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Integrating Participatory Mapping Through a Web Application to Enable Public Involvement in City Planning: The Portneuf River Vision Study

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Abstract

This paper presents a conceptual framework for developing an online public participation geographic information system (PPGIS) to support community engagement in collaborative planning with stakeholders. Its basic characteristics include a lightweight, open internet standard data format GeoJSON (JavaScript Object Notation for geographical features), asynchronous communication between web browser and server, and open source server scripts using PHP and Python. This readily adaptable framework provides viewers with real-time processing and display of geo-comments, and preliminary descriptive statistics of participating social groups based on location and commentary themes. Visualizations are in the form pie charts and word clouds, which are understandable for a wide variety of non-expert GIS and/or urban planning users. This framework can also handle concurrent and multiple user requests. The advantage of this PPGIS web-based mapping application is that any web server can implement the workflow, and its real-time feedback feature supports the monitoring of social groups' participation.

Keywords:

PPGIS, participatory mapping, urban planning, river restoration, ecosystem services

1 Introduction

Public involvement in the planning process traditionally relies on community meetings to present static maps and documents, with public feedback collected through surveys. Since urban planning relies on spatial representation (Elwood, 2006), Geographic Information Systems (GIS) were adopted as an efficient method as well as a powerful tool for presenting and visualizing maps. When GIS are integrated with Information and Communication Technology (ICT) tools, the product can offer the digital infrastructure necessary for spatial planning involving public participation (Voss et al., 2004). One of the early PPGIS studies, the Virtual Slaithewaite project (Kingston, Carver, Evans, & Turton, 2000), enabled web browser commentary based on map features for a two-way flow of information, as participants could query features, zoom in and out, as well as leave feature-based commentary. Thanks to improvements in internet-enabled online collaboration (Goodchild, 2007; Kingston et al., 2000), widespread use of mobile devices (Simao, Densham, & Haklay, 2009), and the advent of social networks and communication tools, customized web applications using Public Participation Geographic Information Systems (PPGIS) (also referred to as Online PPGIS or e-planning; Steiniger, Poorazizi, & Hunter (2016)), have been widely employed. PPGIS and visualizations have been used extensively to aid in the planning process by facilitating widespread sharing of geospatial data (Bugs, Granell, Fonts, Huerta, & Painho, 2010; Nyerges & Barndt, 1997). As a forum for exchanging ideas (Elwood, 2006), PPGIS allows users to perform simple spatial queries and append attributes to features. Moreover, PPGIS provides spatial information, broadens public involvement, promotes goals, and is able to collect local data from various local social groups (Ganapati, 2011; Renee, 2006; Tulloch, 2003).

PPGIS geo-related online commentary is emerging as an effective method for gathering community feedback to aid the decision-making process and improve outreach (Kingston et al., 2000; Moulder, 2010; Simao et al., 2009). Participants enter comments, which are geo-tagged and submitted directly to a server. However, PPGIS also faces challenges to provide equal access at grass-roots level (Ghose, 2001) and for traditionally marginalized citizens (Ghose, 2005; Ghose & Elwood, 2003). A PPGIS application with the functionality of actively monitoring social group participation would be helpful to identify societal elements missing from public engagement, and is something this study addresses. Customized PPGIS web applications can integrate server-hosted spatial data and GIS functionalities (Kingston et al., 2000; Lu, 2006). There are several approaches to accommodate PPGIS applications that use feedback mechanisms. These approaches include using a Geodjango framework and Postgres database with a PostGIS extension on the server side (Czepkiewicz, Młodkowski, Zwoliński, & Jankowski, 2015), and JavaScript frameworks JQuery, OpenLayers and HTML on the client side. Further options include using an open source platform such as Elgg with multiple functionalities to offer problem-exploring opportunities for technology-savvy citizens (Steiniger et al., 2016), or Google API in conjunction with a MySQL database system (Pődör, Révész & Rácskai, 2016). However, these approaches require high levels of computer knowledge and resources that decrease their accessibility for use by stakeholder groups.

Esri's ArcGIS Online Web AppBuilder tool enables a simple implementation of cloud-based online mapping applications and leverages web feature layer hosting capabilities, e.g. view, edit, analyze and query (Fransen, Verrecas, De Maeyer, & Deruyter, 2014; Hu, Janowicz, Prasad, & Gao, 2015). The tool also allows user interaction with text, photos and drop-down menus that can be created by developers without previous software programming expertise. However, ArcGIS online Web AppBuilder lacks the flexibility to customize data display, especially when integrating more traditional survey questions with web-mapping user input. This study addresses this shortcoming with a simple and flexible tool that is compatible with Esri resources (ArcGIS Online web feature services, and ArcGIS services from an in-house ArcGIS server).

The web-mapping tool for integrating public surveys with PPGIS functionality developed for this study is referred to as the MILES (Managing Idaho Landscapes for Ecosystem Services) online comment tool (MOCT). MOCT is a pilot PPGIS effort to serve as the communication platform between various social groups interested in river re-development in a mid-sized Intermountain West city, Pocatello, Idaho. Politically and socially, the region is largely conservative (Lybecker, McBeth, & Stoutenborough, 2016). For the purposes of this case study, we identified social groups from census block data for educational level, income and age; from county parcel data, we used average assessed housing value and the percentage of residential parcels by census block.

Our trial of MOCT was implemented through the city of Pocatello's website from January 13, 2016 to August 10, 2016 and provided an equal (open to governmental agencies, stakeholders and the general public) and dynamic access to spatial data (to explore, compare maps, query, upload and review comments). Traditional surveys are subject to misrepresentations of responses to sensitive questions, such as requiring participants to enter age and income, questions which also tend to produce a high non-response rate and a high number of measurement errors (Tourangeau & Yan, 2007). To address this concern, MOCT geographically relates the census block to participants' neighborhoods and uses this location-based input to characterize in real-time social group participation based on educational level, income and age.

PPGIS typically involve complex database implementation for data retrieval and analysis, as well as a web administrator, for reviewing user interaction and handling information exchange between client and server (Flemons, Guralnick, Krieger, Ranipeta, & Neufeld, 2007). The concurrent editing of multiple databases involves serialization of updates on servers and, for SQL databases, assigning user roles. Some prototypes require participants to log into the system for security reasons, which adds an extra level of effort for participants, especially for those who lack computer skills. These factors can be significant barriers to stakeholder implementation. To solve these and other challenges such as real-time comment reviewing and monitoring user participation according to social groups, this project had three goals: (1) to create a customized, efficient and user-friendly online mapping tool template with simple PPGIS user-interaction options; (2) to enable real-time tracking of geo-comments and monitoring of user participation based on location, and (3) to develop a platform requiring minimum administration for tool implementation. Our research question for this case study was to determine whether social group participation could be monitored over the duration of the study by using location-based information from participants integrated with census data. MOCT addresses criticisms of bias in PPGIS participation and ameliorates reluctance of participants to provide personal data such as income (Ghose, 2005; Ghose & Elwood, 2003; Tourangeau & Yan, 2007). Researchers can monitor whether certain social groups are over-represented and facilitate outreach to under-represented communities, thereby ensuring broad-based participation.

2 Methods and Materials

Application Background

MOCT is an integration of GIS web-mapping applications with public involvement for the Portneuf River Vision Study (City of Pocatello, 2016). The Portneuf River is a tributary of the Snake River in southeastern Idaho, USA. The city of Pocatello is located on the southern edge of the Snake River Plain and is representative of medium-sized cities; it is surrounded by agricultural lands and wilderness regions. A series of large flooding events in Pocatello in 1962 and 1963 prompted the Army Corp of Engineers to expand the flood control program in 1965 by constructing a concrete channel (MILES, 2015; Stoutenborough, 2015a, 2015b). The concrete channel and levee channelized approximately 4.1 miles of the Portneuf River waterway on the west side of Pocatello (Lipple, 2015). Subsequently, changes in ecosystem processes in the Snake River basin, such as nutrient loading, sediment accumulation and bank erosion, have raised aesthetic and public health concerns (DEQ, 1999; Hopkins, Marcarelli, & Bechtold, 2011; Marcarelli, Bechtold, Rugenski, & Inouye, 2009). These negative impacts prompted a visioning effort by the city to engage the community in redesigning the city's river corridor.

In 2016, the city of Pocatello, with support from the U.S. Army Corps, initiated the Portneuf River Vision Study to develop recommendations for restoration along portions of the concrete channel for a more natural, aesthetic and accessible river channel. This initiative's goals are to revitalize environmental, recreational and economic opportunities, as well as to increase community pride, connectivity and quality of life (City of Pocatello, 2016). Public involvement is a vital component of the visioning process to determine the Portneuf River's future. Researchers on the MILES project work with the city of Pocatello to conduct surveys and collect environmental data to support the visioning effort. The research objective is to study the changes of ecosystem services in medium-sized urban/rural communities in Idaho, in addition to the social and natural drivers behind these changes. The project's ultimate goal is to develop science-based tools for sustainable ecosystem services management.

System Design and Data Sources

MOCT was a web-accessible PPGIS used to gather comments from the community, during the period January 13, 2016 to August 10, 2016, to address the Portneuf River Vision Study's goals. MOCT provided user interaction, allowing information from current and historical data layers related to the visioning effort (Table 1) to be queried. MOCT was hosted at Idaho State University and embedded in the city of Pocatello's Portneuf River Vision Study website (http://river.pocatello.us/); it has several tabbed information links on history, and on concerns such as sedimentation, water quality and transportation relating to the Portneuf River. The survey page of MOCT was of a simple design with an easily recognizable map to attract people with varying levels of computer skills. The tool could be accessed from a computer, laptop or mobile device. Interaction is intuitive and user-friendly, and offers quick response times. MOCT is currently archived at (http://miles.giscenter.isu.edu/PokyMap/comment.html) and available for download, with instructions for server deployment, through Github (https://github.com/delparte/MILES).

Table 1: Geospatial data layers in chronological order used in MOCT.

Geospatial data layer	Feature	Source	Year
Portneuf River 1889–present	Polygon	Union Pacific Railroad Survey Maps (1889–1941) Historical Aerial photographs (1941–1985) National Agricultural Imagery Program (1990–present)	Since 1889
Census blocks/ Neighborhood	Polygon	US Census Bureau	2010
Flood potential	Polygon	Federal Emergency Management Agency	2011
Portneuf River	Polyline	National Hydrology Dataset	2011
Bannock County parcel data	Polygon	Bannock County	2014
City Creek trails	Polyline	MILES	2014
Existing river access	Point	City of Pocatello	2015
Pocatello zoning	Polygon	City of Pocatello	2015
Portneuf Greenway	Polyline	City of Pocatello	2015

All geospatial layers were served from an ArcGIS server located at Idaho State University's Pocatello campus, but could just as readily be accessed via ArcGIS Online or other cloud-based web feature services. Based on feedback from Pocatello city planners, these layers were selected as relevant for soliciting comments for the Portneuf visioning effort. The data layers in Table 1 were prepared in ESRI ArcMap and published as map services to the in-premises ArcGIS Server. We chose an ArcGIS implementation as it is a ubiquitous software in government and academia that can leverage both open source and proprietary web feature services from a variety of hosts.

System architecture

MOCT is a web-based system employing a client–server architecture that uses a customized ArcGIS JavaScript API integrated with ArcGIS server web feature services for survey responses and map visualization. On the server side, GIS layers were accessed through

ArcGIS services and an SQL-sponsored database. Data transfer was handled by AJAX (Asynchronous JavaScript and XML) using HTTP-based XML HttpRequest protocol (Sayar, Pierce, & Fox, 2006) and PHP scripts in GeoJSON format (Figure 1). The GeoJSON format collects all the information from the user comments tool and saves it as a single JSON file on the server as a string of text and submission times. The file-naming format followed the metadata standard by Federal Geographic Data Committee (FGDC, 2005) and ISO 8601 data elements and interchange formats (ISO, 2017). An example of a file name is '2016-02-10-16-11-47', which means the comment submission was made on February 10, 2016 at 16:11:47. Using this naming system, MOCT was able to incorporate multiple user interactions at one-second time intervals. To deter spambot entries, an invisible text field was added. Bots have difficulty recognizing invisible fields in JavaScript, thus if values are recorded in the hidden field they are automatically discarded.

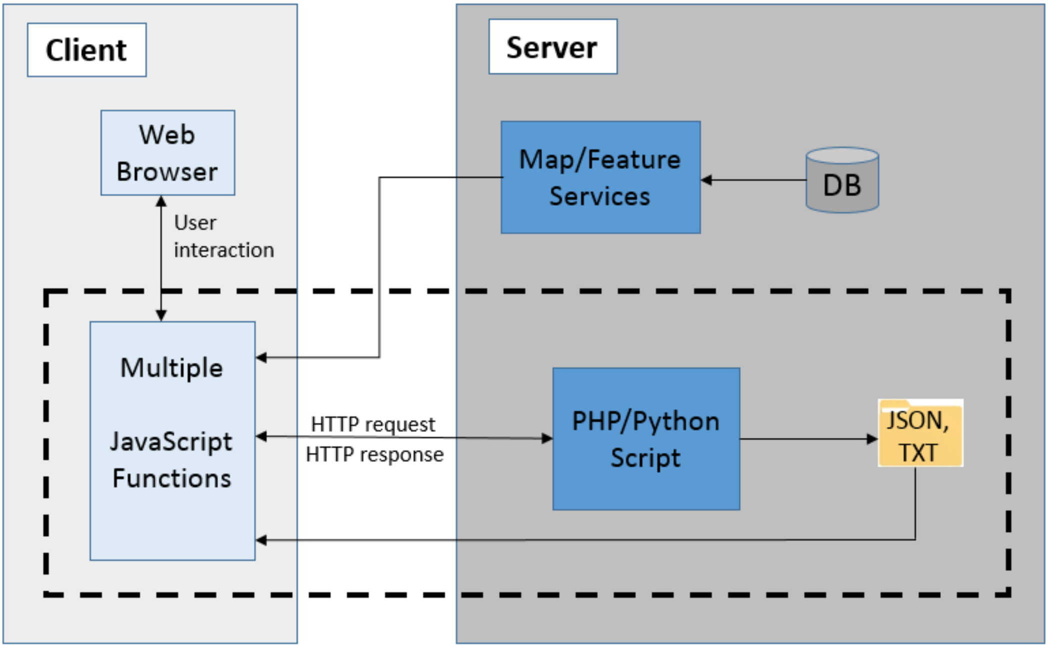

Figure 1: MILES online comment architecture overview. The components within the dashed box can be implemented on any web server.

Map visualization of the user interface involved loading map services from the ArcGIS Server or cloud-based services using ArcGIS JavaScript API. A Python script on the server manipulated the data file and then processed the data to create a preliminary result on the server. The data transfer, comment and statistic result display were coded in HTML pages using query AJAX HttpRequest, JavaScript script packages (Coopey, 2016; Laframboise, 2013) and Highcharts. These pages were made for dynamic real-time user review. The server operating system was Windows Server 2012 Standard with six 1.90 GHz virtual processors, 49 GB RAM, and a 1GB Ethernet connection. The server was licensed to include map and feature services that were sponsored by a standard SQL server. User operation such as query, add, delete and edit could be performed and saved in the SQL database. Microsoft's Internet Information Services (IIS) for Windows Server was also enabled on the server.

Public Participation

Key PPGIS functions of MOCT allow participants to: zoom in and out of the area of interest; add in geotagged points that have an ecosystem services theme along with a personalized comment; turn layers on and off; perform simple spatial queries; identify their neighborhood area of residence; review all historical comments in both text and GIS map; view pie charts of comment type; view a word cloud generated from entered comments, and view column charts of the top participating neighborhoods. Tooltips appear when the user hovers the mouse over the comment collection area on each page. The geospatial layers appear in a mapping window during user interaction, data transfer, and background data processing. A basic map operation tool is available for detailed examination of the geospatial layers, including by zooming and panning. Optional base-map layers and additional geospatial data layers were made available, according to a user's selection.

MOCT allows users to choose a location on the map and record a geo-located comment (Figure 2a). They can also categorize their comments into one of eight themes. 'River access' is defined as points where the public would like to access the river for recreation (e.g. wading, tubing downstream or fishing). 'Water quality' refers to the nutrient and sediment load, and 'water level' is the total water volume or flow of the Portneuf River. The other themes are 'recreation', 'transportation', 'habitat' and 'beautification'. Comment types outside these themes were categorized as 'Other' in the drop-down menu. Users can also enter multiple points and a comment for each. A map legend (Figure 2b) allows users to reference map symbology and turn data layers on and off.

Users identify their neighborhood by drawing a square in the map window. A box selection avoided pinpointing a user's home directly. A Python script sorted through neighborhood data strings based on finding the center-point of the neighborhood from the square that participants drew on the map. To guarantee input data completeness, a filter provided an information box that reminded users if they accidentally submitted an incomplete comment. When the comment was submitted, it appeared at the bottom of the user comment tab. The last step was reviewing historical comments, which directed users to a community feedback page with an ESRI topographic map and multiple point features representing geo-related comments (Figure 2c). Upon clicking on an individual point feature, an information box appeared displaying the comment attached to the feature. A chart button on the community feedback page redirected users to a results page with three panels. The top panel is a pie chart (Figure 2d) with percentages of each comment type relative to the total number of comments. The middle panel shows the top 5 participating neighborhoods (Figure 2e), sorted according to the frequency of participants in the neighborhood. The final panel is a word cloud (Figure 2f) of 100 of the most frequently used comments. Finally, a text file of all comments can be viewed in html (Figure 2g). Instructions for participants using MOCT was provided on the website along with a training video to show them how to enter comments and review feedback. (https://www.youtube.com/watch?v=lukXACrKiYM)

Social Groups

Census blocks were derived from TIGER (Topologically Integrated Geographic Encoding and Referencing) products and collated with 2010 demographic information from the U.S. Census Bureau. Sixty-four census blocks covering urban and rural areas of Pocatello were selected for this study. Educational background for the population aged 25 years and over, household income in the past 12 months, and age were assessed in each individual census block in order to describe residents' social groupings. In addition, assessed housing values, which is calculated by an assessor on a yearly basis to levy property tax for municipalities, were extracted from Bannock County parcel data. Percentage of residential parcels was also derived from parcel data. The census blocks correspond to neighborhoods, and the frequency of respondents from within these boundaries was recorded in real-time by MOCT. Although we selected only these basic social indicators, future studies or other users could readily adopt other location-based metrics and boundaries to further define social groupings, including those based on results from residential surveys. For example, the City of Pocatello included a survey in their monthly water, sewer and waste collection billing to solicit feedback on redevelopment of the river corridor. The responses highlighted residents' concerns with respect to categories focused on environmental quality, water quality and recreation, revealing that neighborhoods had differing priorities.

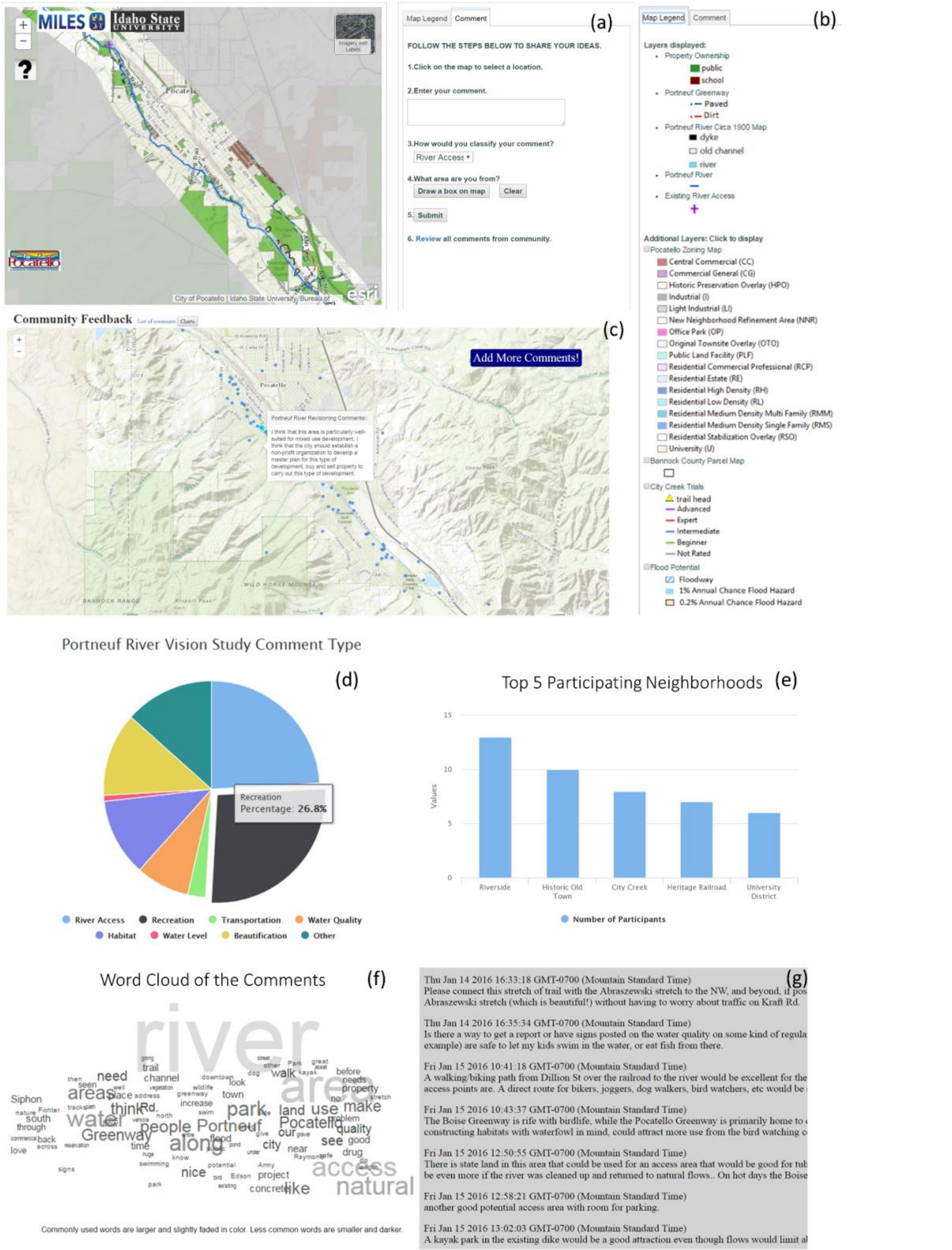

Figure 2: MILES online comment map tool (MOCT) components. (a) Case study map and comment input. (b) Map legend. (c) Comment display window. (d) Percentage for each comment theme. (e) Top 5 participating neighborhoods. (f) Word cloud displaying frequency of words from comments. (g) Text file of all comments.

3 Results

Promoting the usage of MOCT among Pocatello's residents was essential to the overall success of the project. Peaks in user comments corresponded to workshops, environmental fairs and open-house events at which computer tablets were made available for users to enter feedback (Figure 3).

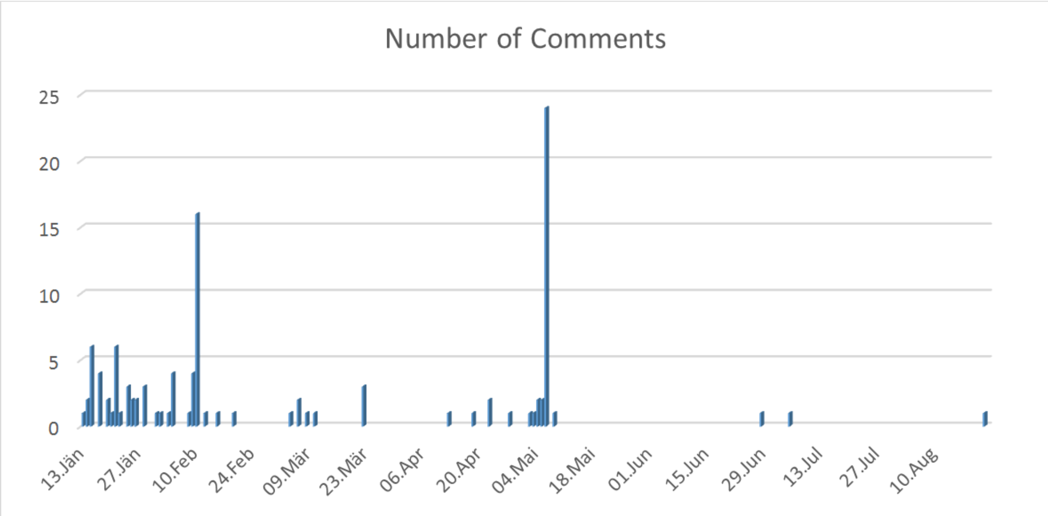

Figure 3: Number of comments submitted from January 13, 2016 to August 10, 2016. High numbers (over 10) correspond to workshops, open-house events and lecture sessions at which computer tablets were made available for attendees to submit feedback.

By the end of August 2016, there was a total of 111 comments. Riverside (14%), Historic Old Town (11%), City Creek (8 %), Heritage Railroad (7%) and University District (6 %) were the top five participating neighborhoods. Recreation was the most prevalent comment theme (26.8% of all responses) followed by River Access (24.1%), as shown in Figure 2d. The remaining 54% of comments came from users in other neighborhoods, who represented less than 5% of the total number of respondents. The highest word frequencies from the comment texts included river, area, access, natural, water, park and greenway (Figure 2f), which reflected users' concerns about the river, nearby greenways and river access. The comments also covered a wide range of problems related to safety, history, and the economic health of Pocatello.

Census information was summarized for respondents from all neighborhoods combined and from the top five participating neighborhoods (n > 5) to describe the predominant social characteristics based on income, age and educational level (Figure 4). The top participating social group, based on the average of all respondents across all neighborhoods, was characterized by residents with an educational level that included at least some college-level studies, up to higher-degree level (65%) (Figure 4a), a household income of less than $40,000 (72%) (Figure 4g), and aged 40 or over (more than 50%) (Figure 4m). This was an overall indicator that the majority of participants were coming from neighborhoods associated with a fixed income. As another example, the Riverside neighborhood has the highest average household income of all top participating neighborhoods (Figure 4h), the highest population of under-18s (29%) (Figure 4n), a substantial population of 40- to 60-year-olds (37%) (Figure 4n), and an educational attainment level of an associate's degree or higher (50%) (Figure 4b). In general terms, the social group of Riverside is dominated by middle-class working families (middle-aged parents with a higher educational background who have children under 18). In comparison to Riverside, the University District is where Idaho State University is located, indicating higher educational attainment (Figure 4f); however, the income level is lower (Figure 4l).

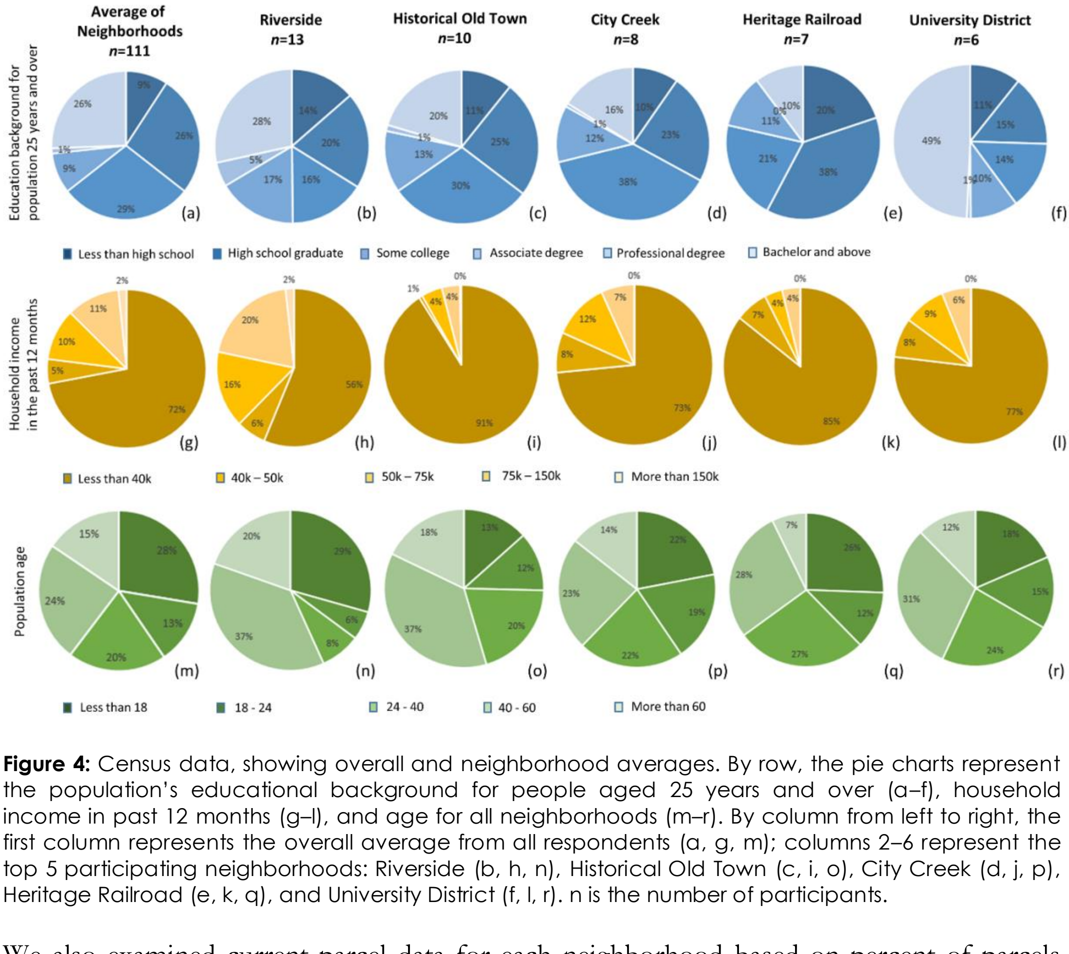

Figure 4: Census data, showing overall and neighborhood averages. By row, the pie charts represent the population's educational background for people aged 25 years and over (a–f), household income in past 12 months (g–l), and age for all neighborhoods (m–r). By column from left to right, the first column represents the overall average from all respondents (a, g, m); columns 2–6 represent the top 5 participating neighborhoods: Riverside (b, h, n), Historical Old Town (c, i, o), City Creek (d, j, p), Heritage Railroad (e, k, q), and University District (f, l, r). n is the number of participants.

We also examined current parcel data for each neighborhood based on percent of parcels zoned as residential and average estimated value of residential properties (Figure 5). Of the top five participating neighborhoods, Riverside and the University District were the neighborhoods with the highest number of parcels zoned as residential (84%), and the highest estimated housing values. City Creek and Heritage Railroad have a more mixed development, with 73% and 75% residential parcels, respectively. Historic Old Town had the lowest residential parcel percentage at 60%. The lowest median house estimated value was $73,639, in the Heritage Railroad neighborhood. Of the top participating neighborhoods, only Riverside had a median house estimated value ($122,325) that exceeded the city median estimated value.

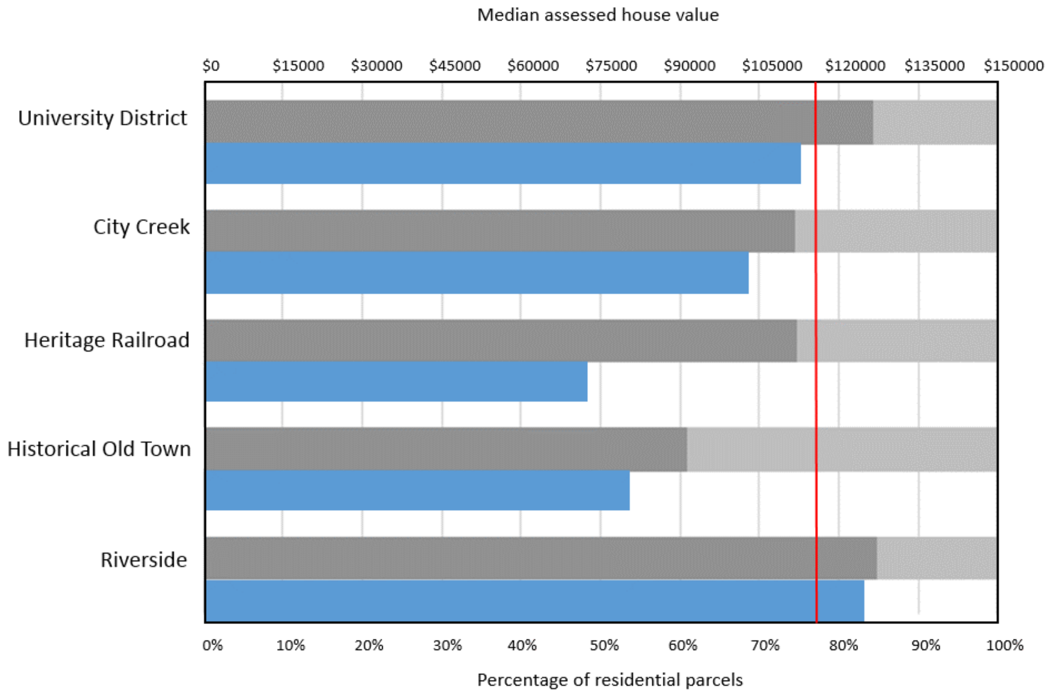

Figure 5: Percentage of residential parcels (gray bars) and median estimated housing value (blue bars) in the top five participating neighborhoods. The red line indicates the median estimated house values for the entire city of Pocatello ($118,607).

4 Discussion and Outlook

This case study focused on the design and implementation of a simple PPGIS. Its goal was to support community planning for the Portneuf River visioning process by reaching the widest possible number of social groups in the community. This goal was realized by collecting, displaying and analyzing public participants' location-based comments. MOCT has several advantages over other web-based mapping tools that solicit participant input. These include its user-friendly interface with straightforward interaction options that individuals with limited computer skills can use. MOCT's real-time feedback also has multiple advantages for participant-driven spatial decision-making tools. For example, real-time feedback enables transparency of communication and can facilitate the sharing of ideas between stakeholders and social groups. The MOCT design allows participants to view other participants' location-based comments, as summarized in a graphical representation by comment theme, and by word frequency extracted from comments entered. Up-to-date community feedback that reflects community input provides on-demand information to planners and developers. Users are also able to see that their comments immediately change the graphics through the webpage of tool visualization. This user experience visually highlights the importance of participation, enhances the user's sense of contribution to the outcome, and potentially increases overall user satisfaction with the process.

Monitoring the frequency of participation by neighborhood allowed assessment of participation based on the geographic proximity of respondents to the proposed river development. The integration of census data also provided insights into social group characteristics. Census data has been used for the past 10–15 years as an indicator of socio-economic status based on neighborhood, as a person's choice of residence is a useful proxy for social class and position, especially in North America, where neighborhoods tend to be more socially segregated (Oakes & Andrade, 2017). Household income, educational attainment and median housing values are commonly used social indicators (Roux et al., 2001). Our results revealed social groups that were characterized differently in specific neighborhoods. In the University District, characterized by higher median housing values, the social group had a high educational attainment but generally lower incomes, probably influenced by students living in the area. A working middle-class family social group in Riverside was highlighted; with higher household incomes and higher estimated housing values, this group comprised more middle-aged adults and children under 18. Overall, our respondents were represented by residents with fixed incomes and older participant groups.

For future research we plan to continue development of our PPGIS web-based community engagement tool (MOCT) with several enhancements. Expanding on location-based social and economic factors through house-to-house surveys would help to improve the resolution of our social groupings. In addition, with a larger representation of participant comments, it would be possible to correlate responses to social groups. Our PPGIS features that monitor community feedback will allow us to extend outreach efforts to those community members who, based on the City's socio-economic groupings, are under-represented both spatially (proximity to the river vs. city-wide) and socially.

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