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Research Article

Data-gathering strategies for social-behavioural research about participatory geographical information system use

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Abstract. Studies about geographical information systems (GIS) use contribute to geographic information science through critical evaluation of the concepts embedded in GIS tools. Social-behavioural studies about group use of GIS help us to understand the social implications of GIS because groups are fundamental units underlying intra-organizational, organization-wide, and inter-organizational activity in society. When group communication technology is integrated with basic GIS capabilities an enhanced version of GIS called 'participatory GIS' (PGIS) is created. Group use of PGIS technology can be studied by sampling social-behavioural events during human–computer–human interaction. Social-behavioural research about PGIS use requires an informed balance among three research domains—substantive, theoretical, and methodological—if we are to make balanced progress in participatory geographical information science associated with the critical evaluation of GIS use. In this paper, we draw from our research on GIS-supported collaborative decision making about land use and resource planning and a conceptual framework called Enhanced Adaptive Structuration Theory. We develop a new framework for understanding choices among data-gathering strategies for social-behavioural studies about PGIS use. The framework for data-gathering strategies is composed of two dimensions. One dimension is the level of induced control in social-behavioural relations during GIS use in a research setting. The other is the amount of pre- or post-structuring of variables embedded in data-collection techniques. Several common data-gathering strategies, e.g. laboratory experiment, field experiment, case study, and field survey, are differentiated in terms of those dimensions. Objectives for empirical research are used to compare and contrast the data-gathering strategies. This framework helps researchers understand the trade-offs among various data-gathering strategies as the core of research designs for critical evaluations of PGIS use.

1. Introduction

Groups are said to stimulate and direct change both within organizations (McGrath 1984, Poole 1985) as well as among organizations (Gray and Wood 1991, Wood and Gray 1991, Duffy *et al.* 1996). Many changes, for example, those involving

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implementation of public-private policies about land planning, become mired in controversy (Popper 1981, 1992, Lake 1987, Healey 1995). Dealing with locational conflict in an open manner is becoming more important as citizen (stakeholder) participation increases in land use, natural resource, and environmental decision making (Crowfoot and Wondolleck 1990, Gregory 1999, Wondolleck and Yaffee 2000). The primary rationale for enhanced stakeholder participation in land planning is based on the democratic maxim that those affected by a decision should participate directly in the decision-making process (Smith 1982, Parenteau 1988, Moote *et al.* 1997).

Over the years geographical information systems (GIS) have been used to support land decision making in a rudimentary (indirect) way, usually as a tool in the hands of analysts passing the information to decision makers. There is a growing trend that indicates that GIS technology is likely to get used in a more direct and strategic way by groups in various parts of the public-private decision-making process. More and more GIS information is proving to be useful to both decision makers and stakeholders (Armstrong 1993, Faber *et al.* 1994, 1995, Nyerges and Jankowski 1997, Obermeyer 1998).

Basic GIS capabilities (i.e. data management, spatial analysis, and map display) have been used to generate various types of geospatial information structures for group interaction, since maps are commonly conversation generators. Recently, GIS have been enhanced with group-based communication capabilities, e.g. group-based map review and editing (Jones 1997, Shiffer 1998) and voting tools for consensus building (Jankowski *et al.* 1997). These types of capabilities encourage researchers to qualify the naming of GIS as 'participatory GIS' (PGIS). PGIS refers to systems that address the needs of people concerned with group participation (Harris *et. al.* 1995, Nyerges *et al.* 1997, Obermeyer 1998, Sheppard *et al.* 1999). In the future, we expect that PGIS will include capabilities such as those proposed for spatial understanding and decision support systems (Jankowski and Stasik 1997a, 1997b, Moore 1997), and map-based argumentation and mediation (Rinner 1999). Such technology is being developed to assist participants with issue management and group-oriented decision analysis carried out during analytic-deliberative investigations of complex, unstructured problems such as those dealing with community, risk-oriented land problems (Stern and Fineberg 1996). Whether such analytic-deliberations support 'data wars' (Kraemer and King 1987), where one side might be disadvantaged or look bad if they do not have technology (Obermeyer and Pinto 1994); or whether such analytic-deliberations are in fact technically, economically, and morally useful remains to be seen. The issue of group use of GIS is very much a part of the concern about the implications the use of GIS has for society. Such concerns are part of the need for critical evaluations of GIS use, particularly in group settings. For the remainder of this paper, reference to GIS is assumed to include PGIS technology.

As we strive to understand the social-behavioural implications of advanced information technologies, studying the use of GIS is as important as developing the technology itself. Furthermore, we find it important to clarify that research 'about GIS use' is different from 'research using GIS'. The former assumes that GIS capabilities are part of the substantive issues to be studied; whereas in the latter, GIS capabilities are taken to be part of the methods employed. Although the two views are related, there is a significant difference. Studies about GIS use are intended as critical evaluations of GIS concepts as much as they are evaluations of tools. Such studies contribute to the advancement of GIScience (Fisher 1998). Using GIS without critical evaluation does not advance GIScience. Anecdotal evidence about the uses

of GIS, although good for sharing experiences and telling stories, has not been sufficient to understand the complexity of how GIS technology is intertwined with social, economic, and political power structures. Without critical evaluations of group use of GIS based on systematic social-behavioural research, poor technology designs are likely to be reproduced again and again having (sometimes unintended) social implications for efficiency, effectiveness and equity in group settings (Pickles 1995, 1997, Fisher 1998). Without a systematic approach to researching GIS use, stories and experiences are difficult to integrate. Consequently, such stories and experiences are less likely to support accrual of 'knowledge about use' as part of geographical information science.

The purpose of this paper is to articulate a social-behavioural-based 'methodological turn' in GIScience that promotes systematic, critical evaluations of how people use GISystems in group settings. To do this we develop a framework that enables us to compare and contrast data-gathering strategies. A data-gathering strategy establishes an approach to data-collection within social-behavioural studies about PGIS use. In our approach, these studies are about human–computer–human interaction (HCHI). In this paper, data-gathering strategies establish an opportunity for data analysis of the social-behavioural aspects about HCHI. Furthermore, we focus on data-gathering strategies as the prerequisite to data analysis. Consequently, we do not discuss the results of empirical research or corroboration of research findings, as they appear elsewhere (Jankowski and Nyerges 2001a, 2001b). Instead, we focus on the trade-offs and choices among data-gathering strategies. We suggest why one strategy is better than another given the objectives a researcher has for different types of social-behavioural evidence to be used in the interpretation of findings. As we contribute to this 'methodological turn', in the same sense as a 'theoretical turn' referred to by Pickles (1997), we elucidate the connection between GIS viewed as a technology (tool) and GIS viewed as geographical information science, a connection suggested by Fisher (1998) in response to the views of separation (Pickles 1997, Wright *et al.* 1997a, 1997b, Goodchild *et al.* 1999). Making such turns in the context of PGIS use helps us take a step toward developing a 'participatory geographical information science' as part of geographical information science.

The relationship between GIScience and GISystems has been described as a cyclic process composed of concept development, implementation, testing, and refinement wherein concepts that are embodied in systems are tested using critical evaluation of GISystem use (Fisher 1998). In this paper we further elucidate the critical evaluation relationship between GIScience and GISystems based on a correspondence among three research domains—substance, theory, and methodology. Brinberg and McGrath (1985) explain how a correspondence among those domains is what motivates, directs, and eventually provides opportunity for verifying validity claims made with regard to a social-behavioural research endeavour. Recognizing an emphasis in the correspondence among those domains helps one to understand the character of alternative research strategies for social-behavioural research in general, and studies about PGIS use in particular. Understanding the correspondence among domains and the implications for research strategies can help link research about GIS tool development (Densham *et al.* 1995) with research about social-behavioural implications of tool use (Pickles 1995, Sheppard 1995).

A deepened understanding of this issue fosters a way to implement the synthesis between the seemingly polar perspectives of tool development (i.e. constructionist) and critical social theory (i.e. deconstructionist) research (Miller 1995). Such a

synthesis fosters a reconstructivist perspective, accommodating both tool development and tool critique simultaneously (Orlikowski 1992). In promoting a reconstructivist perspective, we move beyond a substance versus theory versus methodology debate to show how each research domain is in some way dependent on the other, permitting us to come away with a new sense of research possibilities. Although we discuss all three research domains in this paper, our contribution is intended to be methodological in character as we consider choosing data-gathering strategies given a particular set of research questions. However, we treat theoretical and substantive concerns to complete the discussion.

To articulate a framework through which we elucidate choices and data-gathering strategies for studying group use of PGIS, this paper proceeds as follows. In section 2 we adopt Brinberg and McGrath's (1985) perspective on a social-behavioural research process. It consists of three stages of research, with each stage being a balance among three research domains. We use that perspective to explain challenges in social-behavioural research as they apply to group use of PGIS, and then present a framework for choosing among data-gathering strategies. In section 3, the framework allows us to examine the trade-offs among data-gathering strategies for addressing premises (hence research questions) about group use of PGIS. The final section concludes the paper with a reflection about using mixed-method research strategies.

2. Frameworks for social-behavioural research as critical evaluation of PGIS use

Research is a process during which there are many pitfalls and traps that direct and constrain the character of empirical findings. In this paper we adopt a perspective presented by Brinberg and McGrath (1985) that a research process, particularly an empirical one, consists generally of: (1) planning the research , (2) doing the research, and (3) making a case to verify the results. These three stages describe research as a process of having an idea of what you want to do, following through on that idea, and then assessing whether the evidence makes sense within a body of literature by comparing findings.

Planning a research study is a matter of making choices to compose a research strategy. Important choices include research problem articulation, data-gathering strategy, data analysis strategy, and reporting strategy. Clearly, research problem articulation sets a stage for what research is pursued, and we will treat this issue in a general way below as a matter of 'research orientation'. This paper focuses on choices for data-gathering strategy. Choices can constrain an analysis strategy to develop evidence, and subsequently influence a reporting strategy about findings.

To help unravel some of the seeming complexity of choosing a suitable data-gathering strategy, we further borrow from Brinberg and McGrath (1985) who emphasize the need for balance among three research domains: substantive, conceptual (theoretical) and methodological. The different domains are positioned in lead, supporting, and focusing roles. When the conceptual domain leads we say the research has a basic research orientation. When substance leads it is an applied orientation. When method leads, the research has a methodology-driven orientation. Thus, theoretical, substantive, or methodological research problems are elucidated as a matter of which domain leads to set orientation. Nonetheless, although a lead domain sets the emphasis, and hence the orientation of the research (problem), we should remember that all three domains are important in the balance. Without a contribution from each of the three domains to some sufficient level in that balance,

a study (or research proposal) could be considered incomplete, or at best only a partial study (proposal), left open to criticism.

In detailing the three research domains, like Brinberg and McGrath (1985), we recognize three levels (here we call them abstraction levels) for treating what is at issue in each of the domains. The levels of abstraction are elements, relations, and embedding context (the latter referred to by Brinberg and McGrath as 'embedding systems'). Table 1 provides an example about land redevelopment for discussion. A key concern in research is how to compose a correspondence between relations from domain to domain in a pairwise manner, hence, conceptual–substance, substance–method, and conceptual–method. If we are to 'plan on' attaining valid findings in a study, we posit that a good research design should specify what relations (and embedded phenomenon) in the substantive domain must correspond with what relations (and embedded constructs) in the conceptual domain, and those both must correspond to methodological relations (and embedded variables) that we use to motivate data collection.

In the subsections to follow, based on the need for a balanced emphasis among domains, we treat each of the levels of abstraction for each of the substantive, conceptual and methodological domains. This helps us set up a framework for choosing among data-gathering strategies. We note that the sequence of domain presentation emulates how we have been conducting research related to the use of PGIS over the past few years.

2.1. *Substantive domain—peculiar to place and time*

A substantive context is needed to ground theory and methodology for studies about group use of GIS. So, we review the substance of our own research to provide context for what comes later in the paper. In our research we have been concerned with public-private problems related to land use, environmental clean-up, salmon habitat redevelopment, transportation planning, and health planning in the Pacific Northwest, USA.

Three of the most significant substantive *elements* are problem-topic, people, and information technology. In all studies we have adopted realistic problem-topics as the focus of our substantive domain. In land-use planning we dealt with land-use scenarios for Latah County in Idaho, whereby students as interested and affected parties configured a land-use plan (Jankowski and Stasik 1997a, 1997b, Stasik 1999). For environmental clean-up we have been examining decisions about remediation efforts at the Hanford, Washington Reservation and how decision makers, technical specialists and interested and affected parties take part in the process (Drew *et al.* 2002). We have examined decision making about habitat redevelopment in the Duwamish Waterway in Seattle, Washington in the context of multiple stakeholder concerns (Jankowski *et al.* 1997, Nyerges *et al.* 1998a, Jankowski and Nyerges 2001a, 2001b). In transportation planning we have been dealing with transportation improvement decision making for the central Puget Sound area as concerns local, regional, and state decision analysts (Nyerges *et al.* 1998b, Jankowski and Nyerges 2001b). For health planning we have examined how decision makers allocate funds for primary health care at the county level in the State of Idaho (Jankowski and Nyerges 2001b). To address the above problems, the participants have used geographic information technology as the third element that underpins our substantive interest. Since we are using social-behavioural methods to critically examine GIS use, the GIS technology and methods become part of the substantive domain. All

Table 1. Levels and domains for characterizing social-behavioural research about land redevelopment activities making use of PGIS.

Abstraction levels	Research domains		
	Substantive	Theoretical (conceptual)	Methodological
Elements (e.g. actors, information technology, and/or land parcels, etc.)	Land redevelopment projects as land parcel locations (sites and situations) across the urban landscape as viewed by stakeholders (organizations, groups, etc.) and the information technology they use to make decisions	Categories of demand and supply for land in specific areas; human values for land described in terms of the constructs and aspects within Enhanced Adaptive Structuration Theory (EAST)	Treatment modes for land use analysis as viewed in terms of social-behavioural information developed through use of geographical information technology
Relations (e.g. human behaviours with information technology and/or competition among sites, etc.)	Projects in relation to each other as competing locations, use activities, and/or times for investing funds, e.g. other projects in other areas as in suburban areas or manufacturing versus commercial, and how stakeholders interact to negotiate and create the values	Growth and decline of economic values for land and its impact on demand and supply of land for development; potential best uses of land among choices as described in terms of propositions in EAST	Social-behavioural analysis of the stakeholders performing GIS analysis as land use modelling, researchers making use of qualitative and quantitative techniques to uncover the process of social-behavioural information use
Embedding context (e.g. organizations and/or urban area context, etc.)	The urban area context as competing sub-areas, the regional and national market as competing investment opportunities, plus the organizational connections to information technology (e.g. GIS analysis, archival analysis, computer simulation modelling) used in promoting an understanding of the context	Financial (risk) investment theory; land use theory in growth management context, together with governmental instruments; marketing and finance in local government; as socio-technical and social structures characterized by EAST (see figure 1)	Potential social-behavioural data strategies might include, e.g. usability test, laboratory experiment, experimental simulation, case study, field experiment, field survey

of the participants in the decision situations described above incorporated GIS directly or indirectly into their decision processes. The level of technology and methods has differed across the various decision situations. Some of the GIS technology has been commercial off-the-shelf, whereas other GIS technology has been experimental prototype.

Relations among the people and the technology can be understood as the human–computer–human interaction that occurs in decision situations on a project-by-project basis. Interaction, viewed as increasing participation commitment, takes the form of communication, cooperation, coordination, and collaboration. We are interested in the dynamics of those participatory processes, and how GIS technology plays a role in those processes relative to the types of problems we are studying.

The *embedding context* for the public-private problems in the Pacific Northwest, USA is the place and time situation for participatory activities of an inter-organizational character. The local culture of place is very much a part of the embedded contextual relations in the substantive domain. Organizations and their bureaucracies together with social norms help structure the planning situations in the Pacific Northwest. Given the nature of the problems of our interest, we are very much aware that inter-organizational decision making cuts across a variety of scales. It is important to recognize that a multitude of socio-political relationships exist among people in groups, groups in organizations, organizations in communities, and communities in society, whereby actors at any level can act as agents of change.

2.2. *Theoretical domain—enhanced adaptive structuration theory*

In the theoretical domain, choice of a theory (or building a theory) for articulating human–computer–human interaction provides a way of systematically interpreting how people make use of GIS in a problem context. The conceptual elements and relations of a theory are systematic abstractions of the elements and relations of the decision situations in the substantive domain—the pairwise correspondence to which we referred earlier. In our work we started with Adaptive Structuration Theory (AST) to provide a framework for studying group decision making in an organizational context (DeSanctis and Poole 1994). AST consists of a set of eight constructs (the *elements* of the theory) that outline significant issues for characterizing group decision making, and a set of seven premises that describe the *relations* among the eight constructs. Starting with AST as a conceptual foundation for our experimental research, we found it necessary to develop Enhanced AST (EAST) to frame systematic examinations of complex, inter-organizational collaborative processes that make use of GIS technology (Nyerges and Jankowski 1997). EAST further explicates the character of inter-organizational processes of AST for public-private contexts by treating 21 aspects of group decision making—the 14 of AST plus seven others incorporated from collaboration theory (Gray and Wood 1991, Wood and Gray 1991), participatory negotiation theory (Susskind and Field 1996), political negotiation theory (Kunreuther *et al.* 1983), and communicative action theory (Habermas 1984, Healey 1995). We have since added four more aspects from institutional rational choice theory (Ostrom *et al.* 1994). The result is what we now call EAST2 (figure 1). The dualistic 'structural' and 'agent of change' basis of EAST/EAST2 is the *embedding context* for the theory. Neither technological nor social character of an organization predominates in change—they work together to structure each other.

The eight constructs in EAST2, which are a mid-level grouping of the 25 aspects, are further organized for simplicity according to the major convening, process, and outcome categories. The reader should think of this framework as a 'task level' description, whereby each of the eight constructs might change with (or is relevant to) each task a group might address in a decision situation. As in AST, the seven premises in EAST2 represent fundamental relationships between pairs of constructs, and subsequently each one motivates one or more research questions (as for example

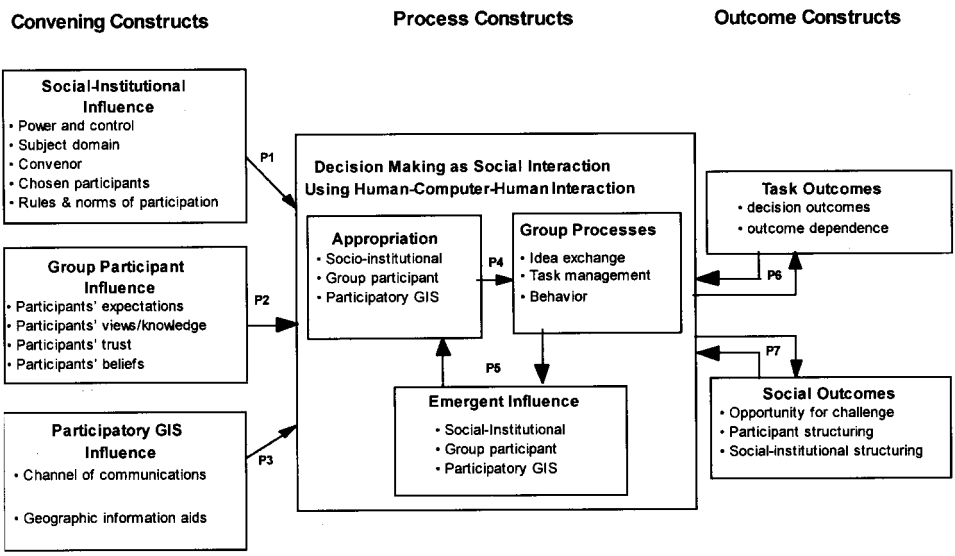

Figure 1. Enhanced Adaptive Structuration Theory 2 (EAST2) frames convening, process, and outcome constructs plus the respective propositions to provide a conceptual map for understanding a group decision support situation.

in table 2). The example research questions in table 2 have been articulated with reference to public-private land development as documented in the substantive domain of table 1. Such questions address the topics related to 'geographical worlds constructed by society' and/or the 'use of geographical concepts to think about geographical phenomena and make decisions about places' as suggested by Goodchild *et al.* (1999 p. 738). However, the premises of table 2 are of a general form such that the reader could develop research questions to suit their own topical situation related to use of PGIS. Whatever questions are used to motivate the research, nouns that detail constructs in the questions inevitably translate into variables for which data are collected (or not) using a choice of data gathering strategies as described in the following subsection.

The seven premises in EAST2, together with the respective example questions, indicate that a wide-variety of interesting, empirical research opportunities exist. Certainly, other theories could be used in the theoretical domain to motivate questions about PGIS use for land development. The point here is that this particular theory accepts technology, a problem, and participation as part of the substantive domain to be investigated. As such, EAST, and now its successor EAST2, is a contribution to 'taking the theoretical turn' in geographical information science that emphasizes the social-behavioural implications of GIS use. Addressing any one or more questions in table 2 calls for a systematic approach to critical evaluation of GIS use as pointed out by Fisher (1998) so that we can better understand how empirical findings relate to each other in our attempts to build knowledge about the implications of PGIS use. In a social-behavioural research study involving primary data collection about PGIS use, choice of a data-gathering strategy follows research question articulation, hence we consider it next.

Table 2. Example research questions motivated by premises in enhanced adaptive structuration theory 2.

Premises	Research question motivated by premise
Premise 1. Basic structures such as task goal, interaction norm, and/or meeting venue influence the appropriation of socio-technical capabilities to generate information structures.	How does each of four meeting venues influence the generation of number and type of information structures useful of understanding spatial criteria that can be processed with a GIS?
Premise 2. Participants' perspectives will influence appropriation of basic structures and various types of geographical information technology.	How do the different perspectives, e.g. those oriented to policy/decision maker, technical/scientific specialist, and interested and affected party, influence the types of geographical information structures appropriated?
Premise 3. Geographical information technology provides social-information structures that can be described in terms of their structural capabilities and spirit. To the extent that the technology varies in their structural capabilities and spirit, different forms of social interaction are encouraged by the technology.	What kinds of information technologies for generating information structures are appropriated over time through various meetings?
Premise 4. Appropriation of PGIS capabilities and the associated information structures influence the dynamics of social interaction during participatory activities.	What kinds of geographical information structures are appropriated during the different levels of social interaction (participation) that seem to facilitate an analytic-deliberative process and which information structures seem to hinder the process?
Premise 5. New information structures emerge as the technology, task, and environmental structures are applied during the course of social interaction, and these new structures in turn influence the dynamics of social interaction.	What new kinds of information structures are called for during a land redevelopment discussion and negotiation?
Premise 6. Given particular GIS technology and other structures, if specific appropriation occurs and decision processes fit task, then desired outcomes result.	Given that a group appropriates a particular type of information structure that has been found to be useful in the past, and if the information structure is appropriated during 'specific conditions', can we expect the outcome from the process to be satisfactory to all participant?
Premise 7. Aspects for convening a process and aspects of the process itself influence the emergence of new social structures reproduced in group interaction over time.	How do inter-organizational protocols and the social interaction during planning and decision making reproduce social structures among organizational representatives that promote or discourage further group work?

The construct and premise numbers here are ordered differently than in original AST. The premises are renumbered for presentation convenience to help with the flow of this discussion in terms of convening, process and outcome constructs. The renumbering does not change the explanatory power of (E)AST(2).

2.3. *Methodological domain—a social-behavioural perspective*

In the methodological domain, social-behavioural (research) settings and data-collection techniques combine to form a data-gathering strategy. The *elements* of the methodological domain are variables that make operational the pairwise correspondence to the elements in the substantive domain as well as the theoretical domain. Researchers select variables based on research questions relevant to the substantive and/or theoretical domain depending on which one has lead emphasis. The data observations that populate variables come about by implementing data-collection techniques associated with particular treatment modes within the context of a social-behavioural setting. Hence, setting provides an opportunity (as well as constraint) for use of treatment mode(s).

Variables can be assigned one of six treatment modes—fixed, partition-controlled, matched-controlled, measured, randomized, or ignored (Runkel and McGrath 1972)—as the basis of a data-gathering strategy. A 'fixed' variable establishes data for a specific unit of observation that will not change relative to the other variables. 'Partitioned-controlled' means that two or more variables have been established for different units of observation, and the variables are mutually exclusive. 'Matched-controlled' variables are those for which two or more units of observation have been established and the units overlap to 'match observations' among the variables. The variables are not surrogates of each other, but they are related to each other for the purpose of data analysis. 'Measured' variables are those whereby data are sampled from a freely changing set of potential observations—free at least in regards to an absence of researcher influence as much as possible. 'Randomized variables' are those for which data being sampled are equally at chance to be observed according to that unit of observation, as in any similar situation. 'Ignored variables' are those for which a researcher knows that a variable exists, but chooses intentionally not to do anything with the units of observations. Whenever a variable is not fixed, partition-controlled, matched-controlled, measured, or randomized, then it is ignored by implication. Unintentionally ignored variables sets up a greater chance of introducing confounding variables into an analysis and subsequent interpretation.

Assigning modes to all variables in a study, as encouraged (or constrained) by social-behavioural setting, is a foundation for research design. For our research, EAST2 helps us understand what mode to assign to a particular variable depending on the research question being posed (as in table 2). Practically speaking, the treatment modes are assigned for data collection in order to promote opportunities for data analysis. Consequently, each mode is applied according to the data units for the variables to be collected and subsequently analysed. As an example, the following treatment modes were used in a laboratory experiment about collaborative spatial decision making (Nyerges *et al.* 1998a, Jankowski and Nyerges 2001a). We 'fixed' a setting to be a Department of Geography decision laboratory wherein 109 participants made use of a prototype PGIS called Spatial Group Choice (Jankowski *et al.* 1997). The participants were involved in face-to-face interaction whose purpose was to choose which of 20 habitat sites to redevelop in an urban estuary. Group participation was 'partitioned-controlled' to be five-person groups (one group had four participants) with the same membership throughout the experiment. We applied 'match-control' to the five decision tasks to differentiate habitat decision situations for each group. This match-control established the exposure of participants to the number of sites (8 or 20) and the number of criteria (3 or 11); the four combinations thus defined tasks 1–4. In each of those four tasks, participants had individual access

to Spatial Group Choice software. In task 5, participants were exposed to a task with 20 sites and 11 criteria, hence matching task 4. However, participants had group-as-a-whole access to Spatial Group Choice software, thus differentiating task 4 from task 5 in terms of technology, but providing for matched-controlled comparison. For our dependent variables we 'observed' (measured through use of videotape coding) three types of data: coding the appropriation of decision aids to represent information use, coding decision functions to be used in determining decision phases, and coding group working relations to represent social conflict among participants. We 'randomized' assignment of participants to a group (hence expertise with habitat/geographical information that might have influenced outcomes). Finally, we ignored other factors such as gender bias/participation in groups and time of day on influence of interaction. A major advantage of laboratory experiments is that they are the most highly controlled of research designs when it comes to treatment modes.

In another example, we used fixed, matched-controlled, and measured treatments to compile data for examining process and technology within a (field) case study about regional transportation decision making (Jankowski and Nyerges 2001b). We fixed the treatment mode for the decision process as the 1999 transportation improvement programme. The match-controlled treatment mode was used to contrast various decision task steps throughout the decision process. We then measured (sampled) the mandates and groups in relation to the geographical information technology adopted for each of the match-controlled decision tasks. We were then able to perform a proposition analysis of information technology use within a regional transportation decision process—whereby each proposition was a specific construct-to-construct relationship to be tested.

As implied above, assignments of treatment modes have significant implications for the 'units of observation' that later become 'units of analysis'. From a substantive and theoretical perspective, when working in a social interaction setting it is important to differentiate the units of observation in terms of 'units of interaction' versus 'units of organization'. A unit of interaction is the sampling unit of (social-behavioural) interaction in terms of the activity of groups, whereas the unit of organization is the grouping of decision actors. Sanderson and Fisher (1994), working in the context of human–computer interaction, clearly point out that units of interaction range from cognitive acts of individual computer users, speech acts of individuals, speech acts directing group attention in meetings, meeting phases of groups, entire meeting sequences of a group project, through to studying a set of group projects over several years. Pasquero (1991) describes how different an inter-organizational level of interaction is from an organizational level of interaction. To a large degree the interaction differs in regards to 'information flow bureaucracy', a key factor in facilitating (hindering) information flow among participants.

Analysis is about establishing *relations* between elements (variables) in the methodological domain. Relations between variables in the methodological domain take their lead from either relations in the substantive domain or the relations in the theoretical domain depending on the research study orientation. In the context of our research, we first look to the substantive domain for interesting events that deal with geographic information, and then ask how the theoretical domain informs us about potential causality among the substantive elements. For example, we address human–computer–human interaction by examining how stakeholders might behave with each other as they consider map information structures as per premise 2 (in figure 1 and table 2). The relations in the methodological domain are implemented

in the form of social-behavioural data-analysis techniques that take advantage of the treatment modes assigned to variables as described earlier. We used difference in means and analysis of variance for the techniques that allowed us to compare the counts of map use and decision model use, plus the number of minutes in various decision phases and in group work conflict as detailed by Jankowski and Nyerges (2001a). The units of observations were gathered based on substantive and conceptual concerns. They were constrained by the structured and simplified nature of laboratory experiment as the principal type of data-gathering strategy we employed in the study.

As in the above example, opportunities for social-behavioural data sampling are part of the *embedding context* of a study. Such opportunities are what Brinberg and McGrath (1985) call research strategies, but we prefer to call such opportunities 'data-gathering strategies' because of the broader connotation for research strategy mentioned earlier. The important point, however, is that data-gathering strategy plays a major role in the *embedding context* of a research project because such a strategy establishes the plan for collecting social-behavioural data observations about PGIS use.

2.4. *An embedding context framework for critical evaluation of data-gathering strategies*

Comprehensive frameworks that compare and contrast data-gathering strategies for empirical social-behavioural research about advanced information technology use are few in number and lacking in providing a systematic approach (Runkel and McGrath 1972, Williams *et al.* 1988, Yin 1993, 1994, Zigurs 1993, McGrath 1995). McGrath (1995), based on his previous work in Runkel and McGrath (1972), uses a circumplex (pie-shaped framework of eight pieces) for comparing eight strategies one to another that can be applied in human–computer interaction research. The circumplex demonstrates the need to trade off research objectives; however, its dimensions are inconsistently labelled across publications (Runkel and McGrath 1972, McGrath 1982, 1995), and are therefore somewhat confusing. From a different perspective, Yin (1993, 1994) describes the use of a case study method, comparing it against three other approaches for evaluative research and offering ideas about trade-offs to be made that have implications for creation of research evidence. However, the discussion about the four strategies does not deal with the trade-offs in a systematic manner. Williams *et al.* (1988) get close to a systematic treatment, laying out a number of issues that must be considered, but fail to create a conceptual framework for understanding trade-offs. Zigurs (1993) presents a list of 18 strategies in the context of group support systems use, but provides little discussion of how they differ one from another so as to provide suggestions of when and why some are more suitable than others. Clearly, there is a need for a framework describing data-gathering strategies that is both comprehensive and systematic.

A data-gathering strategy (as an opportunity for data collection) is a choice within two dimensions (see figure 2). In one dimension, a range of social-behavioural settings is based on the amount of induced control a researcher has over social-behavioural relations. In a second dimension, a range of techniques for data collection is based on pre- or post-structuring variables in relation to the data-collection process. Together, settings and techniques act as opportunities as well as constraints on what data can be collected. McGrath's dimensions were: (1) universal versus particular behaviour systems (i.e. setting independent versus setting dependent behaviours); and (2) obtrusive versus unobtrusive recordings of behaviour. The

dimensions herein are thought to be better descriptions of researcher concerns, although universal/particular and obtrusive/unobtrusive still apply. We make use of settings, whereby behaviour may or may not be influenced by a researcher. We also make use of pre-/post-structuring of data collection, whereby researchers structure data concepts previous to data collection as in a survey instrument, or after data collection as in coding a videotape. In figure 2, the 'least pre-structuring' is meant to imply 'post-structuring'; since a researcher has a rich stream of observations that can be 'coded' in several ways. Surely, there is some pre-structuring in every data-collection technique, but the different amounts among the techniques are significant along the continuum depicted in figure 2.

Our data-gathering strategy framework describes a variation in research setting in terms of three fundamental types based on induced (or lack thereof) social-behavioural control. They are (1) laboratory setting, e.g. a decision support room used for controlled experiments, (2) field setting, e.g. an interagency meeting room used for decision-making meetings with researchers in the role of passive observers, and (3) a field laboratory as a cross between the previous two, e.g. an interagency meeting room equipped with experimental information structures (i.e. information tools) but this time with researchers playing the role of active observers. We would be remiss if we did not recognize that there are important micro variations on each, e.g. an engineering laboratory and a social-behavioural laboratory are meant to structure social-behavioural relations among participants in different ways with the former more controlled for software usability testing than the latter for social-behavioural studies. Field settings are as varied as the number of places of work—hence some settings are more structured than others. However, our main point here is that three settings can characterize sufficiently the variation in 'researcher-induced control over social-behavioral relations' in the setting—the underlying dimension of 'research setting' as shown in figure 2. What this means is that researchers structure laboratory settings. Participants at work, rather than researchers, socially structure field settings. Researchers and participants together structure the social behavioural relations that take place in field laboratories. A researcher must choose among these settings, or choose all three given enough resources, for any particular study depending on the resources available.

The second dimension of the framework makes use of Sackmann's (1991) methodological work on organizational culture that characterizes several data-collection techniques as a researcher's interest in 'data category pre-structuring'. Pre-structuring occurs based on a researcher's pre-existing conceptual framework about a topic, i.e. a structuring of variables (data concepts) for which to collect data that a researcher is 'locked into' when collecting the observations. The continuum she sets up ranges from most pre-structuring to least pre-structuring at time of observation. 'Least pre-structuring' can be thought of as *an opportunity for post-structuring* of the data observations through 'recoding', since sufficiently 'discursive or narrative' detail is available from a 'relatively' unfiltered repository of observations. Obviously, all observations have limits that are specific to place and time, so the difference is really a relative difference among the techniques. Using the underlying dimension of pre-structuring based on the work of Sackmann (1991) we array techniques from 'most to least pre-structuring' resulting in the following relative order—survey instrument, document coding, structured interview, group discussion, in-depth interview, and direct observation with unfiltered coding. We describe examples of the techniques to provide the reader with more insight about the reason for our ordering. As examples

of pre-structuring, both closed-ended and open-ended survey instruments pose directed questions devised from a researcher's pre-existing conceptual framework. A document code is usually assigned from a protocol of codes that develops (or at least is refined) while working with the document materials. Structured interviews have a direction in mind, but the interviewee has a chance to direct the conversation. The direction of group discussions is at the whim of the group. An interviewer in an in-depth interview usually lets a subject talk at will—although of course subtopic questions are prepared in advance. In direct observation, for example, using a video camera, little or no pre-structuring is involved as one observes whatever the camera captures. Of course, all of the data-collection techniques have some amount of pre-structure, but the amount is relatively different along the continuum. A researcher must choose among these techniques, or choose all of them given enough resources, for any particular study in order to collect the most appropriate data representing GIS use.

The bi-dimensionality of the framework sets up a choice among 18 different data-gathering strategies represented as the cells in figure 2. Rather than invent new labels for data-gathering strategies, we make use of the more popular ones that exist. Thus, not all of the cells are uniquely named, and not all of the cells are named with popular labels although the underlying opportunity for data gathering still exists. The two dimensions of the framework help us understand trade-offs among approaches to data observations. At the same time however, the dimensions establish a set of constraints on those trade-offs. For details of how each data-gathering strategy could be used in a research design we refer the reader to Runkel and McGrath (1972) who describe field survey, judgement task, computer simulation, lab experiment, experimental simulations, and field study; to Zmud *et al.* (1989) who describe field experiment; to Onsrud *et al.* (1992) and Yin (1994) who describe case study; and to Avison *et al.* (1999) who describe participant action design. Our purpose here is to examine the trade-offs in strategies, and not to lay out the details of each strategy in relation to research design (Jankowski and Nyerges 2001b).

3. Comparing data-gathering strategies for studying group use of PGIS

It is important to understand that no single strategy is better in general than any other strategy; as there are trade-offs to be made among various objectives for data collection in any particular study. Therefore, in this section we compare and contrast the strategies as a basis of the trade-offs, while keeping in mind that multiple strategies are needed in order to study comprehensively any particular human–computer–human interaction, particularly in the context of EAST2 as we discussed earlier.

Figure 2 suggests that strategies inherently differ based on a researcher's induced control of social-behavioural relations among participants and a researcher's pre-structuring of the data-collection constructs. Although those dimensions are the fundamentals, informing us that trade-offs concerning empirical results are likely, those dimensions potentially induce other implications for empirical findings that can be significant to a study. Those implications are (*a*) generalizability among actors, places, and times, (*b*) realism of a situation, and (*c*) precision in the measurements and controls of the constructs (see figure 2).

The implications are really 'objectives' for the potential evidence of a study. The objectives motivate a choice for one or more data-gathering strategies that lead to such evidence and subsequently, the findings that might be interpreted from such

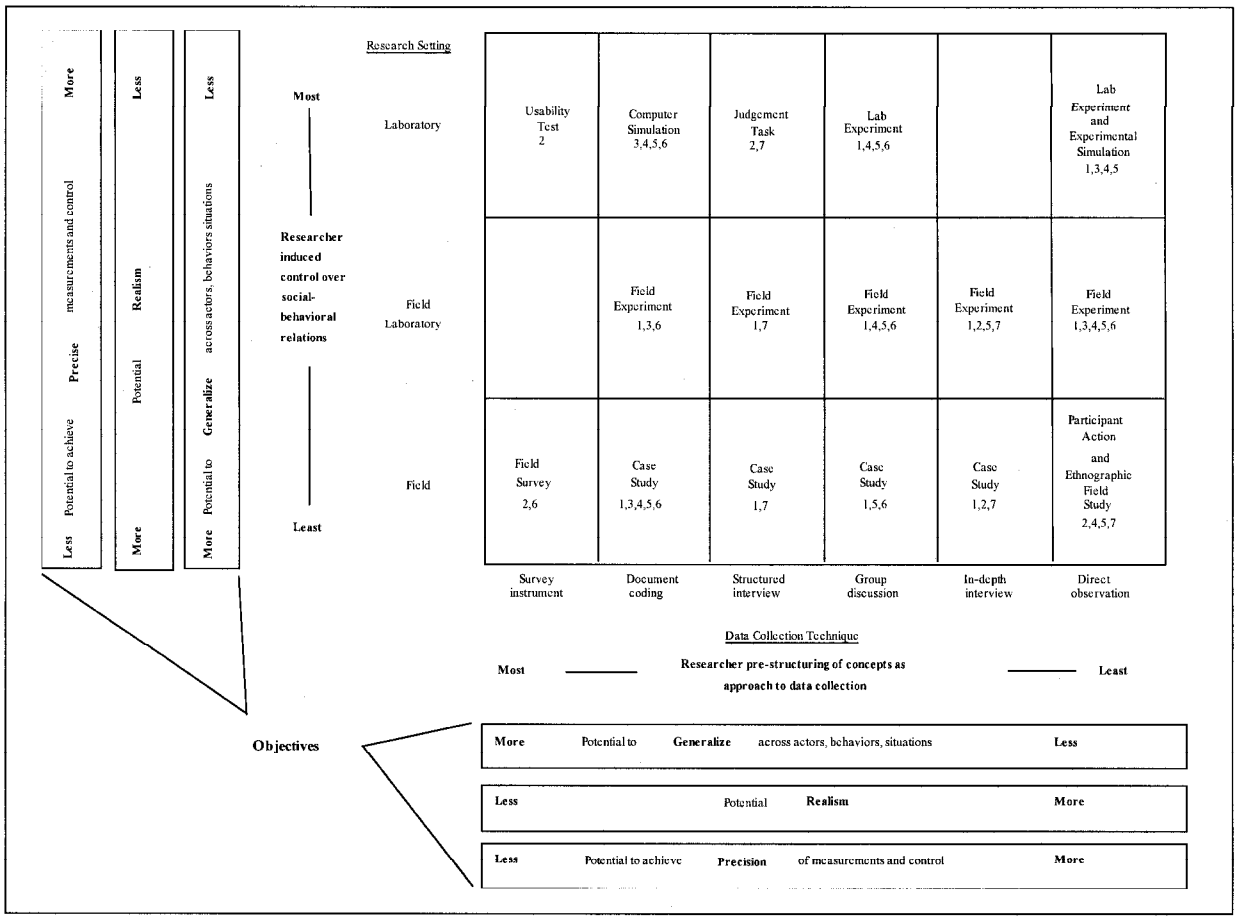

Figure 2. Data-gathering strategy is a choice among a combination of social-behavioural research settings and data-collection techniques. Research-induced control of social-behavioural relations underlies a difference in setting. Pre-/post-structuring of concepts underlies a difference in data-collection technique. Objectives for research findings motivate selection of certain data-gathering strategies. Each of the strategies can address one or more of the seven premises of EAST2 (from table 2). Numbers are placed such that a strategy is useful for capturing 'group attention' about the constructs (variables) appearing in research questions.

evidence. Generalizability of evidence is something to be sought such that research findings potentially apply across multiple actors (groups), multiple behaviours, and multiple situations (multiple places and/or multiple times). In fact, the pursuit of the notion of 'multiple' extends to all of the constructs in EAST2, not just actors, behaviours, and situations. Realism of evidence is something to be sought in order to claim that research findings potentially apply to 'real-world' circumstances. Having an influence on actual situations in the world (or at least transferability) is something sought by most funding agencies to show that research can make a difference to society. Precision and control of measurements (both quantitative and qualitative coding) for evidence are something to be sought such that research findings represent a potential detail that matters for specific situations. Having appropriate level of precision and control in data collection and social-behavioural relations provides some level of confidence that the research is addressing the research questions at an appropriate level of specificity to the situation under study.

The three objectives are inherently in conflict when taken together. A researcher cannot maximize all three objectives simultaneously when choosing a data-gathering strategy. When a researcher strives to maximize one objective, a researcher must forego maximizing at least one of the others, and thus make an important choice in relation to a trade-off in objectives for the evidence to be gathered. If a researcher intends a study to apply to many places and times, a researcher must forego some amount of realism and precision, assuming that we have available a certain level of resources for a study. For example, a field survey can 'potentially' provide data that are the most generalizable along each of the fundamental dimensions—induced control of relations and pre-structuring of data concepts. However, field surveys do not provide situation specific realism because participant responses are usually constrained by researchers to certain predefined categories, and because surveys are usually completed in settings where respondents are removed from the situations being studied.

A further difficulty is that trade-offs work differently in each of the two dimensions. Note that any given strategy in a cell position along both the social-behavioural relations and the pre-structuring of concept dimensions influences each objective in converse ways. For example, a field survey, associated with the most pre-structuring of concepts results in less realism because the instrument can be applied easily and systematically across populations. However, when a survey is implemented in a field setting, it can be generalized more because a researcher influences the social-behavioural relations the least. Such is the nature of the inherent trade-offs associated with objectives for research findings.

Thus, the power in the framework is that it helps researchers understand advantages and disadvantages of data-gathering strategies in terms of the objectives for data as evidence and the potential findings being sought. A major implication is that each data-gathering strategy results in a particular type of data to be collected, which is then made available for analysis. We would then expect the findings to be of a different character because of the inherent differences in the evidence with regard to the two principal dimensions of the framework. What this means is that researchers should vary their approaches to social-behavioural studies as a way to implement critical evaluation of PGIS use. No single strategy will be useful to gather data to inform us fully about all eight EAST2 constructs regarding PGIS use. The framework tells us which strategies are likely to be useful for what reasons as robust knowledge is likely to develop from multiple perspectives.

Based on our own research, we have identified the strategies that are most likely to help us pursue empirical research about the use of PGIS. We have assigned the premises of EAST2 (thus research questions of table 2) to the framework (see figure 2). The assignment of particular premises (research questions) to cells is based on whether a particular social-behavioural relation is important with regard to the way the setting induces control, and whether a particular data-collection technique can sample the interaction of 'group attention' in that type of setting. Group attention in this case is meant to represent a shared understanding of the situation. Notice that the assignment is not one premise to one strategy. When used in this way, the framework is useful for organizing discussions about the pros and cons of data-gathering strategies in terms of specific research premises/questions. Inspection of figure 2 shows that the number of the premises addressed by data-gathering strategies in the lower portion of the figure is greater than the number of premises in the upper potion of the figure. The difference is due to the influence of real settings addressed by field survey, case study, focus group, participant action, and ethnographic field strategies. In the top portion of the framework, representative of laboratory experiments and simulations, fewer premises appear because lab experiments make use of contrived settings, constraining the opportunity to collect a variety of data, but allowing fine-grained data collection. Between laboratory settings and field settings are field laboratory settings. McGrath (1995) argues that field experiments (as the research design based on a field laboratory setting) are not very useful because of the compromise in social-behavioural control. Zmud *et al.* (1989) argue that such settings are among the most valuable because one garners the best of both laboratory and field settings. Perhaps the answer is in the opportunity that presents itself, because of the difficulty of setting up such experiments together with the wealth of evidence that is gained (Zmud *et al.* 1989).

Further inspection of figure 2 suggests that some premises can be addressed by only a few strategies, whereas other premises can be addressed by many. Summarizing the information about premises to be addressed by strategies in figure 2 provides us with the information in table 3. When ranking the strategies from the most to least number of premises addressed by a strategy we see that case studies and field experiments can address all seven premises. This is true only because multiple data-collection techniques are required to collect all appropriate data. Along the bottom

Table 3. Premise investigation supported by data strategy.

	Premises							
Data strategy	1	2	3	4	5	6	7	total
Case study	x	x	x	x	x	x	x	7
Field experiment	x	x	x	x	x	x	x	7
Ethnographic field study		x	x	x	x		x	5
Laboratory experiment	x		x	x	x	x		5
Participant action		x	x	x	x		x	5
Computer simulation			x	x	x	x		4
Experimental simulation	x		x	x	x			4
Focus group	x				x	x		3
Judgment task		x					x	2
Field survey		x				x		2
Usability test		x						1
Number of strategies	5	7	7	7	8	6	5	

of table 3, the fewest number of strategies to address any particular premise is five, and no premise is addressed by all 11 strategies. This provides further indication that choices abound and these choices are likely to make a difference to research findings.

A detailed examination of what strategies are appropriate for what premises would consider the trade-offs in objectives for generality, realism, and precision in the context of a specific research project at hand. The placement of the premises is based on the projects we have undertaken. Position in the framework along the two dimensions shows what type of data we have been able to collect. In our own studies to date, we have conducted lab experiments and case studies. In a study about collaborative spatial decision making about habitat site selection we made use of a laboratory experiment strategy that provided data about group interaction with maps and decision models collected at a 1-minute resolution as coded from video tape (Nyerges *et al.* 1998a, Jankowski and Nyerges 2001a). The contrived, experimental setting was useful for examining process interaction in the group decision situation. The decision outcomes were less interesting because the task goal was contrived, even though we used a task that emulated an actual habitat restoration decision situation. In a case study about public health resource allocation across counties of Idaho, we examined the types of GIS capabilities that public health decision makers put to use; however, we did not have data about how such capabilities were used in the decision process to produce certain outcomes (Jankowski and Nyerges 2001b). In two case studies about transportation improvement decision making we used document coding to examine the potential for use of advanced group-based GIS capabilities, but again fine-grained interaction data about the process was not available (Nyerges *et al.* 1998b, Jankowski and Nyerges 2001b). In a case study examining risk factors in clean-up decisions about hazardous waste at Hanford, document coding provided data at a level of coarse granularity that was useful for describing the cyclic nature of decision chains, i.e. a sequence of decision point to decision point activity (Drew *et al.* 2001).

The above-mentioned studies encourage us to believe that certain types of research questions (generalized here as premises) are more fruitfully investigated using different data-gathering strategies, hence the purpose for systematically exploring that connection in this paper. We believe our framework offers a systematic progression from problem articulation to data-gathering strategy. However, the framework is not meant to 'optimize' for a particular strategy or a particular premise. That would be asking for more 'rigor' in the framework than it offers at this time.

4. Conclusion and prospects for research directions

The research reported in this paper is motivated by a challenge to connect substantive and theoretical research questions to data-gathering strategies in a more effective way. That connection contributes to a broad research agenda about PGIS use and the social implications such use has for society. To make that connection more systematic, we have sorted through the complex and sometimes confusing terminology related to social-behavioural research methods in order to tease apart the nuances of research strategies. Even some of the most complete treatments of social-behavioural research methods in literature (McGrath 1982, 1995, Brinberg and McGrath 1985) still leave room for a better articulation. It is better to develop a clearer sense of the connections between research questions and data-gathering

strategies in the planning stage rather than waiting until the research is underway, particularly when addressing problems that are complex and multidisciplinary.

It is clearer for us how social-behavioural data-gathering strategies provide a wealth of opportunities for pursuing empirical studies about use of GIS in general, and PGIS use in particular. Because all strategies have shortcomings, sorting through the choices of when to select a specific strategy is important. In this paper we developed a new view that has helped us compare and contrast data-gathering strategies as the basis for critical evaluations of GIS use. The framework can help researchers systematically employ nuances in mixed-method research strategies, whether the mix takes place in a single study or across multiple studies (McGrath 1982). Consequently, what we are advocating in this paper is the use of complementary data-gathering strategies to advance knowledge accrual about PGIS use through mixed-method research. We hope this view can help other researchers in formulating research strategies as well as in critiquing research strategies, even if PGIS use is not the chosen topic in the substantive domain. However, only time and research reporting will show which data-gathering strategies alone or in combination with various analysis strategies are the better ones for researching PGIS use as contributions to participatory geographical information science.

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