily routines is shown. This map is in fact a three-dimensional dynamic representation built in a computer aided design (CAD) database. The model can be sorted into layers to reveal selected themes. For example, two-way communications such as telephone conversations can be shown, leaving out one-way communication links such as radio and television. The model can be turned in any direction, and expanded on the screen to reveal particular details. The "map" therefore, like GIS, has no given appearance, but is a representation of information selected and organized by the user. Furthermore, like GIS, this model facilitates analysis of the data because it renders a large amount of data visible in a single image.

This study enhances understanding of how emerging technologies are affecting spatial behavior and suggests new techniques for "mapping" the activity space of people in the information age. It helps discover links between physical and virtual worlds. It indicates the prevalence of a kind of virtual commuting, the movement of agents, if not of bodies, between physical and virtual places. Furthermore, it shows the frequency with which such "commuting" occurs and how it is embedded in daily routines.

**References**

**Adams, Paul**. 1995. A Reconsideration of Personal Boundaries in Space-Time. Annals of the Association of American Geographers 85(2):267-285.

**Hägerstrand, Torsten**. 1970. What About People in Regional Science? Papers of the Regional Science Association 24:7-21.

## Accessibility to Information within the Internet: How can it be Measured and Mapped?

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I will argue that the scope of geographical accessibility needs to be expanded to encompass notions of *information accessibility*. The growing importance of the Internet, and its layered services, for receiving and distributing all manner of information and for personal interaction will require us to consider how concepts of accessibility are played out within these electronic spaces. Gaining access, in a timely fashion, to the right information resources, be that a Web page, an email, a video clip, a chat room or a particular place in a virtual world, is problematic for a number of human and technical reasons.

One definition of the Internet is "*a collection of resources that can be reached from those networks*"(Krol & Hoffman 1993, page 1). This definition provides the starting point for my conceptualization of accessibility in the Information Age. I examine how one can begin to measure and visualize the aspects of accessibility to resources *within* the Internet. My discussion starts with the assumption that a person has physical access to the Internet, via a networked computer. Once this “physical” connectivity has been overcome, how accessible are the information resources, people and electronic places that are potentially available online? What skills and facilities are required to realize the potential of the Internet. As the Microsoft mantra says, "*where do you want to go today?*". This is very much a concern with individual accessibility and developing a behavioral geography for Cyberspace (Kwan 1998).

It is also important to consider how these dimensions of accessibility can be represented, particularly given the abstract nature of information spaces, which often do not have natural spatial structures, and the somewhat ethereal nature of searching, browsing and communicating in Cyberspace. These representations need to be dynamic and interactive, as well as being readily available whilst navigating the Internet (December 1995, Dodge 1998b).

The World-Wide Web may well facilitate easy access to vast arrays of information from servers around the world, but this does not mean one can find useful, current, reliable and affordable information at the right time. As Pirolli *et al* comment, "*The apparent ease with which users can click from page to page on the World-Wide Web belies the real difficulty of understanding the what and where of available information*" (Pirolli et al 1996, page 1). The Web is a sprawling and rapidly growing information space, and the ratio of noise to useful information can be very high. The problems of efficient information retrieval through searching and browsing this massive space are becoming important for conceptualizing accessibility in the Information Age. There is an increasing awareness of the problem of “information overload”, with "*a tsunami of data crashing onto the beaches of the civilized world*" (Wurman 1997, page 15). Accessibility to too much information is potentially as significant an issue as accessibility to too little information. Excessive information impedes its assimilation and therefore does little to improve knowledge and understanding. A great deal of effort is being directed by researchers in a range of disciplines to cope with the problem of information retrieval and information overload and I would argue that much of this research is relevant to broadening the scope of geographic accessibility to encompass information spaces of the global Internet.

In my paper I discuss how we can develop the theme of *information accessibility*, examining the following topics (1) nature of the different Internet information space, (2) issues of network performance and tools to try and diagnose problems (3) the importance of search engines and the problem of "findability" of resources (4) accessibility problems caused by the design of information spaces. The issues of measurement and representation of information accessibility are highlighted in detail for two particular Internet information spaces; an empirical investigation of accessibility between Web sites using the structural information contained in hyperlinks and an examination of accessibility in a 3-d virtual world on the Internet.

**References**

**Dodge M.**, (1998b), *Atlas of Cyberspaces*, Cyber-Geography Research.

(http://www.cybergeography.org/atlas/)

**December J.**, (1995), "A Cybermap Gazetteer", *TeleGeography 1995: Global Communications Traffic Statistics & Commentary*, edited by Gregory C. Staple (TeleGeography Inc.: Washington DC), pages 74-81.

**Krol E. & Hoffman E.**, (1993), "FYI on ‘What is the Internet?’" , *Request for Comments: 1462*, May 1993. (ftp://ftp.ripe.net/rfc/rfc1462.txt)

**Kwan M.P.**, (1998), "Conceptualizing and Measuring Individual Accessibility to Information Resources on the Internet", paper presented Varenius Project meeting *Measuring and Representing Accessibility in the Information Age*, 19-22 November 1998, Pacific Grove, California.

**Pirolli P., Pitkow J. & Rao R.**, 1996, "Silk from a Sow’s Ear: Extracting Usable Structures from the Web", *Computer-Human Interaction (CHI—96) Conference,* April 1996, Vancouver, Canada.

**Wurman R.S.**, (1997), *Information Architects*, (Graphis Press Corp: New York).

## Conceptualizing and Measuring Individual Accessibility to Information Resources on the Internet

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As an increasing range of transactions becomes possible on the Internet, the number of people accessing the Internet has grown rapidly in recent years. This suggests that individual access to the Internet is becoming an important need in everyday life and an indicator of social equality in the near future. Despite the expanding access to the Internet for certain groups of individuals formerly under-represented in recent years, there is a widening gap in the use of personal computers and online services between European Americans and African Americans in the US from 1994 to 1997. In view of the increasing "digital divide", methods for representing and evaluating individual access to resources on the Internet are now urgently needed.

Recent studies on Internet usage largely use zone-based aggregate measures of accessibility. These include the number or proportion of people with access to personal computers and Internet services, or the number of Internet domains, hosts or addresses found in a city or region. Although these studies can reveal the spatial

inequality in the infrastructure for Internet access, their aggregate or zone-based methods cannot reflect fine-scaled differences in the access experience of individuals belonging to various gender/ethnic subgroups. Further, as these measures are based on the physical elements of or information flow on the Internet, observations can still be made with respect to specific geographical locations, and results are "mappable" in geographic space.

However, this reliance on locational referencing breaks down when the analyst attempts to investigate individual access from a behavioral perspective. On the one hand, when an electronic packet can travel from the US to New Zealand or Japan and back in less than one second, time-space convergence is literally complete. Physical distance between the origin and destination of an electronic packet also seems to bear little relationship with the duration taken to traverse such distance. Further, although an individual's experience of using the Internet may engender a sense of "place" or "community", it does not seem to lead to a sense of distance or direction as there is no geographical landmark or physical movement in "cyberspace" for telling either distance or orientation. All these pose a serious challenge to existing geographical concepts and methods, which are largely built upon distance-based location theories and geo-referenced spatial relations. When there is no friction of distance and the Cartesian logic of space does not hold, what conceptual apparatus and operational methods can be used for evaluating individual access to resources on the Internet, given its seemingly placeless and timeless characteristics?

This paper examines individual accessibility in cyberspace through a cognitive-behavioral approach. It argues that the objective structure of information resources in cyberspace is not very relevant for understanding the subjective experience of individual access to these resources. Instead, it suggests that cyberspatial cognition is crucial in constituting the effective cyber-environment in which individuals interact with information resources in cyberspace. A conceptual model, which conceives the individual as an extensible agent, is then proposed. It focuses on the access interface between the individual and cyberspace, and identifies the "portal" and history mechanisms as important elements affecting individual accessibility. Based on this model, notions fundamental in conventional accessibility measures are re-examined. These include the notion of distance, impedance, opportunity set, and attractiveness of opportunities. Two alternative approaches! to measuring individual accessibility in cyberspace are then proposed. One is to adapt space-time accessibility measures for handling cyber-transactions. The other is to formulate new type of measures for evaluating accessibility in cyberspace.

As shown in this paper, human behavior in cyberspace bears certain similarities with spatial behavior in the physical world. Many geographic theories about spatial learning, cognitive mapping, choice and decision-making behavior are therefore helpful for understanding the cognitive experience of individuals in cyberspace. For instance, many features of spatial learning and wayfinding have their equivalents in cyberspace (e.g. using bookmarks as landmarks, and building long-term memory using computer-assisted history mechanisms). As Darken and Sibert (1996) argued, knowledge about human wayfinding in the physical world may be applied to

construct aids for wayfinding in cyberspace. All these suggest that behavioral models may be able to provide the theoretical foundation for cyber-spatial analysis if the focus is on individual differences in personal accessibility in cyberspace. Using this approach, not only individual-level differences can be revealed. The effect of other-person-specific factors on accessibility may also be examined (e.g. gender/ethnic difference in cyber-spatial ability). When linked to the analysis of socio-spatial processes, a contextualized understanding of the situated experience of individuals in a particular locale may become possible.

## The Role of the Real City in Cyberspace: Understanding Regional Variations in Internet Accessibility and Utilization

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Since 1993, when the first graphical web browser, Mosaic, was released into the public domain, the Internet has evolved from an obscure academic and military research network into an international agglomeration of public, private, local, and international telecommunications systems. Much of the academic research and popular writing about the Internet has emphasized the "distance-shrinking" implications and "placelessness" inherent in these rapidly developing networks. Pundits and scholars alike believe that telecommunications will fundamentally transform the economics of space and time so as to render location meaningless in economic and social relationships. Notwithstanding the enduring value of cities as places for serendipitous and planned face-to-face communication, little research has actively investigated how accessibility to telecommunications networks is distributed among geographical locations. However, there is a dearth of empirical research from which to begin developing hypotheses on the relationships between the physical and political geography of cities and regions and the presumably place-independent virtual geography of the Internet.

This paper builds upon the results of several studies we have conducted over the last two years, which indicate a strongly urban and overwhelmingly metropolitan dominance of Internet development by a handful of cities and regions. We identify and describe an emerging structure of "virtual" hubs and pathways that are inter-connecting a set of major cities in the United States in highly complex ways. This evidence suggests that there is an emerging "club" (after Heikkila, 1998) or network of cities distinguished by the intense use of Internet technologies for inter-urban communications. Furthermore, rather than being solely confined to regions of technological innovation like Silicon Valley, the Internet has been most rapidly adopted by the globally-oriented business communities of large American cities and metropolitan areas. As a result, there are great variations among metropolitan areas and regions in the availability of Internet infrastructure, primarily driven by regional differences in the propensity to conduct commerce online.

More importantly, this paper presents three new empirical techniques to geographic variations in Internet utilization, diffusion, and accessibility. As the telecommunications industry becomes increasingly competitive, the difficulties in obtaining timely and accurate data will become more pronounced. We hope that our experience identifying consistent, credible, and cooperative sources for data and formulating methodological techniques and conceptual frameworks for their application to urban research will be useful to other scholars. These measures also provide a baseline data set of the geographic distribution of place-based Internet activity, which complements Shane Murnion's (1998) work on modelling the actual flow of information between centers of Internet use.

Specifically, we analyze the utility and relevance of three measurements of Internet infrastructure for urban research, geography, and public policy analysis. The first measure is the number of host computers connected to the Internet on a full-time basis. We find this measure to be of limited usefulness, as it only measures location-specific hardware installations with little reference to their purpose or function. The second measurement we employ is based on a component of the Internet's addressing scheme, the domain name system. Unique to individual organizations (business, education, non-profit, government), domain names are registered with InterNIC, an administrative clearinghouse contracted by the National Science Foundation. Associated with each domain name is a unique billing address, which permits the localization of the organization using that name. We have found this measure to be the most informative for assessing variations in Internet utilization across a variety of geographic units, from states to individual ZIP codes. The third and final measurement discussed is the capacity of inter-metropolitan "backbone" networks. While the host count measurement describes a completely physical and real phenomenon, and the domain count measurement a thoroughly virtual and logical one, the backbone capacity measurement is a hybrid. Although, some networks operate on isolated fiber optic cables, many are "virtual networks" operated over lines leased from national and regional telephone companies. Finally, we analyze the work of others who have examined geographic patterns of Internet access and utilization.

Based on these three measurements, we find that a small number of cities and metropolitan areas dominate the rapidly emerging telecommunications landscape of the United States, leading the development of increasingly sophisticated applications and technologies. Accessibility to the most advanced and robust real and virtual Internet infrastructure is a metropolitan phenomenon, and highly stratified among regions and cities. Furthermore, we describe each of the three measurements utilized - host counts, domain counts, and backbone network capacity - and their unique advantages and disadvantages for research. Finally, we offer caution to researchers entering this emerging field. Successfully using these measurement methodologies and techniques to advance geographic analysis and urban studies requires understanding not just the fundamental principles of our own disciplines, but also the function, purpose, design and evolution of the vast array of technical systems that comprise modern telecommunications networks.

## References

**Heikkela, Eric J**. "Accessibility and Membership in ‘Fuzzy Clubs’". Paper given at Project Varenius Meeting at Pacific Grove, California. November 20-22, 1998.

**Murnion, Shane**. "Cyber-Spatial Analysis: Modelling Web Server Information Flow". Paper given at Project Varenius Meeting at Pacific Grove, California. November 20-22, 1998.

## Cyber-spatial Analysis: Modelling Web Server Information Flows

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Inequalities between the various global sub-networks may well result in basic asymmetries between service and demand for on-line information services. The basic natures of these asymmetries should influence directly the accessibility of information services in emerging information technology regions to global markets. The resulting development and placement of such services will then influence directly the level of accessibility to information and information services for users in these internet-developing regions. Unfortunately at the present time it is quite difficult or perhaps impossible to determine the nature and effects of these inequalities since little quantitative information is currently available about the quality of remote networks. Historically measurement tools have arisen from a requirement by system administrators to be able to determine and measure the quality of connectivity between a local computer and some remote computer or computers. This has resulted in a wide variety of tools that allow us to measure this one (local) to many (remote) relationships. A wide variety of these services are, producing what are often termed latency or “Internet Weather” maps, available at the current time. However if we wish to determine the quality of many (remote and local) to many (remote and local) relationships then we discover that there are a very limited number of tools and results available for our use. In this work an attempt is made to apply an old geographical technique of triangulation and adapt it to the new medium of the Internet to predict the latency between two remote computer systems. The main difficulty in adapting such a method is that the information does not travel in a direct line from one system to another, but rather travels along a network between the two computers.

Five “Internet triangulation” stations were set up, distributed around the Internet. The distance between two locations in cyberspace and each of these stations was measured simultaneously using simple ping latency measurements. Each of the stations also monitored the latency from their location to the other monitoring stations. Using the simultaneous measurements an attempt, using a neural network, was made to predict the latency between the two locations being

observed. Direct measurements of the latency between the two points were also gathered to compare with the predicted results. The results show that the method shows promise, but did not produce results of sufficient quality for immediate practical use. Some of the possible causes for error were examined. On major reason for interest in getting this method to operate successfully, is that in order for the method to work, it requires that the location of each object being observed in cyber-space must be explicitly defined. By measuring the position of a large number of internet addresses for which geographical locations are available then it may be possible using neural computing techniques to develop a model that can map cyberspace locations as defined by the monitoring stations to geographical locations and vice verse. This would allow us to monitor the temporal changes in cyberspace and its changing relationship with geographical space. Analysis of short-term variations throughout the day may reveal interesting patterns of WWW usage in different parts of the globe and might provide insights into the daily cycles of Internet use. Long term trends may reveal how the quality of the Internet is developing worldwide. Of particular interest is whether or not the disparity between developing and developed nations is increasing or decreasing with time. An automatic gazetteer of this type should also allow us to provide reasonably detailed maps of the density of Internet locations and also of the extents of the current and future Internet domains.

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## The Geography of the E-merging Information Society: Accessibility or Adaptability?

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The recent history of technological innovations has shown that the time it takes for universal access to a new technological innovation has shortened dramatically and thus the importance of accessibility declines as the technology evolves. This paper argues that having access to the right information at the right time and the right place is not as important as what people actually do with the information. Our current concentration on accessibility issues might blind us to the real issues in information society. This paper calls for a shift of research efforts from accessibility to adaptability - to study how people or organizations actually use the information they have access to their best advantage.

Using principles from evolutionary economics as a primary theoretical template, this paper aims to develop an adaptive perspective to understand the geography of the E-merging information society. It is argued that our current focus on accessibility is based upon a mechanistic physical metaphor that is reductionistic, deterministic, ahistorical, and teleological. By contrast, the adaptive perspective emphasizes the organic nature of society and the role of historical contingency and path dependence. The final paper will elaborate on the ontological, epistemological, and methodological differences between the accessibility vs. the adaptability perspective. Internet usage survey data will be deployed to empirically test the key arguments of this paper.

## Reconceptualizing Accessibility

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The advent of information technology (IT) prompts a reassessment of the conceptualization and measurement of accessibility. My central concern is with equity and how new spatial technologies might exacerbate or help reduce existing social and spatial inequities in access. New information technologies, including spatial ones such as GIS, have been widely touted as effective means of bringing about greater equity of access among socio-spatial groups. I argue here that the limits of traditional (i.e., pre-virtual) concepts and measures of accessibility need to be acknowledged and remedied before we attempt to develop new accessibility measures that incorporate IT. Simply trying to evolve new, IT-relevant access measures uncritically from traditional measures will not engage the most difficult and important problems regarding equity in access to information, jobs, services, and goods.

Traditional measures of accessibility focus on the location of potential destinations relative to an origin zone (for aggregate measures) or to an individual’s home location (for individual- or household-level measures). In this sense potential destinations (whether workplaces, stores, hospitals, or parks) are essentially considered as an opportunity surface, centered on an origin. Missing from this concept/measure of access, even before we begin to consider the impact of IT on accessibility, are the informational, social, and cultural dimensions of accessibility. Traditional concepts of accessibility do not recognize that people are embedded in networks of social relations through which information is exchanged; these networks of social relations shape norms and values and, to a great extent, accessibility. Precisely because accessibility requires more than proximity and/or mobility, simply eliminating the friction of distance by using IT will not necessarily yield access.

Using access to employment as an example, I explore the role of information and of social and cultural capital in accessibility, emphasizing the importance of face-to-

face contact and everyday interactions. Information exchanged face to face with people one knows and trusts is often valued over information received via more formal channels (such as the newspaper or the Web) precisely because such informal exchanges are contextualized; social and cultural capital depend upon the expectation of repeated interactions, which have traditionally been place bound. In this sense, social and cultural capital are profoundly geographic and contribute to existing inequities of access, as some places and groups have social and cultural capital that fails to link them to decent jobs.

As networks of social relations are likely, I believe, to remain important in shaping access to employment, a key question in this information age concerns how IT and spatial technologies might intersect with place-based social processes to improve the access of those people whose access to employment is currently poor. I argue that we must conceptualize IT and grounded, face-to-face interactions as synergistic and complementary. I propose and briefly explore two research questions that I believe belong on the research agenda. First, how are people using IT (virtual interactions) and face-to-face interactions to shape—i.e., increase and constrain—their access? How do these different forms of exchanging information interact with and affect each other? How might their complementarities be enhanced? Second, how can we measure and represent each of these types of interaction and information networks (virtual and face to face)? I suggest three components for an information age accessibility measure: 1) the spatial arrangements captured in traditional measures of accessibility (these are admirably dealt with in Lauren Scott's paper), 2) access to IT itself (this is likewise a topic that others at the conference addressed in depth), and 3) access to social and cultural capital. Finally, I outline some ways to operationalize the third component.

Even if everyone had equal access to IT, the Internet, and various spatial technologies, inequality and inequity of access would still arise from people's embeddedness in networks of social relations, which are to a great extent rooted in place. The importance and continuity of this embeddedness raises for me the need to investigate the two research questions I pose.

## Who's Up? Global Interpersonal Temporal Accessibility

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This paper explores the ability of individuals to interact in real-time around the planet by way of the Internet. Beginning with the assumption that the time of day will always be one of the few things truly separating the world's cultures, it explores interpersonal accessibility with a particular emphasis on the role of daily activity patterns. A "personal real-time accessibility index" to measure the potential for

direct, immediate and responsive face-to-face, global, remote interaction is developed.

Interpersonal temporal accessibility (ITA) means an individual is available to interact reciprocally with other individuals in the normal course of daily activity. In its simplest form, the personal real-time accessibility index is the population reach (i.e., the effective number of persons reachable) from a given location at any given time. The index varies both spatially and temporally. The potential for ITA in some locations greatly exceeds the potential in other locations. For any given location, potential will vary over the diurnal cycle as distant locations and people become more or less accessible.

Combining the perspectives of Giddens (1990) and Janelle (1995), communication may involve face-to-face contact requiring spatial and temporal coincidence, contact requiring temporal coincidence, or mediated distanciation requiring no temporal or spatial coincidence. Here importance is attached to mediated face-to-face interaction focusing on communication, rather than transportation, and temporal constraints, rather than spatial constraints.

Capability, coupling, and authority constraints (Hägerstrand, 1970) play a role in determining global ITA. Personal capabilities comprise adequate computer skills and language abilities. Capability constraints, measured in terms of access to appropriate technology, represent the initial constraint on accessibility since technology must be in place for communication to take place and the development of personal skills will follow the availability of technology. Capability measurement requires data on the availability, adequacy and adoption of technology as well as the skill levels needed for successful utilization. Here revealed capability, as measured by estimated Internet usage, was used as a measure.

Assuming appropriate technology is in place, ITA requires temporal coincidence of the communicating parties who are also free to, and have adequate time to, communicate. Such patterns can best be explored in terms of activity settings which encompass one’s location, when, for how long, and with whom (Harvey, 1982).

Following Lewin (1951), behaviour will vary depending on whom one is with, where they are, and when they are there. Time spent awake and alone is the significant factor in individual accessibility. Location must also be considered since the mere act of being alone will not necessarily guarantee accessibility. Individuals will primarily have access for contact over the Internet at home or work. Time-use studies provide a basis for quantifying these dimensions.

Time-diary data suggest people spend approximately 950 to 1,400 minutes of the day awake: about 500 minutes in the household, 170 to 250 minutes alone in the workplace, 140 to 180 minutes in the community, and 70 to 80 minutes in transit. Individuals appear to spend a significant amount of time alone. The Canadian, Norwegian and Swedish data presented suggest that 335 to 396 minutes of the waking day are spent in isolation with the majority at that time (between 211 and 295 minutes) being spent in the household.

The extent to which ITA is affected by the diurnal cycle is amply illustrated with a case study of Canada, one of the few countries to span six time zones. Calculations based on activity patterns and corresponding social environments across Canada enable us to chart potential accessibility at three points in the day according to Newfoundland time. With some extension, the analysis presented can be expanded to encompass time zones around the world.

While many have argued that spatial data are best represented with maps, the graphs, table sand matrices like those demonstrated here provide a familiar if not cumbersome way of representing spatial-temporal patterns since time is less amenable to mapping than space, particularly given present methods and software tools. Spatial changes over time are well-represented on maps; what about time changes over space?

In closing, the paper identifies research needs in five principal areas: (1) interactive geographic visualizations, (2) diminishing accessibility as a result of increasing accessibility, (3) Internet traffic monitoring to compare ITA potential with real-time communication volume, (4) expansion of time-use and internet surveys to collect details on the nature and duration of mediated face-to-face interaction, and (5) continued exploration around the notion of temporal "regions" within and between, the planet’s geographic "regions."

**References**

**Giddens, Anthony** (1990). The consequences of modernity. Stanford, Calif.: Stanford University Press.

**Hägerstrand, T**. (1970). What about people in regional science? *Papers and proceedings of the Regional Science Association*, 24:7-24.

**Harvey, Andrew S**. (1997). From activities to activity settings. In Dick Ettema and Harry Timmermans (co-eds.), *Activity-based approaches to travel analysis*. Tarrytown, New York: Pergamon.

**Janelle, D.G**. (1995). Metropolitan expansion, telecommuting and transportation. In Hanson, S. *The geography of urban transportation, 2nd Ed.* Guilford Press, pp. 407-434.

**Lewin, K.** (1951). Field theory in social science. (D. Cartwright, Ed.). New York: Harper & Row.

## Qualitative GIS: To Mediate, Not Dominate

**Robert Mugerauer**

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Michael Goodchild reminded us of the work of the 17TH century geographer for whom our project is named. Varenius, produced two geographical treatises on general geography (dealing with a general set of principles clearly related to the work of Newton) and ideographic geography, having to do with the special character of places. Varenius' two-fold approach affirms what our society has forgotten, but what is in agreement with Newton: there is both Absolute and Relative Space. The former is assumed by physicists in the course of their abstractions and the latter is experienced by ordinary people in the course of making their way in the world. However, today the powerful realm of GIS, for all its potential for human understanding and good, does substantial violence by requiring that all our transactions and uses translate--radically convert--our experiential realms into the coded terms of GIS as based on data provided and available only in Euclidean geometrical terms for Newtonian space. This paper does not in the least disparage the power of absolute space, Euclidean geometry, nor general geography; but it does argue that we must reaffirm what Varenius and Newton also contended: the specific characteristics of different places and our everyday life experiences relative to ordinary objects must be accepted as complementary to the dominant conceptions. In the case of GIS, this would mean that we need to develop a Qualitative GIS system that will allow us to successfully access one another's life-world's rather than build enclaves through information technology.

The heralded Digital Divide between those who have access to Information Technology and those who do not is even deeper in the case of GIS because the cultural capital of marginalized groups is itself denied when the foreign conceptualizations of GIS are used according to the required technological format. In contrast, Qualitative GIS would operate to either build models from other modes of data bases or to inscribe other kinds of hyper-media into standard GIS bases, actually superimposing qualitatively distinct information upon that standard base. The GIS modeling alternative could proceed on the basis of non-Newtonian, non-Cartesian, non-Euclidean databases as found in the extensive ethnographic research data sets. The more conservative hyper-media model would insert personal, local, imaginative, navigation, story-telling, or other perceptual-qualitative information over the standard GIS spatial lay-out in the manner of medieval mappings with glosses and drawings over the base cartography.

The result would be a mode of GIS that presents a set of alternative geographies and ways of visualizing those spaces and places that diverse groups inhabit and experience—a new geographis specificus. This would enfranchise groups otherwise marginalized, allowing them and the rest of us to begin to understand their worlds as they articulate them in their own terms and as embodying their own value systems. The result would be the affirmation of multiple worldviews and multiple geographies, rather than the reductive homogenization taking place through current technologies. Our policy for access would change our professional and technical missions to helping others say what they want to say in their own terms, to delineate their own worlds so we all could become conscious of them in their similarities and differences and responsible toward them.

# Revisiting the Concept of Accessibility: Some Comments and Research Questions

**Sylvie Occelli**

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As shown in the literature which has been accumulating over the past ten years, almost all urban systems in developed countries are undergoing a number of institutional, socio-economic and cultural changes pushing them towards a 'new' societal configuration which is generally taken to be more democratic, better educated, culture-based and environmentally sensitive, i.e. the so-called “Post-Fordist society” (Amin, ed., 1994). Space-adjusting technologies, and particularly the New Information Technologies (NIT), are playing a substantial role in this transition since they affect both the range and time-related organisation of activities offered in an urban setting and the ways individuals participate in them (see Castells, 1989, Bertuglia and Occelli, 1995, Graham and Martin, 1996).

Due to its intrinsic ability to provide the 'connections' between the pattern of activities and their interdependencies, accessibility is a very sensitive concept for analysing these changes. In the current transition to a Post-Fordist society, however, the notions currently used are revealing many drawbacks and limitations and need to be extended.

The need for this revision has already been advocated in a number of studies (see Couclelis ed., 1996, Handy and Niemeier, 1997, Occelli, 1998) and is a major theme of the Asilomar meeting. In this respect one extension which has been recently suggested (Occelli, 1998) relates to the effect of New Information Technologies (NIT) on the time dimension underlying the notion of accessibility. Thanks to the new potential offered by NIT, accessibility is not simply a time-space opportunity, but also a 'resource'.

In this paper we intend to sharpen some of the topics introduced in previous works. One implicit aim is to show how ‘reasoning about accessibility’ can help both in disentangling accessibility problems and defining better policy measures.

The discussion is divided into four parts.

1. The first part revisits the concept of accessibility. It emphasizes how the appealing aspect of accessibility is in its ability to bridge the spatio-temporal and spatio-functional component of spatial systems. It is this 'junction role' which is mostly sensitive to NIT. On the other hand, the widespread diffusion of NIT is giving new scope for examining the 'junction role' of accessibility. It is argued that the effects of the impact of NIT on accessibility are both substantive (the kind of changes occurring in urban system as a result 'time-space shrinking possibilities' and 'enabling potential') and methodological

(the changes occurring in our way of conceiving 'accessibility' and its role in relation to urban evolution).

2. The second part recalls some classical definitions of accessibility proposed in the literature. It is argued that these reflect the features of the city, which have progressively consolidated in the historical process of urbanisation. A 'meta-typology' of urban development is proposed which might help to improve our understanding of accessibility features in relation to the stages of urban evolution (i.e. the industrial, Fordist City and Post Fordist City). Although the labels and features of the stages of urban evolution are not new, the proposed meta-typology matches a set of socio-economic and institutional features with a corresponding set of spatial features. What the 'meta-typology' shows is that whereas, on phenomenological grounds, an increasing 'complexification' of cities is recognisable, the fact that accessibility is becoming more complex should also be acknowledged.
3. In the third part, an effort is made to show that the claimed extensions in the analysis of accessibility do not simply result from 'phenomenological' issues (i.e. those associated with the developments characterizing the transition to a Post-Fordist society). They also emerge from the shift in the approach to analysis, which has occurred in mainstream quantitative geography. Some implications of this new approach to the understanding of accessibility are illustrated. A major point which is highlighted is the fact that accessibility is an intrinsically complex notion, encompassing definitions which can co-exist but not be reducible to each other. In particular, three distinct analytical levels were mentioned as having relevance for representing accessibility, i.e. the individual, systemic and policy level (this, to some extent, can be related to the discussion of self-referentiality in Sui's paper) . Although this may appear a trivial result on speculative grounds, it is certainly not from a policy point of view. Most definitions of accessibility currently used do not, in fact, consider this distinction and usually assume that a same notion of accessibility (i.e. a same indicator) can be applied (have the same meaning) in very different planning contexts. In dealing with the methodological aspects, we also observed that the many different notions of accessibility depend on the kind of representations we have. Besides having a substantial role in the formation and updating of these representations NI, as echoed in Mugerauer's paper, might be helpful in allowing an 'informational convergence' between them, thus providing a bridge between the various analytical levels.
4. Finally, the last section focuses on the formulation of some 'questions' likely to be given priority in future research on the relationships between NIT, urban evolution and accessibility. These concern:
    - The identification of the 'appropriate level of definition for a certain representation of accessibility'. The problems are both conceptual (i.e. the need to formulate an appropriate time-space framework of reference) and empirical (i.e. the kind of process and outcome indicators to be used);

- The fact that any definition of accessibility in a 'Post-Fordist' city should be accompanied by an evaluation of the associated benefits likely to be accrued to individuals and organizations. In particular, considering accessibility as a resource, implies that attention should be paid to:
- The type and quality of urban products to be accessed. This means that 'what' is to be accessed and 'how', is not irrelevant in the determination of these benefits. This issue in turn raises questions relating to the scarcity and efficiency in the provision of a range of urban services, and the co-ordination of the various activities (i.e. opening times of the various population services and transportation service availability);
- The ways of overcoming spatial separation, i.e. the kind of communication links involved in the various human interactions. In this connection, the 'value' of time associated with the communication links should be given further attention (i.e. integrating the analysis of both cognitive and practical aspects);
- The kind of trade-offs likely to be involved, in terms of positive effects obtained at the individual level and negative externalities which might result at more aggregate levels (i.e. increased traffic congestion in some neighbourhoods of the city. This would probably lead to a revision of the mechanisms by which the accessibility has been provided with respect to the spatial expansion of settlements and the daily engagement in urban activities (i.e. the possibility offered by the new communications technologies for substituting certain trips by other forms of interaction).
- Our representation of accessibility and the recognition that the kind of 'knowledge' individuals and decision-makers has about accessibility is a fundamental determinant in the use of the accessibility resource, as well as in the preservation and regeneration of the resource itself. One related problem is the risk that, in the current transition to a Post-Fordist urban development, a gap between different 'representations' of accessibility (i.e. in particular between those of the general public and decision-makers) might exacerbate 'accessibility needs', raising problems of equity and social justice. Improving information about accessibility, therefore, should be an essential component of any policy strategies since it can improve not only accessibility, but also social equity.
- The practical measurement of accessibility. A number of requirements have already been pointed out in the literature. Experience also indicates that some of these requirements may prove to be in conflict. The desire, for example, to define measurements, which are more theoretically acceptable, can be made impracticable by the lack of adequate information or even cause greater difficulty of interpretation. The kind of extensions of accessibility suggested in this note highlights

a paradox between the claim of a more comprehensive and holistic approach and the need for a more focused reduced one. Whereas this may shake our confidence in the possibility of developing 'one single behaviourally-based, policy-relevant and socially agreed measure', it emphasises the need for a frame of reference within which a variety of accessibility measures can be developed and compared. In this respect, we may ask whether NIT will provide the suitable 'environment' for such a framework. This certainly throws out a challenge for the analysis of accessibility.

**Key-words:** activity space, multi-level, Post-Fordist City, New Information Technologies (NIT), complexity

**References**

**Amin A.** (Ed.) (1994) *Post-Fordism*, Blackwell, Oxford.

**Bertuglia C.S., Occelli S.** (1995) Transportation, Communications and Patterns of Location, in Bertuglia C.S., Fischer M.M. and G. Preto (Eds.), *Technological Change, Economic Development and Space*, Springer, Berlin, 92-117.

**Castells M**. (1989) *The Informational City*, Blackwell, Cambridge.

**Casti J.L.** (1986) On System Complexity: Identification, Measurement, and Management, in Castii J.L., Karlqvist A. (Eds.), *Complexity, Language and Life: Mathematical Approaches*, Springer, Berlin, 146-173.

**Couclelis H**. (Ed.) (1996) Spatial Technologies, Geographic Information, and the City, Technical Report, 96-10, NCGIA, Santa Barbara, CA:

**Graham S., Marvin S**. (1996) *Telecommunications and the City*, Routledge, London.

**Handy S.L., Niemeier D.A**. (1997) Measuring Accessibility: an Exploration of Issues and Alternatives, *Environment and Planning A, 29,* 1175-1194.

**Occelli S**. (1998) Accessibility and Time Use in a Post-Fordist Urban System. Some notes for a Research Agenda, Paper presented at The International Conference on Time Use, Luneberg, April 22-25.

**Comments on the Asilomar Conference (S. Occelli):**

**Outcome of meeting.** Besides the publication of a book, I think that - within the Varenius Project - the creation of a Web site on accessibility would promote advancement in GIS. Although I am not an 'expert' on the Web, most web sites prove to be not informative. Building an accessible, manageable and really informative web site on accessibility, therefore, would be a challenge for both the analysis of 'virtual spaces' (i.e., to monitor access to the Web and to assess the performance of the accessed topic...) and for advancement in accessibility studies. In this direction, the book’s organization and ideas might provide a primary

backbone. To some extent the Accessibility Web site could be considered a natural continuation of the book (i.e., a place where some of the ideas suggested in the book can be realized, extended, tested, updated, and diffused).

In particular, I would be very interested in obtaining information about:

- the software packages aimed at 'visualizing' accessibility in urban and regional settings;
- methods/models for the 'description/measurement of accessibility'; and
- results of empirical applications.

**Reflections on the discussion.** The discussion was very broad and covered a number of relevant topics. However, the implications for the evolution of cities and spatial systems seemed to me rather neglected (or at least too optimistically superseded).

1. I believe that one major research theme is how 'virtual access' affects (facilitates/enables) 'spatial access', and how it re-shapes mobility and spatial behaviour of individuals and firms, within existing urban settings. The problem is how and to what extent the 'expected re-shaping' can improve the sustainability and quality of life, given the existing 'constraints' in various 'geographical areas' (characteristics of the built-form, transportation network, social fabric, institutional rules, and so forth).
2. A related research theme is suggested by the peculiarity of 'virtual access': its invisibility. In this direction, improving 'awareness' of opportunities for 'virtual access' seems to me a crucial issue (this is also linked with the questions of accessibility representations and modelling that I raised in my paper).
3. A final research topic is the fact that in a 'Post-Fordist' type of development, 'accessibility' should (probably) become a 'new' policy issue, from both a social (i.e., we should improve accessibility and not simply transport) and a management point-of-view (i.e., as a 'means' for co-ordinating different urban policies).

## The Rise of Digital Libraries and the Fall of Public Rights in GeographicData

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The balance in interests supported by current intellectual property laws in the US has made conventional libraries highly successful and valued social institutions. That balance has been disturbed by the shift to electronic publication and dissemination. The ongoing technological shift has placed the interests of the scientific and academic communities, entrepreneurial businesses, and the general public at a distinct disadvantage relative to the interests of publishers and large corporations with the ability to amass intellectual content. In order to support both fairness in access to data sets among all sectors of US society and continued economic vitality for the nation, the imbalance needs to be addressed. Solutions are not simple.

In the traditional publishing world, authors and publishers receive a level of protection sufficient to provide incentives for them to make their works available for purchase by individuals and libraries. Libraries, of course, lend out the books, maps, magazines, films and other intellectual works they purchase. Any man, woman or child is typically free to borrow material from the library without paying a per-usage fee and use the material for whatever purpose they see fit. No inquiry is made regarding their intended use. Upon returning the material, no record of who borrowed the material is maintained. The anonymity provided by the purposeful failure of the library to ask about use and failure to track the identity of users promotes free exploration of ideas and concepts without fear that one's exploration may be viewed as socially or politically unacceptable.

The ability to freely browse, study, explore, and borrow library materials provides a highly valuable common good upon which anyone may draw knowledge for any purpose. Communities financially support public libraries because all in the community may use the works contained in the library for educational, scientific, business, entertainment and other socially constructive purposes. After a library has purchased an intellectual work such as a book or map or has been given a copy that was legally obtained, neither the author nor the publisher can prevent the work from being placed in a library and lent. We do not support public libraries in order to reward authors and publishers. Indeed, many may object to their works being lent by libraries. Thus, the goal of copyright and the library as an institution has been to strike a balance between giving authors sufficient incentive to make their works available and supporting the rights of users to use the intellectual works of others for socially constructive purposes. A similar balance of interests has not yet been achieved in the on-line world.

Many in the digital library research community as well as the geographic database community appear to believe that the marketplace will "provide the answer" in resolving the relationships between public access and private rights in data sets. In this marketplace approach the library patron is treated primarily as a consumer with relationships primarily controlled through contract law principles. In acting on our own behalf we often do act as consumers. However, in acting on behalf of others we act as citizens (Sagoff 1992, 373). As citizens we decide through representative government "the right thing to do" rather than allowing economics solely to decide our fate. Our relationships are defined by responsibility as well as by efficiency (Gilroy and Wade 1992, 519). Considerations such as equity, justice and fairness

come into play through the political process. We admittedly live in an imperfect and unfair world. However, depending on economics and freedom to contract as the sole or even the primary means for ensuring access to knowledge in future digital library environments will exacerbate current inequities, not lessen them.

This paper explains why we do not have on-line the equivalent of a traditional library from a legal rights perspective and why the public commons in intellectual property traditionally provided by libraries is in jeopardy for both the scientific community and the community at large. The evolving social situation is primarily will want access to bodies of intellectual work from future digital libraries as opposed to "correct" or "reliable" answers automatically fed to them from the system (Murr and Williams 19xx). Some of the options to correct the current imbalance in private versus public rights in digital library works are explored and the argument is made that a pressing need exists to explore a full range of economic, legal, and institutional models and prototypes for geolibraries. The research community's goal should be to develop models that will support the public goods benefits of traditional libraries while providing sufficient incentives for private individuals, private publishers, and government publishers to make their spatial data products available through networked library environments.

# APPENDICES

## CALL FOR PARTICIPATION

### Varenius: NCGIA's Project to Advance Geographic Information Science

### *Measuring and Representing Accessibility in the Information Age*

A Meeting of Specialists

Asilomar Conference Center, Pacific Grove, California, 20-22 November 1998

Concepts of potential and realized interaction and accessibility are central to geographic theory and models. Current models are based, however, on physical notions of distance and connectivity that are insufficient for understanding new forms of structures and behaviors characterizing an information age. Accessibility and spatial interaction in the traditional physical sense remain important, but information technologies are dramatically modifying and expanding the scope of these core geographical concepts. Through technological, structural but also social developments, an increasing range of transactions takes place in virtual space, or in some new hybrid space combining the physical with the virtual. Of importance also is the influence of new forms of communication on the use of and investment in traditional transportation infrastructure. Moreover, just as space can be fragmented so too can time, as activity rhythms in one place become increasingly synchronized with those in distant places. Geographic information science and technology, themselves products of this new information age, potentially have a major role to play in helping reconceptualize, measure, represent, monitor, and plan for the new emergent geographies.

Accessibility, both *within* and *to* communications and transportation networks, is the central concept in the geographic definition of opportunity. Since humans communicate continually as a part of knowledge building and social interaction, gaining access to a computer is equivalent to changing one's accessibility within the broader flux of society. Since the information age has not made the information society ubiquitous, it is essential that geographical and planning models incorporate measures that reflect restructuring of geographical space and space-time differentials in accessibility to virtual networks. Models of how institutional and other contingencies influence who has access to whom, what, when, and where, via physical and especially via virtual contact, are also required for assessment of policy approaches to reduce inequalities in opportunities for social and economic interaction. Analytical measures and computerized visualizations of accessibility are needed to reflect hardware and software availability, inadequacies of education and training, cultural factors, and differential relevance of the Internet to everyday life. Such measures and representations of accessibility will contribute insights and reference points for judging efforts to mitigate the perpetuation of 'information poverty' for certain places and social groups.

This specialist meeting will examine how geographic information science can assist research into the geographies of the information age. By helping to reconceptualize

accessibility through appropriate representations of accessibility opportunity and inequality, this Varenius initiative seeks expanded models of space (and time) that encompass both the physical and the virtual.

Some of the **key questions** that require consideration follow:

- What are the information age counterparts to the accessibility and potential surfaces developed for interaction in physical space?
- What space-time topologies need to be developed to accommodate both the physical and virtual worlds?
- How do emerging conceptions of virtual space map onto traditional conceptions of geographic space and how do we handle their interfaces analytically?
- How can interactions and accessibility gradients within these new hybrid spaces (and space-times) be represented and visualized within GIS?
- How useful are traditional spatial interaction and urban computable general equilibrium models for the analysis of the new forms of accessibility? How should they be altered?
- What are the technical and societal impediments to network access in different social domains, particularly for geographic information?
- What representations can highlight patterns of lack of access independently of the lack of interaction?

The **goals** of plenary and small-group sessions will be to:

- identify and demonstrate conceptual and analytical approaches for accessibility research in the information age,
- review and demonstrate possible contributions for GIS in representing geographies of the information society,
- formulate an agenda for continuing research and research proposals to be assisted in part by Varenius seed grants,
- establish a communications network of accessibility researchers, and
- organize reports and publications from papers and presentations.

This specialist meeting is sponsored by the Varenius project, with funding from the National Science Foundation. Varenius is a project of the National Center for Geographic Information and Analysis (NCGIA), and seeks to advance geographic information science through research to extend our understanding the three strategic areas: Cognitive Models of Geographic Space, Computational Implementations of Geographic Concepts, and Geographies of the Information Society. Varenius is a three-year project, and is described in greater detail in materials available at the NCGIA Web site **http://www.ncgia.ucsb.edu**.

**Proposals to participate in this specialist meeting should consist of three parts:**

1. a one-page indication of why you want to participate in the meeting and what you would contribute, and a commitment that, if your proposal is accepted, a formal research paper will be prepared for distribution to participants two months prior to the meeting,
2. a 750-word abstract of your intended research or position paper, and
3. a one-page curriculum vitae with up to five (5) selected publications most relevant to the topic. Completed proposals should be sent to one of the co-leaders by 1 May, 1998, in both hard-copy and email formats (ASCII or WORD).

Notices of acceptance and travel awards will be issued on 1 June 1998. All submissions will be reviewed by Initiative co-leaders and by the Steering Committee. Participation will be limited to 25-30 people, and will be by invitation only. The project will reimburse reasonable travel and accommodation costs for participants. Please include a quote of lowest available airfare in your application. Funded foreign participants must use U.S. air carriers and meet immigration/visa requirements.

**Please direct requests for information and proposals to the project co-leaders:**

- **David Hodge**, College of Arts and Sciences, University of Washington, Seattle, WA 98195-3765
- **Donald Janelle**, Department of Geography, University of Western Ontario, London, Ontario N6A

**Conference steering committee:**

- **Michael Batty**, University College London
- **Helen Couclelis**, University of California, Santa Barbara
- **Arthur Getis**, San Diego State University
- **Harvey Miller**, University of Utah
- **Mark Wilson**, Michigan State University

**CONFERENCE PROGRAM**

A VARENIUS SPECIALIST MEETING:

**MEASURING AND REPRESENTING ACCESSIBILITY IN THE INFORMATION AGE**

Pacific Grove, California

19–22 November 1998

**THURSDAY evening, 19 November**

**Dinner and Introductions**

**FRIDAY, 20 November**

**Opening Session (Oak Shelter)**

- **Michael Goodchild** GIS and Varenius
- **Eric Sheppard** Varenius and Geographies of Information Society
- **David Hodge** Workshop Objectives
- **Donald Janelle** Post Workshop Objectives

**Conceptualizing and Measuring Accessibility in Physical (Geographical) and Virtual Worlds (Space)**

- Session Leaders: **Helen Couclelis and Arthur Getis**
- Panelists: **Pip Forer, Eric Heikkila, Otto Huisman, Lauren Scott, and Qing Shen**

**Breakout Groups I** (Oak Shelter, Forest Lodge Living Room, and Acorn Room)

**Plenary Reports/Discussion—Breakout Groups I**

**Visualizing and Representing Information Space within GIS**

- Session Leaders: **Michael Batty and Harvey Miller**
- Participants**: Paul Adams, Martin Dodge, Mei-Po Kwan, Shane Murnion, Daniel Sui, and Anthony Townsend**

**Breakout Groups II (Oak Shelter, Forest Lodge Living Room, and Acorn Room)**

**SATURDAY, 21 November:**

**Plenary Reports/Discussion—Breakout Groups II**

**Societal Issues informing the Measurement and Representation of Accessibility in the Information Age**

- Session Leaders: **Mark Wilson and Eric Sheppard**
- Participants: **Susan Hanson, Andrew Harvey, Paul Macnab, Sylvie Occelli, Robert Mugerauer, and Harlan Onsrud**

**Breakout Groups III**

**Plenary Reports/Discussion - Breakout Groups III**

**Plenary Session—Research Agenda and Publication Plans** (Reviewing Objectives and Plans for Sunday)

- Session Leaders: **David Hodge and Donald Janelle**

**Exploring Asilomar: Beach and Forest OR Demonstrations of Innovative Tools for Accessibility Research**

**SUNDAY, 22 November:**

**Outcomes and Prospects (Oak Shelter)**

- Session Leaders: **David Hodge and Donald Janelle**

**Summation on Research Themes**

- **Helen Couclelis and Arthur Getis**
- **Michael Batty and Harvey Miller**
- **Mark Wilson and Eric Sheppard**

**Research Seed Grant Proposals**

**Publication Plans**

**Communication Plans**