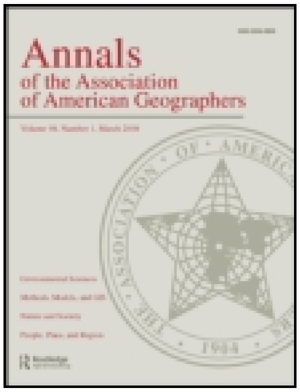

Annals of the Association of American Geographers
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/raag20

Public Participation in Analytic-Deliberative Decision Making: Evaluating a Large-Group Online Field Experiment

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Available online: 08 Apr 2011

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This article reports an evaluation of the quality and scale of interactions during an online field experiment. A large number of individuals ($n = 179$) worked with an online public participation geographic information system (PPGIS) platform during a month-long field experiment about regional transportation improvement decision making in the central Puget Sound area of Washington. The system platform logged more than 120,000 client–server interaction events. We developed a geovisual analytic technique called a *grapevine* to evaluate the quality and scale of public participation using event log data. The grapevine 4D space–time geographic information system (GIS) visualization helps distinguish productive clusters of analytic-deliberative process and for guiding content analysis of the user-generated discussion. Comparison of the nature and content of participant message exchanges before and after GIS-based analytic activities revealed a significant shift in focus. We characterize this shift in the focus of deliberation as the result of participants sharing their lay expertise, in the form of simplifying assumptions, to cope with the technical details of the GIS-based analysis and move the large group toward agreeing on a transportation package for the region. The article concludes by extending the implications of the research with a three-part framework called *participatory interaction modeling*, wherein geographically distributed networks of designers and developers, participant users, and social and behavioral science evaluators learn how to create PPGIS capabilities that can better address societal goals. *Key Words: analytic-deliberative, decision making, deliberation, PPGIS, public participation.*

本文报告一个在网上现场试验过程中互动的质量和规模的评价。大量的人员（n = 179）通过网上公众参与的地理信息系统（PPGIS）平台参与了中央华盛顿州普吉特海湾地区进行的关于改善区域交通的为期一个月的野外试验。该系统平台记录了超过 12 万客户端服务器交互的事件。我们制定了一个称为葡萄藤的地理可视化分析技术，以使用事件日志数据来评估公众参与的质量和规模。该葡萄藤四维时空地理信息系统（GIS）的可视化有助于分辨分析-审议过程的生产集群和指导对用户生成讨论的内容分析。对地理信息系统分析活动前后的参与者信息交流的性质和内容的比较分析，揭示了重点的显著转变。我们概括此考虑重点的转变是参加者为配合基于地理信息系统的分析技术细节和为了使大型团体在地区运输包装上达成共识，而分享他们的专业知识的结果。文章最后通过扩展由三部分组成的框架，既所谓参与性的交往建模的研究意义，总结在地理上分散的网络中，设计者和开发者，参与用户，社会和行为科学的评估者学习如何创建 PPGIS 的能力，以更好地解决社会目标。*关键词：分析-审议，决策，审议，PPGIS 的，公众的参与。*

En este artículo se informa sobre una evaluación de la calidad y escala de las interacciones registradas durante un experimento de campo a través de la web. Un gran número de individuos ($n = 179$) trabajaron en red con la plataforma de un sistema de información geográfica de participación pública (SIGPP) durante un experimento de campo de un mes de duración, acerca de la toma de decisiones para mejora del transporte regional en el área central del Puget Sound del estado de Washington. La plataforma del sistema cargó más de 120.000 eventos de interacción cliente-servidor. Utilizando datos de eventos de entradas, desarrollamos una técnica analítica geovisual denominada *grapewine* ("viña") para evaluar la calidad y escala de la participación pública. La visualización espacio-tiempo 4D de *grapevine* del sistema de información geográfica (SIG) ayuda a distinguir aglomeraciones productivas de proceso analítico-deliberativo y a guiar el análisis de contenido de la discusión generada por el usuario. La comparación de la naturaleza y contenido de los intercambios de mensajes del participante antes y después de las actividades analíticas basadas en SIG revela un cambio significativo de foco. Caracterizamos este cambio en el foco de la deliberación como el resultado de la

Annals of the Association of American Geographers, 101(3) 2011, pp. 561–586
Initial submission, August 2009; revised submissions, January and April 2010; final acceptance, April 2010
Published by Taylor & Francis, LLC.

decisión de los participantes de compartir su experticia de legos en forma de suposiciones simplificadoras, para competir con los detalles técnicos del análisis basado en SIG y mover al grupo mayor a concordar sobre el paquete de transporte para la región. El artículo concluye extendiendo las implicaciones de la investigación con un marco tripartita denominado *modelado de interacción participativa*, en el cual las redes de diseñadores y desarrolladores distribuidos geográficamente, usuarios participantes y evaluadores de ciencia social y comportamental aprenden cómo crear capacidades SIGPP que puedan aproximarse mejor a las metas de la sociedad. *Palabras clave: analítico-deliberativo, toma de decisiones, deliberación, SIGPP, participación pública.*

Many federal, state, and local laws mandate public participation in decision making about long-range planning, capital improvement programming, or major investment studies when public funds are involved (Federal Highway Administration 2005). For years, researchers have been evaluating public participation in decisions about transportation, the environment, and other publicly oriented situations and reporting mixed results about whether meaningful and diverse interactions among the diverse lay public, technical experts, and decision executives occurs or whether it is just the standard pro forma public meeting (e.g., see Steger 1974; National Research Council 1996; Renn, Blattel-Mink, and Kastenholz 1997; Webler and Tuler 1998). The Social-Behavioral Science Committee of the National Research Council (NRC 1996, 2005) performed a synthesis of research from the past fifteen years about public participation in environmental decision making and concluded that meaningful and diverse participation in decision making is possible when using a conceptual model of best practice called the *analytic-deliberative process* (NRC 1996, 2005; Renn, Blattel-Mink, and Kastenholz 1997). The term *meaningful* implies a three-way interaction among technical experts, decision executives, and the lay public characterized by a high level of factual competence and a high level of shared understanding (Renn, Webler, and Wiedemann 1995; NRC 1996, 2002; S. Smith 1999). *Diverse* public participation implies a wide breadth of voice representing the values, interests, and concerns of federal, state, and local governments; private–public partnerships; members of community groups and special interest organizations; and large numbers of otherwise unaffiliated nonspecialists and interested citizens (Arnstein 1969; Taylor 1998; Rayner 2003). Somewhat surprisingly, although public participation geographic information system (PPGIS) research has been ongoing over that same time frame of the past fifteen years, there is little reference to the NRC's analytic-deliberative approach in the PPGIS literature, aside from the stream of research reported herein, which is one of the reasons that approach is deserving of continued in-depth exploration.

The analytic-deliberative framework is not the only framework being used to explore structured participation in a systematic manner. Systematic research about structuring the process of public involvement in transportation decision making has been explored by Bailey and his colleagues (Bailey, Brumm, and Grossardt 2001; Bailey and Grossardt 2003, 2010) but with several differences. They have been reporting for several years about transportation-focused research projects involving structured involvement conducted in real-world, face-to-face settings using the Arnstein (1969) ladder combined with Rawls's (1971) theory of justice. Their research reports, most recently in Bailey and Grossardt (2010), describe empirical results about metrics for structured involvement and show there to be considerable promise for improving our understanding of public involvement processes. Such research contributes to debunking the widely held general perception about public participation in decision making that the lay public is not knowledgeable enough to interact meaningfully with technical experts and make meaningful contributions. Their research is couched in a face-to-face setting, however. A future synthesis of findings from face-to-face and online settings is likely to be fruitful, but the research reported herein will not undertake that synthesis.

This article reports on an evaluation of the quality and scale of public participation in decision making during an online field experiment at a regional scale making use of an analytic-deliberative framework. The experiment convened a large group of participants in an analytic-deliberative process about regional transportation improvement programming in the central Puget Sound region (Seattle metro area) of Washington State. The main research question for the project was this: What online platform designs and capabilities, particularly including geographic information system (GIS) technology, can improve public participation in analytic-deliberative decision making about transportation within large groups? The online platform used for the online field experiment is designed, implemented, deployed, and maintained as a PPGIS technology test bed for the study of public participation in decision making among large groups that use an analytic-deliberative process. To date, the PPGIS test bed has been modified for two different online decision situations, regional transportation improvement programming for the central Puget Sound region discussed in this article and adapting to the regional impacts of climate change on the Oregon coast still in progress.

The article proceeds as follows. The second section reviews research about the analytic-deliberative framework, showing why this is a valuable approach as suggested by the NRC (1996, 2005). The third section reviews research about PPGIS using a chronological perspective and suggests how PPGIS can benefit by looking at comparable research findings about public participation in broadly based analytic-deliberative processes, despite the minimal connection between the two literatures over the past several years. Two PPGIS frameworks composed by the authors are used in situating this research. One framework involves a way to situate this research within the PPGIS literature. Another framework involves a way to situate this research in large-scale systems development. The fourth section introduces the reader to the participatory GIS for transportation (PGIST) project, which began in the domain of Web system development (design, implementation, deployment), then moved to systems use by nearly 200 participants, and then finally ended with evaluation of participants' use of the system. The fifth section focuses on participant use and illustrates why a comparative research design and targeted recruitment strategy for participants are both important. The sixth section presents research findings from the domain of social and behavioral science evaluation, including Phase I findings based on participant self-reported data, Phase II findings based on event data and use of a technique called a grapevine, and Phase III findings based on content analysis. The article concludes by using the evaluation findings to look forward to another cycle of design and development of online PPGIS tools.

Analytic-Deliberative Decision Making

The NRC (1996) suggested that analysis and deliberation are distinct activities involved in knowing within an overall decision process. The purpose of an analytic-deliberative process is to pose a broadly based deliberative counterweight to analysis; in other words, to engage a diverse group of the lay public in a deliberation about data, analytical procedures, and findings of fact to expose simplifying assumptions and omissions in the analysis itself. Analysis is a standard element in decision making and ensures that factual perspectives are based on valid methods and procedures. Broadly based deliberation implies that a diverse spectrum of values and concerns, governance issues, and factual knowledge are being represented, suggesting the need to scale public participation to larger and more diverse numbers of people over wider regional areas.

The purpose of an analytic-deliberative process often seems difficult to understand for those who feel that asking a large group of nonspecialists to inform technical specialists about the ins and outs of analytical procedures is simply a waste of time (Bradbury 2001). There are those, however, who feel just as strongly that technical experts should not presume to know how the procedures or findings of their analyses will impact a broad spectrum of community representatives or presume that their technical expertise is superior to the experience, local knowledge, or scientific intuition of members of the lay public.

When Is Broadly Based Analytic-Deliberative Process Needed?

One of the early criticisms of the NRC (1996) report was that although its treatment of the analytic-deliberative process provided a compelling best practice concept, the question of exactly how to structure and evaluate a broadly based analytic-deliberative process and when to convene it still remained unanswered and needed a second volume by the NRC (e.g., see Chess, Dietz, and Shannon 1998). The NRC (1996) did not prescribe a broadly based analytic-deliberative process for every situation, nor did it delve into the philosophy of participatory democracy and why the lay public should be involved in decision making (e.g., Habermas 1984, 1987; Fiorino 1989). The NRC (1996) pointed out that an unnecessary analytic-deliberative process, or one that has been structured poorly, might actually make things worse.

Convening a broadly based analytic-deliberative process is more desirable or necessary under certain conditions. The NRC says that the higher the expected likelihood that scientific analysis will be criticized, the more desirable or necessary it is to convene a broadly based analytic-deliberative process. Likewise, the NRC says that the greater the uncertainty about the use of scientific analysis to inform decision making, the more desirable or necessary it is to convene a broadly based analytic-deliberative process. Funtowicz and Ravetz (1992, 1993) similarly articulated two conditions—*stakes* and *uncertainty*—that make public participation necessary (see also Rosa 1998a, 1998b). Funtowicz and Ravetz (1992, 1993) suggested that when either the decision stakes and number of conflicting issues are high or the level of uncertainty and number of contested analytical procedures are high, it is desirable to adopt a broadly based participatory strategy using an extended, rather than restricted, peer community. An extended peer community in a participatory strategy is able to generate rich local knowledge through a process of participatory deliberation (e.g., see Renn et al. 1993; Renn, Webler, and Wiedemann 1995), rather than general-purpose scientific knowledge generated through a set of standardized analytical procedures.

Scaling the Analytic-Deliberative Process

Even when conditions are right, scaling a broadly based analytic-deliberative process to a large and diverse public group within a face-to-face setting can be an unwieldy, expensive, and time-consuming activity. This is true for both the sophistication of the decision process as well as what it takes to evaluate it (Nyerges and Patrick 2007). As a result, most well-known empirical studies of public participation with an analytic-deliberative process have tended to be based on groups of limited size (e.g., Renn, Webler, and Wiedemann 1995; Rowe and Frewer 2000; Webler and Tuler 2001). An Internet platform provides three ways of enabling and scaling online participation in terms of (1) scaling a participatory process "out" to include hundreds (and eventually thousands) of people, (2) assisting with scaling "up" to encompass people from a wide regional area, and (3) scaling "higher" to engage participants in more of the technical details about the analysis used in decision making (Nyerges 2005). A majority of households in the Puget Sound region have access to high-speed Internet connections, providing a basis for scaling out to large numbers of people who are interested in transportation issues, given that transportation improvement is always in the news. The entire region is influenced by megaprojects, and thus a regional perspective is growing in importance for economy and transportation. Web 2.0 technologies are available that can enrich materials and improve interaction methods and thereby encourage higher levels of engagement.

Framing Analytic-Deliberative Process Within Public Participation GIS

PPGIS research by its five-letter acronym is progressing through its second decade. There has been much that has been accomplished, but there is much to do in regard to people's contributions to community well-being. Many researchers point to fulfillment of considerable potential for PPGIS as smaller groups of people are routinely involved in using GIS for community-oriented decision making (Jankowski and Nyerges 2001; Elwood 2002). Some researchers, however, suggest that PPGIS has not fulfilled its potential; for example, very large groups of 100 or more people are not routinely involved in GIS-based processes for community-oriented decision making (aside from special projects like that reported by Bailey and Grossardt 2010). The research frontier is about engaging very large groups in a more deliberative democracy (Gutmann and Thompson 2004; Gastil and Levine 2005; NRC 2005; Nyerges 2005). Framing PPGIS research to examine how to address the frontier about how to "scale" engagement is important for guiding the research, particularly because PPGIS is such a diverse topic. We offer a framework, elaborated here, in which PPGIS is considered in light of parallel research on analytic-deliberative processes for environmental decision making motivated by NRC (1996, 2005) reports but focus our interest on "scaling engagement" to very large groups of more than 100 people.

Starting in the late 1990s, several researchers began offering conceptual frameworks to synthesize research about different aspects of PPGIS (Nyerges and Jankowski 1997; Leitner et al. 2000; Jankowski and Nyerges 2001; Carver 2003; Schlossberg and Shuford 2005; Elwood 2006; Sieber 2006). We offer a meta-framework suggesting there are metadimensions about PPGIS work (people, group process, and GIS technology) that, depending on which one is emphasized, explain the similarities and differences among the major realms of PPGIS, which are grassroots GIS, collaborative GIS, and Web GIS (see Figure 1). For instance, *grassroots GIS* emphasizes the metadimension of people, especially marginalized populations who can gain power through participatory processes using off-the-shelf GIS technology. *Collaborative GIS* emphasizes the metadimension of group process, with a focus on face-to-face meetings and different social–behavioral science research designs to study public participation processes and outcomes. Finally, *Web GIS* emphasizes

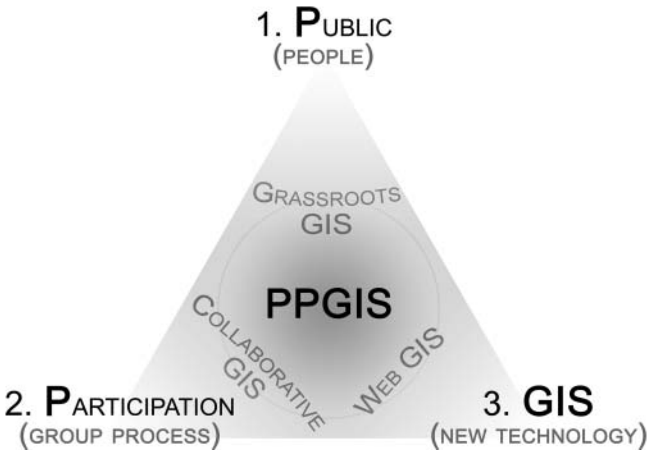

Figure 1. The three realms (1, 2, 3) of PPGIS research. GIS = geographic information system; PPGIS = public participation geographic information system.

the metadimension of technology and new tool development or new methods, with a focus on broader access and multimedia in what some have referred to as GIS2. We observe that Web GIS, with its emphasis on improving access to information, has taken a lead role in our research as a platform that tries to scale engagement out to large numbers of people. The collaborative GIS emphasis comes into the research through exploration of the analytic-deliberative processes but is now turning to structured participation methods to organize participation of very large groups in knowledge production (i.e., decision processes). Support for a diversity of people is also important, and this aspect enters the research through attention to research design and sampling.

Although the preceding framing provides general insight, it does not offer enough guidance for our research. Thus, we present a more detailed approach (see Table 1) to compare and contrast conceptual frameworks and individual contributions to gain clearer insight about analytic-deliberative processes. This approach helps to frame our empirical research from a broad base of participatory GIS research, recognizing that nuances exist within the three realms (Elwood 2006) and highlighting topics in need of further exploration. In Table 1, we compare and contrast conceptual frameworks by identifying cross-cutting themes and then describe how this evaluation frames large-scale analytic-deliberative decision activity. We label each of the conceptual frameworks referenced earlier from A to F roughly in chronological order. The frameworks first created by Nyerges and Jankowski (1997) together with Jankowski and Nyerges (2001), which we label as A in Table 1, focus on the theme of new technology used by diverse groups undertaking participatory processes and emphasize the research realms of participation (2) and GIS (3) in Figure 1. The Leitner et al. (2000) framework, which we label B in Table 1, focuses on the theme of synthesized models of participation and macro process as influenced by the physical arrangements of settings in which the participants interacted and emphasizes the realm of people (1) in Figure 1. Carver (2003), labeled as framework C in Table 1, synthesized across a number of developments and articulated several directions for PPGIS research, emphasizing the realms of participation (2) and GIS (3) in Figure 1. Schlossberg and Shuford (2005), labeled as framework D, asked two fundamental questions—Who are the public? and What is participation?—to motivate their exploration of those terms as a way of unpacking PPGIS, emphasizing the realms of public (1) and participation (2) in Figure 1. Sieber (2006), labeled framework E, drew on many developments of process and technology to create an overview of PPGIS, emphasizing the realms of public (1) and GIS (3) in Figure 1. Elwood (2006), which we label framework F, offered critical insights about public participation and GIS, calling for more formal investigations into the languages that are used in PPGIS, emphasizing the realm of public (1) in Figure 1.

Table 1. Common themes across six different public participation geographic information system (PPGIS) research frameworks (A–F)

PPGIS themes	Count	Frameworks
Task, people, and place	6	A, B, C, D, E, F
Participation process (macro-, meso-, and micro-process)	4	A, D, E, F
Social and institutional (financial) influence, including power	4	A, B, C, F
Technology and data	3	A, B, E
Task outcomes	3	A, D, E
Evaluation	3	A, E, F
Geographic scales	2	A, C
Social outcomes	2	A, D
Invoking information aids	2	A, F
Emergent influences from institutions, groups, and technology	1	A
Appropriations of social–institutional, people, and technology influences	1	A
Culture	1	C

Based on the six research frameworks A through F, we identified twelve cross-cutting themes and then counted the frequency of occurrence within each conceptual framework (see Table 1). The purpose of the count is to highlight which cross-cutting themes are more frequently considered by the authors of the frameworks as well as cited within those frameworks. In addition, the count calls out themes not receiving as much attention, although perhaps they should based on suggestions by the framework authors. There is no surprise that task, people, and place as a theme were the most frequently addressed (Table 1). Task, people, and place lie at the core of any GIS activity and are perhaps best understood as the essential inputs into any decision-making situation. Participation process is the next most frequently considered theme, which takes the inputs of task, people, and place and acts on them to create a public participation outcome. The theme of social and institutional context is equally important as participation process but is cited by a somewhat different collection of frameworks. At least half of the six PPGIS conceptual frameworks note the theme of evaluation as important.

Comparative framing of PPGIS demonstrates that research about the realms of people, group process, and technology underpins any future progress to enable new forms of public participation with GIS. Although considerable progress has been made to fulfill the potential of PPGIS for small groups, not all small-group projects have been successful (Kyem 2004). Nonetheless, we conclude that although small-group analytic-deliberative decision processes have been enhanced, very large group analytic-deliberative processes have not. PPGIS has not made progress in terms of enabling very large public groups in participatory processes because structured participation methods are needed to scale engagement out to very large groups. Without structured participation processes underpinning participation, the processes are chaotic; hence little knowledge production (decision activity) gets accomplished. Evaluation of that interaction shows up in Table 2 at frequency level 3, which suggests that more emphasis is needed to make progress. Before system designs can enable very large public groups, more systematic evaluations of PPGIS designs, particularly the potential for online systems, have to be undertaken to help us understand how to scale participation processes out to larger numbers of people, up to larger regional areas (given that most people's reference frame is fairly local), and higher in terms of introducing people to more detailed levels of analysis and technical information. It is with that motivation we undertook and report on this research about large-scale participatory interaction. Before we do that, we first examine what has been accomplished in the literature that evaluates interaction processes to provide context.

Evaluating PPGIS and Public Governance Decision Making

Evaluation of participatory processes, whether at higher or lower levels of public participation, has remained a challenge. There are comparatively few empirical evaluations of PPGIS tools in real-life situations, although notable exceptions do exist (e.g., Shiffer 1998; Kingston et al. 2000; Drew, Nyerges, and Leschine 2004; Nyerges, Jankowski, Tuthill, and Ramsey 2006; Kingston 2007). Few systematic comparisons have been made based on two or more large or diverse case studies, although Gastil and Levine (2005) presented several individual case studies and offered generalizations about deliberative participatory processes. Some authors even suggested that evaluation of public participation does not move much beyond introspective evaluation, prejudiced in one way or another by the sympathies of the researchers themselves, and lacking the scientific validity to explain whether a process of public participation enabled any technical or social outcome that would not have been achieved anyway (Rayner 2003). The reasons for a lack of rigorous evaluation of real-life PPGIS are several and likely include

Table 2. The public participation spectrum

Level	Participant's activities	Participant's outcome
1. Inform	Listen	Public is informed
2. Consult	Listen, respond	Public is informed and provides feedback
3. Involve	Listen, respond, recommend	Public concerns are incorporated
4. Collaborate	Listen, respond, recommend, negotiate, analyze	Public helps form concerns and solutions
5. Empower	Listen, respond, recommend, analyze, negotiate, decide	Public decides on concerns and solutions

Note: After International Association of Public Participation (2007) and Nyerges and Patrick (2007).

lack of solid research connections to governing administrations, a lack of resources and expertise to carry out systematic evaluations, or the fact that perhaps the public is just not ready for intense use of geospatial technology.

If there are so many barriers to evaluation, resulting in so few insightful studies, then why bother? The NRC (1996) reported that careful observers of decision making about risks to the environment, public health, and public safety consistently noted the importance of broadly based deliberation to the outcomes of a decision. On this basis, the NRC presented an initial research challenge to the scientific community to learn more about the optimal conditions and new online technological means for cultivating broadly based analytic-deliberative decision making (NRC 1996), a challenge it repeated in 2005 (NRC 2005), stressing a continued need for better empirical evaluation because robust evaluations do not yet exist. PPGIS researchers have studied cases about how broadly based peer networks of local neighborhood and community groups use desktop or online geospatial technology, empowering them with alternative factual perspectives and how such use influences decisions that directly affect their interests (Elwood 2002). For all the PPGIS research dealing with environmental and community-based decision making, however, it is surprising how few citations are found to the NRC (1996, 2005) reports in the PPGIS literature, as we mentioned earlier. Why? Perhaps it is because advocates of PPGIS endorse "broadly based analysis," which seeks to put similar analytical data and procedures used by public agencies into the hands of a broad-based spectrum of users at a grassroots level. In contrast, the NRC makes limited endorsement of placing sophisticated analytic techniques in the hands of stakeholder publics (Creighton 2005). The NRC suggests that grassroots or broad-based public participation should focus for the most part on deliberating about analyses used in public agency decision making. The NRC's point of view is that broadly based deliberation forces change from the inside out when it comes to the data, procedures, or findings of fact used by public agencies in their decision making. In short, the perspective of NRC (1996) is that a broadly based analytic-deliberative process does not simply make better policy—it makes better science (Stern 1998). That is not to say, though, that a broad base of participants should not undertake analysis; it is welcome but simply not expected by the NRC committee findings.

Design and Development of a PPGIS Online Platform

The point of view of the authors' research agenda is not that PPGIS technology alone provides a simple fix for low levels of public interest and involvement. Nor is our point of view that PPGIS technology changes any of the fundamental conditions that make public participation more necessary or desirable. We are, however, optimistic about being able to adequately answer concerns like those of Carver (2003) and Rayner (2003) by empirically evaluating how online technology and the analytic-deliberative process together can generate more diverse and more meaningful public participation interactions for decision-making purposes, as outlined by authors like Wiedemann and Femers (1993), R. Smith and Craglia (2003), and Nyerges and Patrick (2007).

A custom PPGIS online platform and field experiment called "Let's Improve Transportation" (LIT) was designed and developed by the PGIST project (PGIST 2007). The platform and the results of the 2007 online field experiment are to date fully viewable to guests (Nyerges 2007). Most of the project's time and effort was spent in the domain of design and development, which began with theoretical concepts about system design based on deliberative democracy (Gutmann and Thompson 2004), then moved to initial design considerations and design artifacts (Nyerges, Ramsey, and Wilson 2006), and finally ended with the final programming and usability testing (Haklay and Tobon 2003) of an online PPGIS implementation for use by participants (Lowry, Nyerges, and Rutherford 2008). In the course of design and development, project researchers generated design artifacts of several different types (Nyerges, Ramsey, and Wilson 2006; Wu 2007). Design choices made early on, coupled with the fact that development of the LIT Challenge unfolded over such a long period of time, impacted research design choices when it came to the online field experiment in October 2007.

The LIT PPGIS platform is a collection of tools and information supporting analytic and deliberative activities organized in a sequence supported by a workflow engine and accessible to participants through a normal Web browser (Russell et al. 2006; Wang 2008). The project's design and development group programmed the LIT PPGIS platform so that participants had an agenda and would be given access to certain tools at a certain time to complete a sequence of LIT steps. Nyerges, Ramsey, and Wilson (2006) described the spirit

Table 3. Let's Improve Transportation workflow agenda listing participant's step and substep activities

Step 1.	**Discuss concerns**
	1a: Map your daily travel
	1b: Brainstorm concerns
	1c: Review summaries
Step 2.	**Assess improvement factors**
	2a: Review factors
	2b: Weigh factors
Step 3.	**Create transportation packages**
	3a: Discuss projects
	3b: Discuss funding options
	3c: Create your own package
Step 4.	**Select a package for recommendation**
	4a: Discuss candidate packages
	4b: Vote on package recommendation
Step 5.	**Prepare group report**
	5a: Review draft report
	5b: Vote on report endorsement

and goals of the wireframe design, whereas Lowry, Nyerges, and Rutherford (2008) provided several screenshots of the completed interface plus other details of use. Using the LIT Web site, participants worked asynchronously as a group at their own convenience but roughly within the same general time frame. Participants were given a month to complete five steps in the LIT online field experiment (Table 3). Each step was broken down into two or more substeps, twelve in all, but our focus in this article is on activities at the step level for brevity.

After registering for the online field experiment and giving informed consent as a voluntary human subject, participants entered information about their travel path and then voiced their concerns about improving transportation in the central Puget Sound region of Washington. The moderator performed an offline synthesis of concerns using a moderator tool that organizes comments by keywords and helps the moderator group individual comments into a set of common themes. Participants also reviewed the themes and discussed as well as voted on whether or not they agreed that the themes adequately represent their concerns, which the moderators in turn might use to change the themes as created (LIT Step 1). After voicing concerns and voting on concern themes, participants began an introduction to transportation improvement analysis by reviewing and weighing different improvement factors, which were used as multiple criteria for creating the best transportation improvement package (LIT Step 2). After participants reviewed how multiple factors are used to characterize options and create a transportation improvement package, they created their own package using a geospatial analysis "spreadsheet" tool. Participants selected from a spatial inventory of projects and then selected a funding mechanism for the package (LIT Step 3). After each participant created a transportation improvement package, a transportation specialist used an offline clustering process to identify six representatively diverse packages. Participants deliberated about the six diverse packages and then voted on which they preferred (LIT Step 4). Finally, participants reviewed and endorsed a final report that was to be submitted to agency decision makers and technical specialists describing the decision-making process and the final package recommendation outcome (LIT Step 5). As the process was an experiment, the report was submitted to Puget Sound Regional Council and the Regional Transportation Investment District personnel, but they were not obligated to use the information for actual package selection. Many of the projects, however, were part of an actual package that was being considered by voters at the time of the experiment.

Research Design, Recruitment, and Participant Use Within an Online Field Experiment

The field experiment had two principal research design considerations. One consideration was to collect observations of participants working on a realistic decision-making problem in an online PPGIS environment. Participant online activities were unobtrusively recorded by the PPGIS platform's client–server event log. Participants were also asked to answer several detailed online questionnaires at different points along the way, and two different subsamples of participants were asked to volunteer for talk-aloud screen recordings and hour-long interviews.[1] To give participants a realistic decision-making situation, the project used a quasi-experimental approach that crossed a field study with a laboratory experiment (Cook and Campbell 1979). Field experiments balance experimental control with allowing people to interact naturally over a long period of time, both equally important advantages for validity in research (Brinberg and McGrath 1985; Benbasat 1989; Cash and Lawrence 1989; Kraemer 1991). Because a field experiment is a cross between a field study with realistic conditions and a laboratory experiment with controlled variables, researchers can use multiple instruments to capture a variety of potentially meaningful data that take full advantage of a field experimental setting (Nyerges, Jankowski, and Drew 2002). The LIT Challenge online field experiment ran from 15 October 2007 to 13 November 2007 to coincide with an actual 6 November 2007 ballot initiative asking voters to support a $17.8 billion regional transportation improvement package for the central Puget Sound region of Washington State. The LIT Challenge presented participants with a set of transportation package options similar to the 6 November 2007 ballot initiative.

A second research design consideration was to recruit a large and diverse sample of participants that adhered to the NRC's (1996) concept of broadly based deliberation. In our judgment, having at least 100 active participants or more qualified as a very large group of participants for a public participation exercise. A diverse group of participants meant having people representing as much of the three-county central Puget Sound area as possible. Because of peculiarities about how Washington campaign finance law and state employee ethics laws apply to university research, we were only allowed a total participant sample of 300 participants. Washington State campaign finance and ethics laws are intended to make sure that the resources and employees of a state agency or institution, including those of a state university, are not used to assist in an election campaign, endorse or oppose a ballot proposition or initiative, or lobby the state legislature. Over the course of the experiment we discovered that being limited to 300 registered participants, in total, meant only having 120 to 180 active participants at any one time. A total of 246 participants registered for the experiment but only 179 qualified for payment based on the geographic quota, the group we call our quota participants. Only about half of the 179 quota participants were active in the LIT Challenge at any one time, ranging from a high of 60 percent to a low of 40 percent by the end of the experiment.

Several authors have offered their opinions about the merits of different methods of recruitment for a public participation situation by comparing the use of voluntary and non-randomly selected participants based on samples of convenience (Konstan and Chen 2007), randomly sampled participants (Jefferson Center 2009), or participants nominated by their community as representatives (Carson and Martin 2002; Rayner 2003). Our recruitment strategy in the LIT Challenge used an open and voluntary sample of paid participants, who although non-randomly selected, would represent those more likely to engage in public participation about regional transportation improvement. Recruitment e-mails asking for participation and offering payment specifically targeted organizations whose members were involved in regional transportation issues such as metro advisory groups, transportation activist organizations, and local chambers of commerce. The project also sent recruitment e-mails to public libraries, community technology centers, local newspapers, and community message boards. Participants responding to the recruitment e-mail could register to participate in the LIT Challenge on a first-come, first-served basis, but not all registered participants were then eligible to receive payment. We used controls on quota participants to prevent overrepresentation from the City of Seattle. The LIT PPGIS automatically capped the total number of paid participants by ZIP code to scale up to encompass representation of as much of the three-county central Puget Sound region as possible and scale in to reduce the number of paid participants from the City of Seattle itself. In Figure 2, the two-dimensional top-down view displays the central location of the LIT PPGIS platform server relative to the self-reported locations of registered participants throughout the central Puget Sound region.

The research design prepared us to investigate theoretical questions about public participation with an analytic-deliberative decision-making process and how that process can be improved using innovative participatory structuring with an online PPGIS. More specifically, our investigation of how public participation in an analytic-deliberative decision-making process can be improved using an online PPGIS focused on distinguishing the effects of scaling public participation out, up, and higher; that is, to examine differences when participant activities are scaled out to include a larger number of people, scaled up to encompass more of a regional area, and scaled higher when participants are given more technical tasks using GIS-based information.

The research design and evaluation of findings were not intended to compare an online PPGIS situation and a face-to-face PPGIS situation, although other authors have considered differences in face-to-face and online structured participation, in part providing motivation for our research (Dowling and St. Louis 2000). Neither could we compare use of an online PPGIS across different regional transportation decision-making situations, as that will come in future projects. Likewise, although the importance of the decision-making situation itself has been the subject of past research (Jankowski and Nyerges 2001; Nyerges et al. 2006), as well as an important element of convening a broadly based analytic-deliberative decision-making process, our research design did not compare two or more decision-making situations with different levels of complexity

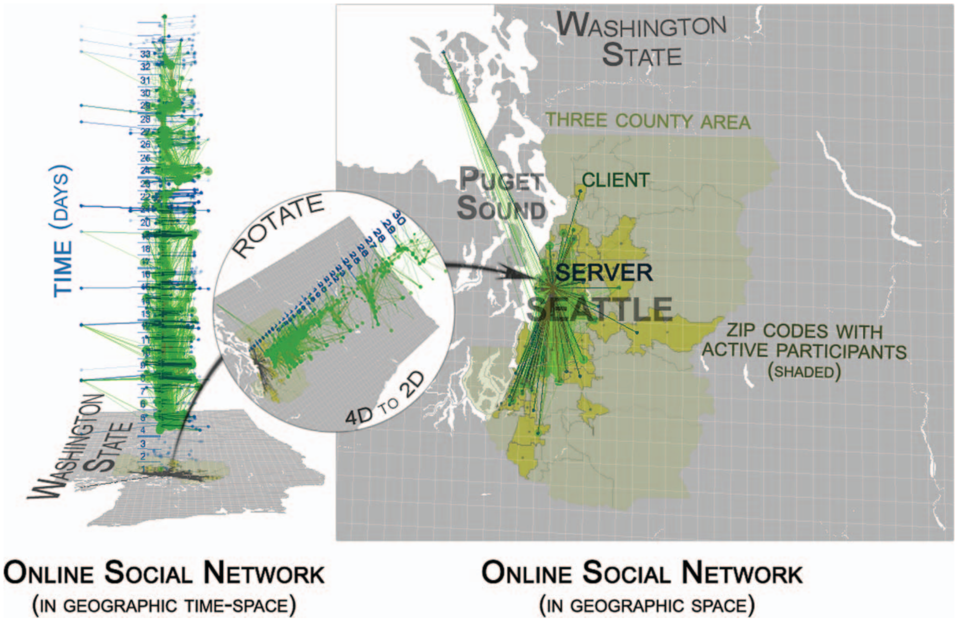

Figure 2. Grapevine (left) and a two-dimensional top-down view displays the central location of the Let's Improve Transportation (right) public participation geographic information system platform server.

or uncertainty. The research funds were dedicated to new technology development for only a single type of decision situation. Finally, our design was not intended to calculate the financial cost savings or gauge the civic merits of public participation in decision making in general, nor was the research design to test a particular theoretical assumption about public participation or participatory governance from among the many that have already been offered by a wide range of scholars, advocates, or practitioners over the past several decades.

Findings

Evaluation of the findings from the online field experiment contained three phases of analysis. All three phases focused on the same principal research question: How can an online PPGIS platform improve the quality and scale of public participation in analytic-deliberative decision-making process about regional transportation improvement? Each phase, though, relied on different observations and methods and we used the findings of each phase to triangulate the overall findings. Phases I, II, and III of the analysis differed greatly by the type of data collected and the analytical techniques and methods used. Because of the nature of the different observations and methods used, the results of each of the three phases of analysis were based on different levels of observational granularity with findings that sometimes contradicted each other. In terms of validity, we feel that the sometimes contradictory findings of all three phases have to be considered as a whole, and possibly encourage further examination to sort through those contradictions.

Phase I was based on a statistical analysis of self-report data from several online questionnaires given to participants over the course of the experiment. As part of Phase I we also include an explanation for why we did not report on a qualitative analysis of transcribed interviews based on a subsample of participants who reflected on their activities after the end of the experiment. Phase II was based on a geovisual analysis of unobtrusively collected data from the system event log, and we include several details explaining the grapevine technique and method we developed. Phase III was based on a content analysis of participant message exchanges, which relied in part on the findings of Phase II to help us subsample messages for further content analysis. We analyzed the fine-grained content of participant message in terms of the frequency of words used as subjects or objects of sentences, and most important, in terms of what participants meant to say with these words in the context of the analytic activities of the step and their ongoing discussion.

The main objective in going from Phase I to Phase II and then to Phase III was to progress step by step from coarser grained to more finely grained sets of observations. At the same time, we wanted to include both self-report and unobtrusively collected data to discover what content or set of ideas about the transportation improvement situation participants themselves were most interested in discussing, measured in terms of participation from a greater number of people over a wider area.

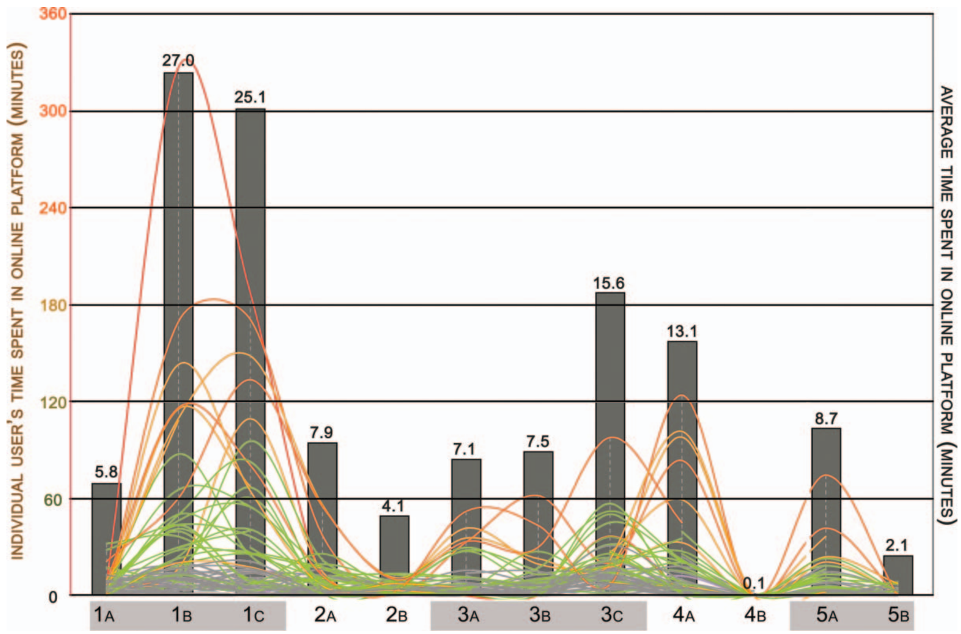

Figure 3. Differences in individual and average levels of activity (time spent) during the Let's Improve Transportation online field experiment by substep.

We feel that the combined Phase I, II, and III approach represents an important foundation for exploring validity when it comes to triangulating different sets of observations and methods. Some of the results of a statistical analysis of questionnaire data collected at breakpoints during an experiment might contradict the results of a qualitative analysis of in-depth interviews collected after the end of an experiment, which might in turn contradict the results of a visual analysis of system event log data collected unobtrusively throughout the course of an experiment. We expect that other researchers with similar concerns about triangulation issues will see the value in a multiphase approach, so that biases generated from one source of data or preferred method do not lead to unsubstantiated impressions or inferences about the superiority or inferiority of a particular theoretical concept.

Phase I Evaluation: Quality and Scale of Public Participation

The first phase of our evaluation focused on self-reported information from participants collected at the end of each step and at the end of the online field experiment. We examined quota participant responses to online questionnaires asking them about themselves and their experiences with the online PPGIS platform, as well as data from two subsamples of participants who volunteered for screen recordings and interviews. We then summarized self-reported differences between participants in terms of individual characteristics and experiences using the online PPGIS with the assumption that significant and meaningful patterns among participants might emerge based on anything from where they lived to their cognitive preferences.

Of the 179 quota participants who registered, 153 participated in at least one step. Of those 153 participants, it was clear that a few spent much more time working with the PPGIS platform than the rest of the group, which is consistent with general findings about differences in individual online activity following a Poisson distribution. Figure 3 illustrates some of the differences in participation by substep and by individual user. Average time per substep varied from a high of 27 minutes in Step 1b to a low of less than 1 minute in Step 4b. The colored lines in Figure 3 are trend lines in participant activity per substep, not continuous measurements. The trend line illustrates the fact that participants varied widely in terms of the time they devoted to particular substeps. For instance, one user spent almost 5.5 hours working in Step 1b alone (Figure 3). On average, participants spent 5 hours of online activity for the entire month-long simulation (Nyerges and Aguirre 2008), suggesting that participants would have spent less than 10 minutes per day and about an hour per week interacting with the PPGIS platform, although it is unlikely that many participants visited the LIT Challenge every day.[2] Among quota participants who reported (n = 74) about their perceived level of participation in the LIT Challenge, twice as many people felt that they participated less (n = 21) than other participants, as compared with those who felt they participated more ($n = 9$) than other participants. Of those who reported ($n = 75$) about their enthusiasm for participating in the LIT Challenge over the four-week period, nearly 40 percent said that their enthusiasm decreased as time progressed, whereas only 17 percent felt their enthusiasm increased over time.

A pre- and post-test design was used to ask participants to rate their experiences in the LIT Challenge and the results suggest that participants were basically ambivalent about their overall experiences using the online PPGIS platform to create a transportation improvement package for the central Puget Sound region. In our pre- and post-test design, participants were asked in an entrance questionnaire to indicate their level of agreement with different statements about their expectations of participation in the LIT Challenge. The same Likert-type item questions were repeated in an exit questionnaire. We performed a marginal homogeneity (MH) test, a nonparametric version of a paired-sample t test, on participant responses to Likert-type item questions.[3] Based on the results of the MH test, only three of the nine entrance and exit responses were statistically different.[4] All three, however, indicated a more negative experience.[5] The results of the MH test of the questionnaire conflicted with the positive impressions offered by a subsample of participants ($n = 20$) who described their experiences during in-depth interviews with the moderators at the end of the experiment.

Another aspect of the first phase of our evaluation looked at data from a subsample of participants who were asked to volunteer for screen recordings and interviews. Phase I findings relied on comparison between participants who could be clearly defined as either public activists or nonactivists, or as expert and nonexpert Internet users, which would then be used to explain differences in online activities as captured during screen recordings or to explain differences in responses during in-depth interviews. However, about 90 percent of those participants reporting said that they used the Internet several times a day and considered themselves to be either experts or nearly experts in terms of their familiarity with computers and the Internet, and nearly two thirds (65 percent) of those reporting said that they had participated in online discussions before. Almost all (94 percent) of those reporting stated that they tried to stay informed about transportation issues in the Puget Sound region. One in five participants indicated that they were either affiliated with or an actual member of an organization that was active in transportation planning or advocated for transportation issues. It is likely that the self-reported differences among our sample of highly activist and Internet expert participants were not significantly different when compared to most of the rest of the population of the central Puget Sound region. Therefore, much of our Phase I evaluation, although suggestive, could not be considered conclusive and the findings are not elaborated in this article.

Phase II Evaluation: Quality and Scale of Public Participation

The results of the first phase of our evaluation focused on self-report data from subsamples of participants who were asked to reflect on their experiences with the PPGIS online platform. We also wanted to examine participant analytic and deliberative activities at a fine-grained level, finer than we could expect our participants to be willing or able to reflect on. Therefore, the second phase of evaluation focused on unobtrusively collected system event log data about participant activity during the month-long online field experiment. An *event* is a data element that stands for a geographic occurrence; in other words, something that happens in geographic space and has a location but only persists in that location for a limited amount of time, after which it goes away, such as a lightning strike (Peuquet and Duan 1995; Worboys and Hornsby 2004; Worboys 2005; Yuan and Hornsby 2007). Related generally to the geographic literature, a client–server event is considered a geographic occurrence, logged as a request by a client browser application running on a participant's computer at a particular location to an Internet PPGIS application running on a server computer at another location. Although interactions between clients and servers occur in cyberspace they also must occur in real geographic space; thus observations of client–server interactions can be used to infer things about analytic and deliberation interactions between people in real geographic space and time (Zook, Dodge, and Aoyama 2004).

Information about requests by a client to a server is recorded by the online PPGIS platform within the system log of events. The PPGIS platform logged a total of more than 120,000 client–server interaction events as a result of the LIT Challenge. It was certainly a methodological challenge to process client–server interaction event data and to map the structure of client–server interactions in a 3D GIS display. However, the real research challenge was theoretical. We had to make inferences about why the event occurred, whether it was possible to distinguish an event as the

Table 4. A representative example of how we made inferences about human-computer-human-interaction (HCHI) activity based on client–server event data logged by the Let's Improve Transportation (LIT) public participation geographic information system (PPGIS) platform

Six levels of granularity about events logged by the LIT Web portal
CCTAgent.setCommentVotingId=1087375
1. "Act" The server logs a record that it successfully executed a key script and method for a specific client identified by a User ID, giving it a unique Event ID and including additional information about the target and any user-generated content as a result of executing the script and method. Based on the fact that the user-generated vote content as a "1" and not a "0," and because the log includes the target of the vote, we can infer that a specific human participant voted to "agree" with a another participant's comment, identified as comment No. 1087375.
c0-e1=number:1086435
2. "Paired-Act" Now we also know that the target of the voting act was a comment event that had been logged earlier by the server as Event ID 1086435, from which we can find out the specific user ID of the participant who posted the original message, when they posted it, and where they posted it from (i.e., their self-reported home address or zip code).
ioid=1107097
3. "Technique" Because the act was logged with the information object ID (ioid) 1107097, we know the participant voted while doing a sequence of events associated with browsing all of the messages in Step 1 that the moderator felt fit into a "Governance and Funding" theme.
activityId=1078294
4. "Method" Activity ID is 1078294, which also tells us that the participant voted while working within "Step 1c: Review summaries." If browsing the "Governance and Funding" theme were possible in more than one LIT step or substep, we would be able to distinguish where the participant was working when he or she voted.
contextId=1078302
5. "Session" The PPGIS platform supports multiple steps within an experiment. Context ID 1078302 tells us that the participant voted to agree with while working within "Step 1: Discuss concerns."
workflowId=1078232
6. "Situation" The LIT PPGIS platform can support multiple experiments. Workflow ID 1078232 tells us that the participant voted in the "Final LIT" experiment.

result of an analytic or deliberative human-computer-human-interaction (HCHI) activity, and, finally, what the intent of the person might have been based on where they were in the decision-making situation or the user-generated content. We distinguished 120 different types of client–server interactions based on its JavaScript and method and then attempted to describe what participant HCHI activity would have created the client–server event we observed, by interacting with the online PPGIS platform ourselves or reviewing actual participant screen recordings (see Table 4). Every record of a client–server interaction event included a unique sequential ID, the time of the event Pacific Standard Time, the registered user ID, the JavaScript and method called by the browser or performed by the server, the LIT step or substep in the site where the interaction event took place, the unique ID of whatever content a client requested from the server, and the unique ID of the content the client posted to the server (Table 4). For Phase II and III evaluations, we focused on five deliberative acts indicating that participants had just done the following activities: (1) write a concern, (2) write a comment on someone else's concern, (3) write a post, (4) write a reply to someone else's post, and, finally, (5) vote to agree or disagree with any of the above.[6]

In any investigation, there are units of analysis that carry data and then there are units of analysis pertinent to theory. We felt that client–server interaction events were especially pertinent units of analysis to examine the NRC's theoretical assumptions about what people do during an analytic-deliberative decision-making process and the value of broadly based analytic and deliberative activities, and could be used to distinguish the effects of scaling the dimensions of participant activities. Another advantage of using a client–server event log is that it can store a very large amount of highly detailed information that was collected automatically, reliably, and, perhaps most important, unobtrusively from very large numbers of participants over long periods of time as natural by-products of ongoing HCHI activity (Tanimoto, Hubbard, and Winn 2005).

We processed and visually mapped client–server interaction events using a 3D structure called a grapevine over time (hence 4D) to see at what points in the decision-making process participants were more actively engaged with the online PPGIS platform's maps and at what points they were more actively engaged with each other. We also used client–server event data to examine how participants working individually used technical information including maps to do their own analysis of the central Puget Sound's regional transportation needs and how they deliberated with each other about the results of their individual work.

The rationale behind designing a 4D geovisual analytic technique for evaluating the event log data is elaborated elsewhere (Aguirre and Nyerges forthcoming), but it is important to provide background context to establish the motivation for the second and third phases of our evaluation of the time-space structure of participants' deliberation. Thomas and Cook (2005); Andrienko, Andrienko, and Gatalsky (2003); Andrienko et al. (2007); and Kraak (2007) have made calls for research about the use of exploratory information visualizations to support individual and group problem solving. We felt that we could create a custom geovisual analytic technique that balanced the computing power of a GIS to display large amounts of data with the power of human spatial thinking and visual reasoning to recognize emergent patterns (NRC 2006). Our grapevine technique is based on an organic shape found in nature, but more formally speaking it is a sequential, social, and space–time data visualization for evaluating the quality and scale of the analytic-deliberative process in public participation decision making. The grapevine is developed from a synthesis of three different bodies of research including exploratory sequential data analysis (Getis 1966; Olson, Herbsleb, and Rueter 1994; Sanderson and Fisher 1994; Nyerges et al. 1998; Magnusson 2000; Hewagamage and Hirakawa 2001), social network analysis with event logs (van der Aalst et al. 2003; van der Aalst, Reijers, and Song 2005; Kossinets and Watts 2006), sociogeographic network analysis (Wallace 1993; Metcalf and Paich 2005), and, finally, spatiotemporal or time geography involving flows of people and messages (Hägerstrand 1966, 1970; Pred 1984a, 1984b; Hedley et al. 1999; Kwan 2000, 2002; Miller 2007; Yu and Shaw 2007).

Phase II Findings: Participant Analytic Activity with Maps

Whereas LIT Step 1 was mostly a deliberative step, participant activity in LIT Steps 2, 3, and 4 required participants to do both analytic and deliberative activities. Participants were asked to browse and select spatial information individually and then deliberate about their choices as a group. LIT Steps 2, 3, and 4 were where we expected that participants would most likely use GIS maps (Table 3). Participants could browse maps of the nineteen proposed road or transit improvement projects (together with various alternatives) in two different parts of the LIT Web platform including a general information section entitled "Review Projects" or as a part of Step 3a. In Step 3a, participants browsed a map of a particular transportation improvement project by clicking on one of the improvement project links listed on the page, which would then open a new tab in their browser with a standardized physical description of the project, the cost to complete it, and a Google map application displaying the location and extent of the proposed project including three or four different alternatives. In Step 3b, participants could browse and select from fifteen categories of funding options and were assisted in their choice with a Tax Calculator tool that opened in a new tab in their browser. For example, participants could browse the funding option category Gas tax increase and select from five options: 2 cents per gallon, 6 cents per gallon, 12 cents per gallon, 16 cents per gallon, and 20 cents per gallon. By using the Tax Calculator, participants could enter their personal travel and household financial information to estimate how much money they themselves would be responsible for on a yearly basis given their choice of funding option.

To investigate the use of GIS maps during the LIT online field experiment, we identified two key event types from the system event log indicating when participants were browsing maps of roads or transit projects. Decoding the two event types allowed us to distinguish the individual participant browsing a map, when they did so and for how long, which of the nineteen improvement projects (including sixty-six different alternatives) they browsed, and whether or not they performed any additional map manipulations such as panning, zooming, or clicking on features in the map itself. There seemed to be differences in what participants were interested in looking at although there did not appear to be any significant relationship between how many times a project map was browsed and the amount of money needed to pay for it. An important question about participants' browsing and selecting activities was this: What direct impact did technical information about transportation planning have on participants' deliberation? We found that participants were actually not discussing the maps as much as they were discussing the funding options. To better answer the primary research question about online platform designs and capabilities improving public participation in analytic-deliberative transportation decision making within large groups, we turn to the results of the grapevine geovisual analytic technique.

Using the Grapevine Technique for Evaluating Public Participation

In a vineyard, a cultivated grapevine's growth is trained to a support structure and it is continually coerced to develop a particular shape optimal for the production of grape clusters. The viticulturist's job is to balance the grapevine's natural vegetative growth (i.e., energies spent to spread out new shoots and leaves) with its reproductive growth (i.e., energies spent to produce grape clusters). The viticulturist achieves a balance by modifying the grapevine's growth and training the grapevine to latch onto a supporting structure, like a metal cable, then pruning the growth of new stems so the grapevine produces the optimal abundance of grapes to maximize the quality of the juice.

The challenge in convening and moderating a broadly based analytic-deliberative process is similar to the job of the viticulturist in the vineyard. In an analytic-deliberative decision-making process, the moderator's job is to balance breadth of deliberation (i.e., energies spent contributing new messages or new threads of discussion that broaden the spectrum of concerns about the analysis) with depth of deliberation (i.e., energies spent responding to each other's messages and generating a shared understanding about simplifying assumptions or omissions in a particular analysis). Software designers and online moderators achieve an analytic-deliberative balance by getting participants to wrap themselves and their deliberative energies directly around the data, methods, simplifying assumptions, or omissions of a particular scientific analysis without going off into dangling conversations that have nothing to do with the technical information structure being presented. By continually facilitating the growth of a structured analytic-deliberative process, and by providing new support structures built out of the methods and procedures of analysis used in decision making, a moderator can get a large and diverse number of people over a wide regional area to generate productive clusters of high-quality shared understanding.

Our grapevine visualization showed us the organic growth of participant deliberation coiling up through time and latching onto the analytic structure provided by GIS-based information in the online PPGIS platform. In Figure 4, the twisting grapevine structure (A) represents all of the deliberative activity logged during the LIT Challenge. The straight structure in blue in Figure 4 represents all of the analytic activity. The analytic interactions with the LIT PPGIS platform in Figure 4 are essential to the productive growth of the grapevine and represent the structure without which the deliberative grapevine would have nothing to latch onto. The visual information features in the deliberative part of the grapevine are described in Table 5 (see also Figure 5). The complexity of any grapevine structure comes from different combinations and properties

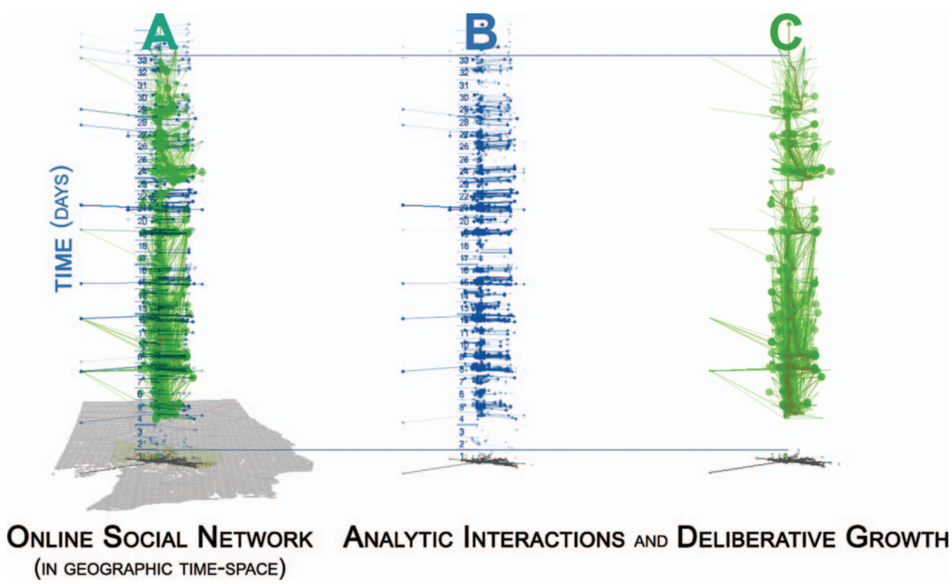

Figure 4. Grapevine depicts all analytic-deliberative activity (A), analytic activity only (B), and deliberative activity only (C).

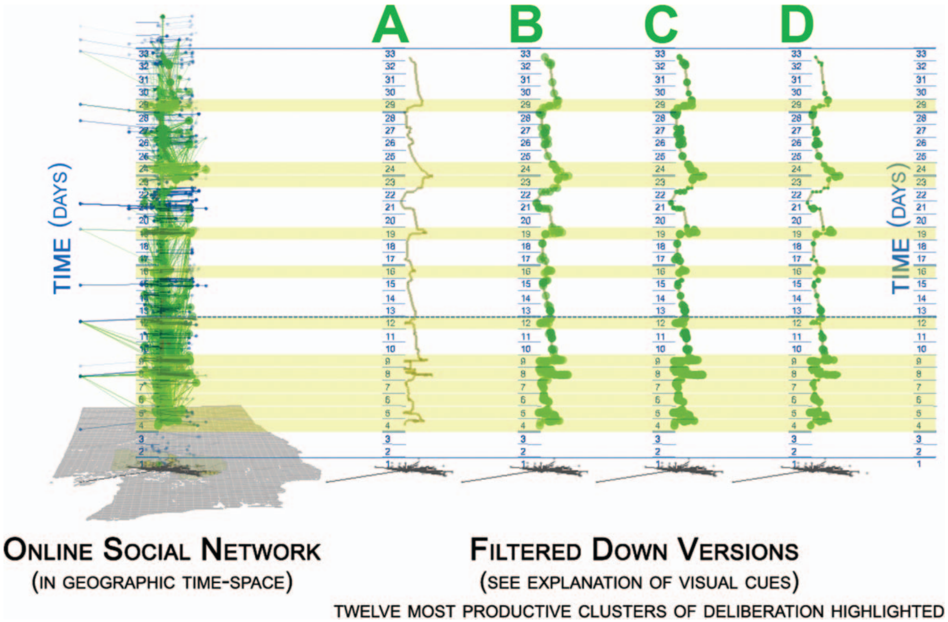

Figure 5. Filtered elements of the grapevine including main stem only (A), nodes (B), nodes proportional to votes received (C), and nodes proportional to replies received (D). Productive clusters are highlighted.

of its seven features (Table 5) including a main stem, nodes-internodes and buds that grow along its main stem, tendrils that grow out of nodes and latch onto the analytic support structure, and finally shoots that grow from buds and end in a leaf (Figure 5). Looking for productive patterns in nodes, buds, leaves, main stem, and tendrils on the basis of six different visual cues, we tallied the most productive clusters of shared understanding to harvest for further analysis. To validate visual analyst rankings of each visual cue we developed a computer calculation and then compared computer to human rankings. We discuss each visual cue in more detail in other publications (Aguirre and Nyerges forthcoming) but provide a brief overview of the visual cue results in Table 6.

Phase II Findings: Use of the Grapevine Technique to Study Participant Deliberations

One of the first things we noticed using the grapevine technique was that nodes were not evenly distributed along the main stem (Figure 6). There was a much higher abundance of nodes associated with activity in LIT Step 1, whereas there were internode segments of bare stem after LIT Step 1 indicating declining deliberative activity, except for one distinctive surge of activity. The general participation findings in Phase I had shown us that participant activity in terms of numbers participating and average time spent had been gradually declining since the end of LIT Step 1. However, activity increased during LIT substeps 3c and 4a when participants were deciding which projects were best for the central Puget Sound region and which funding options should be used to pay for them. Recall that among quota or paid participants ($n = 179$) the number of people actively participating declined from 60 percent to 40 percent, which gave the late surge that occurred mainly during Steps 3c and 4a (days 23 and 24 of the experiment) a unique importance.

We calculated computer ranks for each visual cue and compared human visual rankings versus computer calculated rankings (see also Aguirre and Nyerges forthcoming). We used a simple MH test to see whether the two different methods of ranking visual cues (1–5) were significantly different. The MH test results indicated that the human visual analyst's rankings and the calculated rankings were not significantly different and in fact were almost identical. After verifying human judgment of productive clusters, we subselected or "harvested" the user-generated content of the highest ranking dozen clusters as the most productive.

Six of the top dozens clusters of deliberation were associated with LIT Step 1 and six were associated with later steps, for a total of 209 individual message exchanges or paired acts of deliberation. Relying primarily on the computer calculations of visual cues, we further subselected forty-five above-average deliberative exchanges and processed the text content using a demo version of a software tool called Connexor (2008). The Connexor software parsed the forty-five messages into 17,145 individual elements of content.

Table 5. The seven main features of the grapevine, in terms of what it represents as a visualization of event-based human-computer-human-interaction (HCHI) activity and expected patterns in productive versus unproductive growth

Feature	What it represents	Productive	Unproductive
A. Main stem	A running average of the locations of the last ten participants who generated a message.	Stem twists back and forth because of rapid message turn-taking from participants at different locations.	Main stem grows straight up with little twisting because of a lack of rapid message exchange or lack of geographic diversity.
B. Node-Internode	A message added along the main stem from a particular location and point in time. Nodes can generate buds if there is a reply.	Many large nodes with short internodes, because participants are rapidly posting messages and voting to agree or disagree.	Few or mostly small nodes are generated, because participants are not posting messages or voting on each other's messages.
C. Bud	A message that at least one other participant replied to with his or her own message. Buds generate shoots and leaves.	Many large buds are generated because many participants are replying to each other's messages.	Few mostly small buds, or a greater proportion of nodes to buds, because participants are not replying to each other's messages.
D. Tendril	A vote to agree or disagree with the message in a node, bud, or leaf. A tendril grows from a node, bud, or leaf to the specific time and location of the voting participant.	Nodes with many tendrils, both short and long, branching out in all directions at a relatively low angle, indicating rapid and geographically diverse voting responses.	Nodes with a few short tendrils branching out in only a few directions at a relatively high angle, indicating delayed and nongeographically diverse voting responses.
E. Shoot	A reply to a bud. A shoot grows from a bud and ends in a leaf at the time and location of the responding participant.	Many shoots both short and long branching out in all directions at a relatively low angle to the bud.	Few or no shoots branching out in only a few directions at a high angle relative to the bud.
F. Leaf	A message sent as a reply. A leaf is generated from a bud and exists at the end of a shoot.	Many large leaves, because participants voted to agree or disagree with a reply.	Few or small leaves, because few participants voted to agree or disagree with a reply.
G. Cluster	A cluster of shared understanding, the proverbial fruits of an analytic-deliberative process. A synthesis of sense and meaning in message exchange, best harvested from productive areas of a grapevine.	Participants balance their discussion energies between posting their own messages or new topics, with replying to each other's messages and focusing on their shared understanding about something in particular.	Participants spend too much discussion energy posting their own messages about unrelated topics, rather than replying to others or discussing their shared understanding about something.

Note: See also Figure 2.

Each individual content element was tagged with detailed information including a unique ID, the cluster and day the element was generated by a user, the numerical order of the element in the sentence, its word base form, and its syntactic relation, syntax, and morphology.

Phase III Evaluation: Grapevine Technique with Content Analysis

The third phase of evaluation focused on content of the forty-five most productive deliberative exchanges. This phase also examined the nature and content of participant deliberations as a result of using technical information in GIS maps or as a result of being more highly engaged in discussions with one another.

We expected that participants would express transportation-related features, objects, concepts, or occurrences in the central Puget Sound region as nouns, either the subject or object of the sentence or of a prepositional phrase within the sentence (Mark 1999; Mark, Skupin, and Smith 2001). The method of content analysis "distilled" important elements of meaning out of a cluster of deliberation, in this case, the most frequently occurring noun base forms. During the forty-five most highly productive discussions, participants mentioned 3,728 unique nouns representing 1,155 noun base forms. For example, the words *bike* and *bicycle* are just different forms of the same base form *bicycle*. After distilling the discussion into noun base forms, we looked at the sentence and phrase context of the original messages to get a sense of why participants were using these words so frequently.

Table 6. A brief description of the visual cues used in tandem with the grapevine technique

Visual cue	Description	What to look for
1	A coiling main stem	If participants interact with rapid turn-taking from many different locations, the main stem twists and turns back and forth with a dense collection of nodes (Figure 6).
2	Many nodes	A productive segment of grapevine will display large nodes evenly distributed (Figure 6). An unproductive pattern in the grapevine as a whole is when only one small segment of the main stem contains a dense distribution of large nodes while the rest of the stem has tiny nodes, indicating unevenly distributed voting activity.
3	Many buds	A productive grapevine will have an abundance of buds, especially large buds, distributed along the main stem, indicating that there was relatively sustained reply activity (Figure 6).
4	An open proliferation of shoots and leaves	A node develops into a bud when other participants reply. A productive bud generates an open pattern of shoots branching off at a low angle to the bud and extending out in all directions, indicating that participants from many different locations replied (Figure 9; see also Figure 5).
5	An open proliferation of tendrils	Tendrils grow up and out from the site of a node or a leaf to the time and location at which a participant voted. Overall, a healthy mixture of long and short tendrils branching out at low angles in many different directions from a large node means participants from many different locations voted on a post or concern and did so relatively rapidly (Figure 9; see also Figure 5).
6	Associated analytic activity	To visually judge what analytic activity a productive or unproductive pattern of deliberative activity was associated with, based on where the majority of participants were at the time, we visually filtered analytic events by Let's Improve Transportation substep.

Phase III Findings: Results of Grapevine-Based Content Analysis

The results of message content analysis indicated that there was a substantial shift in participant shared understanding after the end of LIT Step 1 as a result of analytic browsing and selecting activities. The ninety-ninth percentile of subjects or objects of participant's sentences before the end of LIT Step 1, with a frequency of thirty or more in the first six clusters, included the following ten words with number of times used as the subject or object of the sentence in parentheses (see Figure 7): *bicycle* (ninety-one times), *bus* (seventy-three times), *transit* (sixty-two times), *pedestrian* (forty times), *car* (thirty-nine times), *bicyclist* (thirty-four times), *transportation* (thirty-three times), *people* (thirty-one times), *road* (thirty-one times), and *traffic* (thirty-one times). The ninety-ninth percentile of subjects or objects of participant's sentences in the last six clusters after the end of LIT Step 1, with a frequency of sixteen or more,

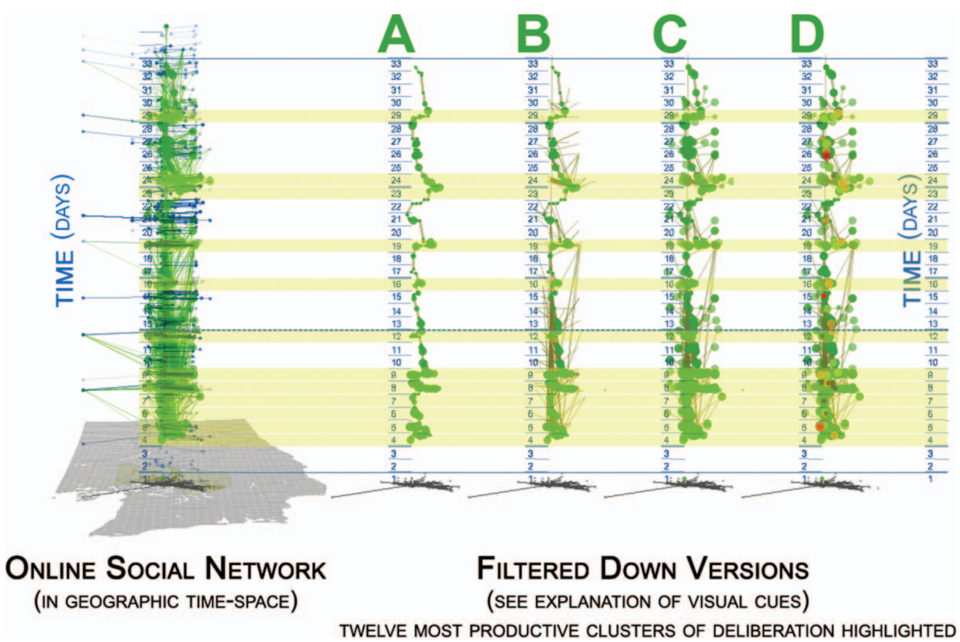

Figure 6. Filtered elements of the grapevine including buds proportional to replies received (A), node-buds proportional to votes received, and shoots (B), same as A but with leaves proportional to votes received (C), same as C with node-buds proportional to votes received and colored proportion to agreement (green) or disagreement (red) (D). Productive clusters are highlighted.

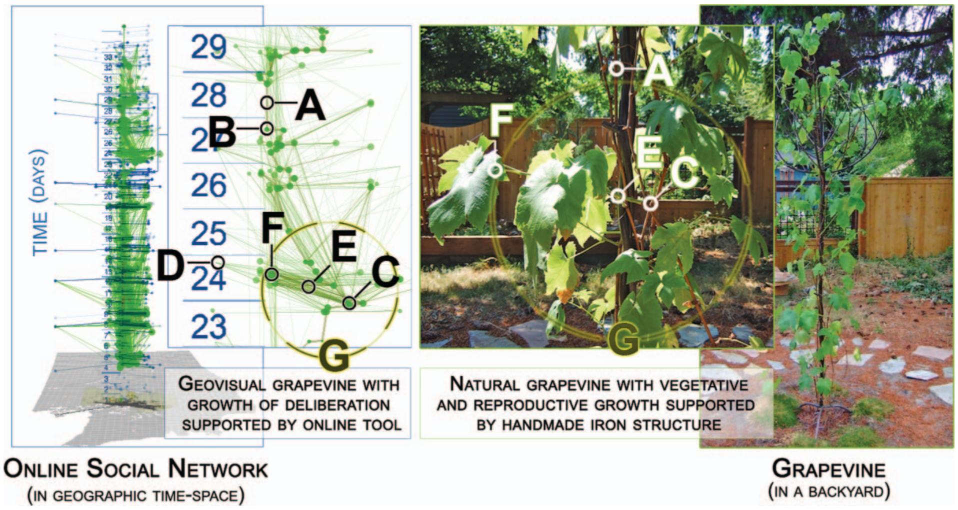

Figure 7. Elements of the geovisual grapevine, in comparison to natural grapevine, including main stem (A), nodes (B), buds (C), tendrils (D), shoots (E), leaves (F), and clusters (G) (see Table 5 for detailed description of each).

included the following six words, also with number of times used as the subject or object of the sentence in parentheses (see Figure 8): *toll* (thirty-six times), *project* (thirty-two times), *package* (twenty-three times), *people* (twenty times), *improvement* (sixteen times), and *tax* (sixteen times). The noun base form *package* was used only once during the most productive deliberative exchanges of LIT Step 1 (Figure 9). Yet package was the third most frequently mentioned subject or object of a participant's sentence (twenty-three times) during the most productive exchanges after the end of LIT Step 1 (see Figure 8).

The observed increase in the frequency of the noun base form *package* suggested that the shift in shared understanding after the end of LIT Step 1 was a result of participant experience using geospatial tools to browse and select projects and funding options to create a transportation project improvement package and not a result of their exposure to things outside of the LIT Challenge. Rereading the original messages with the ninety-ninth percentile subjects or objects of participants' sentences in mind confirmed that the major shift in the frequency of noun base forms corresponded with a major shift in the nature of discussion.

Discussion of Phase III Findings

When asked to deliberate about their values and concerns for improving transportation during LIT Step 1, participants spent their energies discussing alternate

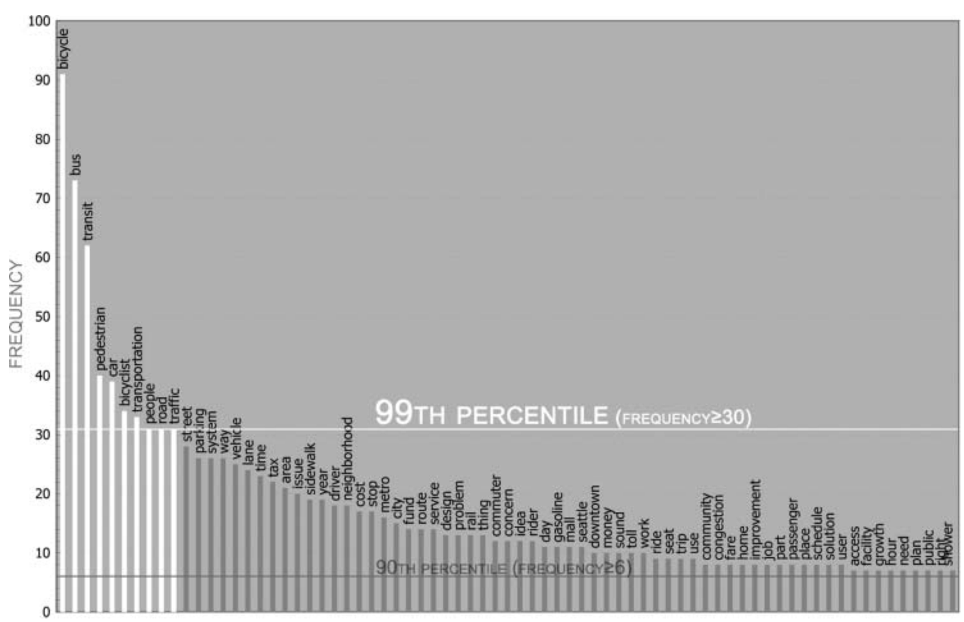

Figure 8. Frequency of top ten noun base forms used as the subject or object of a sentence during message exchanges during Step 1 within first six clusters.

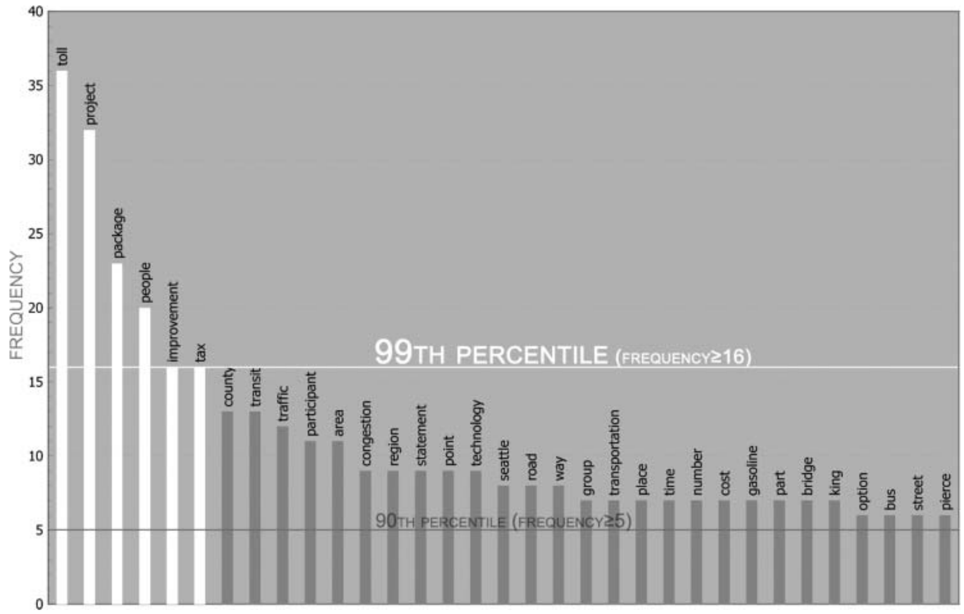

Figure 9. Frequency of top six noun baseforms used as the subject or object of a sentence during message exchanges after Step 1 within last six clusters.

modes of transportation like bicycle, bus, or rail in a broad discussion about ways of reducing car traffic and thus reducing the need for expensive road projects. Participants were fairly productive when they were asked to exchange messages about past personal experiences with the region's transportation system, a task meant to add as much breadth and depth as possible to group categories of concerns. In some cases, the first rounds of daily message exchange during LIT Step 1 might have also served as an opening display of a participant's factual knowledge about the origins and possible solutions to the region's transportation problems.

After LIT Step 1, participants had to perform a spatially enabled transportation planning analysis and then discuss their choices. Participants selected a set of improvement projects and then used different funding options to pay for their preferred projects. In many cases, the most frequently occurring noun base forms, like *toll*, were used as part of a simplifying assumption by the participant. A simplifying assumption might make reference to factual evidence from analysis or local knowledge, a logical understanding, or simple intuition, but it is "simplifying" because it is not a qualified statement specifying why it might not apply in all cases at all times. What was particularly interesting was when participants discussed simplifying assumptions and omissions not only in each other's work, because each participant was expected to play the role of transportation planning analyst, but in the expert transportation analysis itself.

The most productively scaled clusters of deliberative activity after LIT Step 1 suggested that participants were interested in exchanging and negotiating simplifying assumptions about funding options. The fact that participants deliberated about the selection of funding options more than improvement projects indicated that participants could more easily match simplifying assumptions about different funding options to their personal values. In other words, participant energies were able to latch onto the funding option portion of the transportation planning analysis more than any other task in the analysis they were required to do because they could clearly see where simplifying assumptions and omissions about funding affected their personal values. Participants seemed to see the choice of funding options as a larger social issue of equitably spreading enormous cost burdens, as well as an activist opportunity to force people to reevaluate the region's emphasis on roads rather than public transit and traffic-reducing measures.

For example, User 1148677 posted a message (ID 1201078) with at least two simplifying assumptions about the choice of tolls as a funding option for the final packages:

> I am a bit unsettled about the inclusion of so many *tolls* in these packages—$5.25 for I-5 north of 90?? $4.00 to cross 520?? I understand money is trying to be raised here but there are other means of doing so. **Personally, I don't think *tolls* are a logical choice if we're trying to improve transportation, as this will mean everyone will have to slow down at the *toll* plaza to pay (or have their**

GoodToGo pass scanned) and this will simply bottleneck traffic and create more congestion. I mean, 520 is a headache during rush hours; 167 is a mess without tolls; 405 . . . yikes! **On the plus side, if heavy *tolling*were to materialize, I am sure more people would be inclined to take the bus or carpool to their respective destinations.** However, with our region's population expected to double (or more) in the next five years, I would prefer to see a *toll*-less revenue collection system. It can be done—in my package, I included 22 proposals for a cost of $7 billion—without a single *toll*!" (bold emphasis added, *toll* base form italicized)

User 1148677's two simplifying assumptions, emphasized in bold, are that (1) tolls will create a traffic bottleneck and congestion because everyone will have to slow down but (2) heavy tolls will encourage more people to take public transit or carpool. Even though User 1148677 was unsettled by the number of potential tolls and did not use tolls as a funding option in their improvement package, their simplifying assumption was that heavy tolling would generate the positive outcome of taking cars off the road and making more people use carpools and public transit.

User 57456 was one of those who replied to the preceding message, broadly challenging any skepticism about tolls by introducing a contrary set of simplifying assumptions:

> I'm really tired of the Northwest/Seattle attitude of "it couldn't work here"—***tolls* are extremely effective in other parts of the country, and while nobody loves paying *tolls*, they are a fair revenue source and the closest thing to an honest use-tax we've got—they also change behaviors, foster density, and provide jobs and opportunities for technological innovation**. We need to stop making this silly argument that we're so special that nothing other than endless increases in sales taxes, gas taxes, and magical mysterious windfalls will solve all our problems. **You'll also note that in the states that have *tolls*, there is a state sales tax, gas tax, property tax, income tax, and sometimes even a city or county tax—but in those places, believe it or not, the tax burden on the majority of people is *lower* than it is on people in this region**. The main reason this has stayed the same in WA is because of our backwards, provincial attitude of "being different"—so different we price our working classes out of living in the place they helped build in the first place. (bold emphasis added, *toll* base form italicized)

User 57456's simplifying assumptions are that (1) although nobody loves paying tolls they have been "extremely" effective in other parts of the country, tolls are fair, and tolls create positive outcomes; and (2) in states that use tolls taxpayers actually pay less. User 57456 does not discuss what conditions might impact whether tolls are extremely effective or merely moderately effective, which parts of the country are being referred to, or, finally, whether tolls always produce positive outcomes or only under special circumstances. User 57456 simply makes the case that the population of the central Puget Sound region has been unwilling to accept tolls because of a provincial Pacific Northwest attitude.

Conclusion

Under decision-making conditions where an analytic-deliberative process is desirable, necessary, or mandated, online technologies are expected to scale public participation out to larger numbers of people and up over wider regional areas while maintaining a high level of technical information. Client–server or client-side interaction event data can provide meaningful inferences about the quality of public participation in analytic-deliberative decision-making situations when scaled to hundreds and triangulated with self-reported information or in-depth interviews. Thomas and Cook (2005) and Andrienko et al. (Andrienko, Andrienko, and Gatalsky 2003; Andrienko et al. 2007) called for research about group-based geovisual analytic investigations to unpack problem-solving processes. The NRC (1996, 2005) reports called for systematic investigations about appropriate balances between analytic and deliberative activities. This study addresses the NRC's calls by examining the analytic-deliberative process at multiple levels of event granularity. The analysis at different levels of granularity shows that computer-supported semantic integration could be used productively to "scale" meaning syntheses for asynchronous deliberations, with visual tools developed in a similar way used for face-to-face sense-making (Keel 2007).

By supporting an analytic-deliberative process with geospatial analysis tools, the LIT PPGIS platform seemed to refocus broadly based participant energies on deliberating about the analysis. Among large groups, natural participant deliberative energies have to be unleashed in the public participation process, but the growth of the discussion should be trained to latch onto an analytical support structure so that it does not grow off in every direction and ultimately collapse and to focus deliberative energy to produce clusters of deliberation about an analysis. Just like in a vineyard, or even just a grapevine growing in your backyard, the moderated analytic-deliberative process in later steps of the

LIT Challenge successfully trained participant deliberative energies to latch onto the GIS-based analytic support structure provided by the transportation package analysis. When participants were asked to browse and select from among a set of improvement project and funding options using GIS-based maps, participants refocused their deliberation on simplifying assumptions and omissions particularly about the funding options component of the analysis in LIT Step 5, rather than continuing as they had in LIT Step 1 to contribute to the growth of a broad and unattached discussion about personal values and concerns. To deal with their uncertainties about what to select, participants resorted to discussing and sharing simplifying assumptions based on their own expertise about what would or would not solve the region's future transportation problems more efficiently, effectively, or equitably. Key to identifying patterns in participants' shared, negotiated, or debated simplifying assumptions were the most frequently occurring noun base forms that acted as the subject or object of the sentence or prepositional phrase within the sentence.

The most productive clusters of deliberation after LIT Step 1 occurred when there was a spirited negotiation about which simplifying assumptions should stand and which should fall. Interestingly, not only did participants interrogate each others' simplifying assumptions or omissions, but they also interrogated those of the transportation planning analysis they were given as well, often revealing that the reason why was because it just did not fit with their values about things like distributing costs fairly. Simplifying assumptions that were persuasive or stood the test of debate could be used to justify a particular transportation package. As indicated by voting, participants tended to agree with each others' simplifying assumptions more than disagree, which might have been the emergent group deliberative strategy for coming to a consensus quickly about the best overall transportation improvement package given either the limited amount of time participants had to discuss their packages, the perceived need to vote and reach a consensus on a transportation, or perhaps simply because of participants' fatigue with the month-long public participation process.

Future insights about multiple dimensions of people, process, and technology could make use of additional broad-based framing. Future directions for examining how to scale out, up, and higher online analytic-deliberative processes could benefit from reexamining the relationships among advocates and practitioners of PPGIS who (1) build new technology capable of hosting larger scale decision venues, (2) recruit and engage a diverse public to use those systems, and (3) use social and behavioral science methods to evaluate those systems. To address those relationships we are beginning to draw on a new PPGIS framework we call *participatory interaction modeling*. A major challenge in participatory interaction modeling is to understand how PPGIS developers, users, and evaluators actually work together to tighten or close the loop of their interactions and create more effective or socially adaptive online systems that, in turn, work better for larger social goals. Such a tightening of interaction can add to a science of human–computer–human (participatory) interaction design (Pirolli et al. 2002; MacEachren 2005; Thomas and Cook 2005; Andrienko et al. 2007). We expect that such a framework will help us explore many of the nuances of analytic-deliberative decision processes, but as we develop the framework we hope that such a framework can help others as well, regardless of the type of geospatial decision support processes, participants involved within the process, and the geospatial technology being developed and evaluated.

Acknowledgments

This research was supported by National Science Foundation Information Technology Research Program Grant No. EIA 0325916. Support of the National Science Foundation is gratefully acknowledged. We would also like to acknowledge the PGIST research team and especially Piotr Jankowski, Michael Lowry, Arika Lingmann-Zielinska, Michael Patrick, Kevin Ramsey, Martin Swobodinski, Zhong Wang, Matthew Wilson, Jie Wu, and Guirong Zhou for their contributions to a completed system and the approaches we discussed relative to evaluation. We thank the reviewers for their thorough critique of the manuscript drafts. The authors are solely responsible for the content.

Notes

1. There are four general settings for any field experiment, derived by cross-tabulating how participants interact in time (synchronous or asynchronous) and space (presence or telepresence-online) as outlined by Jankowski and Nyerges (2001). These four general categories of experimental setting have appeared in many different forms in the literature; see Miller (2007) for other approaches.
2. For comparison, an ongoing survey of more than 2,000 individuals in the United States by the 2008 Digital Future Project reported that the average Internet user to

date spends about 15.3 hours every week online (Center for the Digital Future 2009).

3. The MH test uses the chi-square distribution and is useful for distinguishing changes in questionnaire response due to experimental treatments in pre- and post-test sample designs when assumptions of normality cannot be met. In most cases, a parametric paired-sample *t* test would be the appropriate test for a pre–post study. Because variables in a questionnaire are self-reported ordinal ranks, differences between reported values are arbitrary, so use of a nonparametric test is more appropriate.
4. Any MH test result for paired questions of less than 0.05 (asymptotically significant, two-tailed < 0.05), which measures the probability of obtaining a chi-square as extreme in repeated samples if the difference was merely random, would mean that participant's responses before versus after using the LIT PPGIS platform were significantly different.
5. Compared with their expectations before using the LIT PPGIS platform, after using the LIT PPGIS platform participants responded more negatively to (1) having an interest in these kinds of discussions on the Internet (asymptotically significant, two-tailed = 0.022, Std. MH statistic = 2.286), (2) believing that discussions they have with other participants in the LIT Challenge will help them understand transportation problems and proposed improvements in the central Puget Sound region (asymptotically significant, two-tailed = 0.000, Std. MH statistic = 3.922), and (3) expecting that their own opinions about transportation issues in the central Puget Sound region might be shaped by participating in the LIT Challenge (asymptotically significant, two-tailed = 0.000, Std. MH statistic = 3.923).
6. For preliminary purposes, we decided that any other event type than those indicating the five listed deliberative activities would be provisionally classed as an analytic activity.

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