MEASURING THE SPATIAL SIMILARITIES IN VOLUNTEERED GEOGRAPHIC INFORMATION

N. Mahmoody-Vanolya [1], M. R. Jelokhani-Niaraki [2]*

[1] Ph.D. student of Remote Sensing and GIS, Faculty of Geography, University of Tehran, Tehran, Iran - mahmoodi.narjes.v@ut.ac.ir
[2] Remote Sensing and GIS, Faculty of Geography, University of Tehran, Tehran, Iran - mrjelokhani@ut.ac.ir

Commission IV, WG IV/3

KEYWORDS: VGI, Citizen-Generated, Spatial Similarity, Web-GIS, Frequency, Babolsar City.

ABSTRACT:

Volunteered citizens have the potential to be used as social and distributed sensors, monitoring their surroundings and producing and sharing massive amounts of geographic data. The degree of spatial similarities in Volunteered Geographic Information (VGI) somehow indicates an index for the accuracy and precision of user-generated spatial data. In other words, the spatial similarities in VGI refer to how close a citizen-generated spatial feature is to the true (or accepted one) or how close the citizen-generated spatial features of the same geographic phenomenon are to each other. The present study aims at developing a Web-based GIS tool to collect VGI and extract the spatial similarity indexes. To this end, a case study involving the identification of optimal areas for restaurants in Babolsar, Mazandaran province was used. The degree of similarity between the areas (polygons) proposed by citizens was then investigated using spatial indicators of intersection and minimum central distance. The results show that with the increase in the frequency of citizen-generated polygons, the geometric dispersion of the polygons decreases, and the similarity of citizens' polygons to establish a restaurant increases. With the increasing agreement, the amount of standard deviation in the area, perimeter, and minimum central distance of intersection areas reduces from 4645 to 15.4, 134.5 to 21.6, and 42.4 to 4.2, respectively.

1. INTRODUCTION

Contrary to Web 1.0 technology, the availability of Web 2.0 technologies has increased over the past two decades, transforming many web-based apps into fully interactive platforms that allow for collaboration. The public can now produce spatial data voluntarily thanks to the advancement of technology and the emergence of new opportunities in the Internet sector. So that users can add, modify, or remove complications and can change, manipulate, and share data. Everybody may now develop and share geographic data, making it possible for everyone to be both a producer and a user of spatial data (Gosztonyi, 2022; Niaz et al, 2022; Jelokhani-Niaraki, 2021; Kollmann et al, 2016).

With the advent of Volunteered Geographic Information (VGI) in 2007, it became clear that anybody, regardless of their level of education or experience, could contribute to the creation and exchange of geographical data on a variety of subjects (Goodchild, 2007). The gathering of geographic information from volunteer citizens has resulted in the delegation of some duties to local institutions through decentralization and the division of labor between citizens and government agencies. This can be an important step in the process of decisions that are centered on the needs of the citizens (Astaburuaga et al., 2022; Apostolopoulos & Potsiou, 2022; Allam, 2020; Johnson et al, 2020; Khan & Johnson, 2020; Johnson & Sieber, 2013). Web-GIS systems, by integrating Geographic Information System elements into the web platform, offer a collection of spatial display and analysis tools to capture and share people's requests and proposals in the VGI format. With the establishment of involvement through these technologies, communities and their issues may be supported, and good citizen communication can help communities and their challenges (Anshori et al, 2022; Schmidt et al, 2021; Fontes et al., 2017; Verplanke et al., 2016).

The degree of success and acceptability of the outcomes of collaborative group processes is determined by the degree of agreement and similarity between the members' opinions and suggestions. The existence of high spatial similarity in VGI indicates the agreement and closeness of individuals' perspectives on a geographic occurrence, which can be used to gauge the correctness and precision of spatial data provided. Group online maps like OpenStreetMap (OSM) and Google Maps, which are used as base maps to gather and update users' preferences and suggestions in web-GIS systems, can also be used to assess the degree of spatial similarity of the generated data. In this regard, some spatial indexes such as the form and location of data are utilized to determine the degree of spatial similarity (Jelokhani-Niaraki, 2021).

The review of research literature demonstrates the significance of developing web-GIS systems to generate, gather, and assess the degree of VGI data similarity to improve the management and performance of municipal administrators. For example, Anshori et al. (2022) in their study developed, and utilized the VGI mobile app for collaborative landslide inventory mapping. The Free Open-Source Software for Geospatial Applications server-client software is used as the foundation for the design of the VGI mobile app to assure repeatability, flexibility, and cost savings. The VGI mobile app's landslide inventory demonstrates that the technology and approach successfully map landslides in landslide-prone areas. Dixon et al. (2021) have researched how well a participatory Geo-web reporting

* Corresponding author

program works in the area of socio-economic and biophysical vulnerabilities associated with flood disasters. Through the engagement of citizens in the program and analysis of the frequency and degree of similarity of the reports connected to the issues and requirements of various neighborhoods in the face of floods, it has been possible to manage and monitor the affected regions more successfully. Hashemi et al. (2021) created and implemented a spatial decision-making system based on VGI in their research for the goal of proper and equitable distribution of assistance in the event of natural disasters, which supports managers' requirements and performance. The suggested approach, with the active engagement of sufferers and rescuers, speeds up the identification of impacted areas and the timely and targeted distribution of relief based on the nature and amount of needs, preventing potential abuses and saving time and money. Sadeghi-Niarki et al. (2020) developed a decision-support tool based on VGI for gathering data on environmental pollution, which makes it simpler for individuals to actively engage in the prompt reporting of waste pollution and provides practical analytical tools for waste management. This study also used Borda's method to examine how similar the public's viewpoints were over where to dispose of their garbage. Vanolya et al. (2019) used a web-based PPGIS system in their study, utilizing information generated by citizens as reference data to validate the results of spatial Multi-Criteria Decision Analysis (MCDA). This validation was carried out with the use of specific spatial indicators such as complete coverage, geometric intersection, central distances, and statistical indicators. The results of this study show the degree of consistency between expert solutions and citizen opinions. Giuffrida et al. (2019) investigated the use of VGI and PPGIS in the transportation sector and outline their contribution to the creation of geographical data as well as the potential for public engagement. This study demonstrates the value of using quantitative evaluation techniques, GIS, and public engagement in making more informed decisions. Neis (2015) in his study employed a combination of VGI data available in OSM and MCDA methods for wheelchair routing in Germany. In this study, users determine the best routes by weighing several criteria. The routes provided by users are then assessed by generating a confidence factor based on VGI data.

As was stated in the research's background, the degree of similarity of the data generated by VGI can be utilized as an effective and efficient phenomenon to manage urban and environmental issues by reporting on citizens' concerns, views, and wants. The current study's objective is to create a web-GIS system to assess the spatial similarity of the areas proposed by citizens of Babolsar city, Mazandaran province, to identify ideal locations for restaurant establishments.

2. MAIN BODY

In this study, by designing and developing a web-GIS system, Babolsar citizens' suggestions for establishing a restaurant are collected in the form of VGI. The degree of spatial similarity between the (polygons) areas offered by citizens was then assessed using some spatial index. Figure (1) depicts the framework of this study.

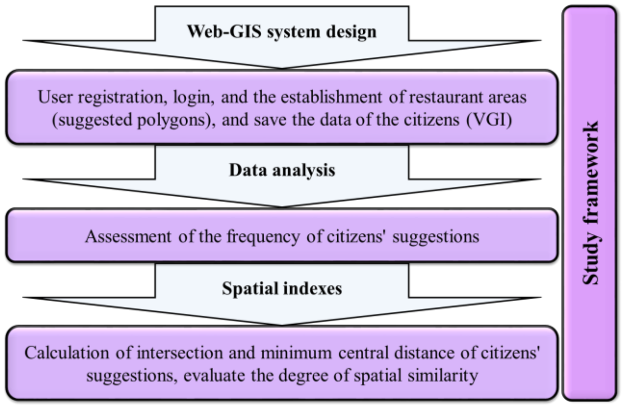

Figure 1. Study framework.

2.1 Study area

Babolsar city, with an area of around 40 square kilometers, is one of Mazandaran province's seaside cities. Because of its position on the southern shore of the Caspian Sea and its warm temperature, this city is regarded as ideal for attracting immigrants and visitors. This has resulted in a considerable population increase in the city of Babolsar in recent years (Vanolya et al, 2019; Mirkatooli et al., 2011), and the presence of touristic infrastructure and proper catering such as restaurants becomes increasingly necessary in response to the expanding population. Figure (5) shows an overview of the city of Babolsar.

2.2 Web-GIS system framework

In this study, a web-GIS system has been designed and implemented using an open-source framework to gather the areas proposed by citizens. Today, several platforms are allowing huge user groups to collaborate. For instance, users of OSM or Wikimapia can create geographic data based on their in-depth understanding of a particular physical reality or change data that has already been submitted. Users of OSM may utilize "tags" to define map elements like highways, water bodies, and locations of interest, giving information at a degree of detail that frequently exceeds that available from conventional geospatial data suppliers (Goetz et al., 2012). The key distinction between the system design of this study and other current platforms is its focus on a collaborative project for a specified objective (Identifying the best locations to build a restaurant). The Django web application development framework was utilized to construct the suggested system since it is extremely efficient in terms of speed and power and can be used to generate high-quality web applications. In addition, the PostgresSQL database is employed in this system to hold information on user accounts and places nominated by citizens. Bing and OSM basic maps, which are accessible via Application Programming Interfaces (API), enable the display of citizens' data on satellite images.

The second portion of the proposed design comprises the system's major services and it was developed in the View layer of the Django architecture, which allow citizens to sketch their proposed areas. The third part of the proposed system is the display component, which allows users to interact with the Graphical User Interface (GUI), and these GUIs can be accessed using standard browsers. The display part's principal purpose is to receive inputs and present the needed outputs to users. The JavaScript programming language, HTML markup language, and CSS style sheet language are utilized in the proposed design, together with the Jquery and Leaflet libraries.

After the main structure of the system was designed, the citizens of Babolsar were invited to voluntarily draw their preferred geographic areas in the system. To do this, the users first register in the system, and after visiting the main page, by selecting one of the system's base maps and using the different capabilities incorporated into the system, they can create their proposed areas in polygon form.

2.3 Data analysis

The citizen-generated polygons were combined using the union operation. The non-overlapping areas of polygons created by citizens are unaffected by this procedure, but the overlapped areas will be divided into new features to preserve the areas created by all of the citizens. As a result, it is possible to estimate the frequency of citizen areas (Figure 2).

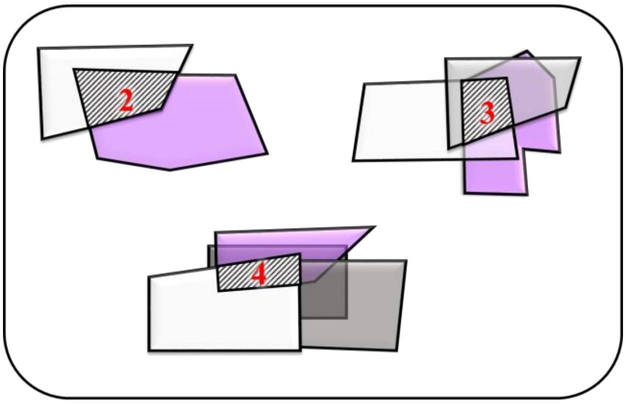

Figure 2. The frequency of polygons.

2.4 Spatial indexes

Because of the differences between the types of linear and polygonal features, the method for evaluating their degree of similarity differs. As a result, various indices are utilized to measure the degree of similarity between them (Li et al., 2019, Chen et al., 2020). In this study, the intersection and minimum central distance indexes were employed to assess the degree of similarity of citizens' proposed areas (Figure 3). These indexes reflect how close citizens' opinions are to one another. The intersection index represents the amount of overlap of the polygons, and the minimum central distance index computes the nearest centers of citizens' drawing polygons at different frequencies. Equations 1 and 2 have been used to obtain the center coordinates of each polygon:

$$C_x = \frac{1}{NA}\sum_{i=0}^{N-1}(x_i + x_{i+1})(x_i y_{i+1} - x_{i+1} y_i) \quad (1)$$

$$C_y = \frac{1}{NA}\sum_{i=0}^{N-1}(y_i + y_{i+1})(x_i y_{i+1} - x_{i+1} y_i) \quad (2)$$

Where N = number of vertices
A = area of the polygon
X_i, Y_i = vertices' coordinates
C_x, C_y = the coordinates of the center of the polygon

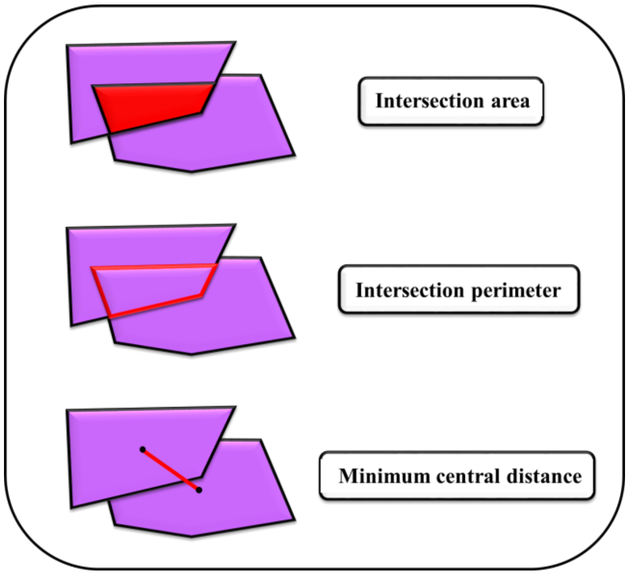

Figure 3. Spatial indexes

3. CONCLUSIONS

This study used a web-based system to collect suggestions from the citizens for establishing restaurants in Babolsar City. Following registration and system access, each user can draw their proposed areas (polygons). Figure (4) shows the designed system's overview as well as the ability to draw any proposed polygons by the citizens. 150 persons have enrolled in this system, and a total of 323 places have been nominated by citizens. Depending on their needs, some users have merely drawn one area while others have drawn four or more.

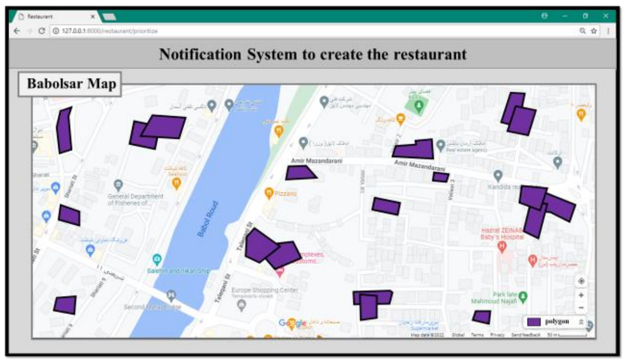

Figure 4. The designed web-GIS system for registering citizens' spatial opinions.

The majority of the proposed areas, as shown in Figure (5), are situated in Babolsar City's northern, particularly close to the Babolroud River and the Caspian Sea's coastlines. These areas are among the popular tourist destinations in Babolsar City, which attracts a lot of tourists each year because of its magnificent natural surroundings. Additionally, the proposed eastern areas are connected by roadways to Mazandaran University, where students reside and commute throughout the academic year and these areas currently do not have access to the requisite dining facilities. Given the significance of the tourism and educational sectors to Babolsar City and the absence of enough infrastructure to satisfy the demands of the beneficiaries, restaurant investors may want to examine the proposed areas as sites that both citizens and tourists would need.

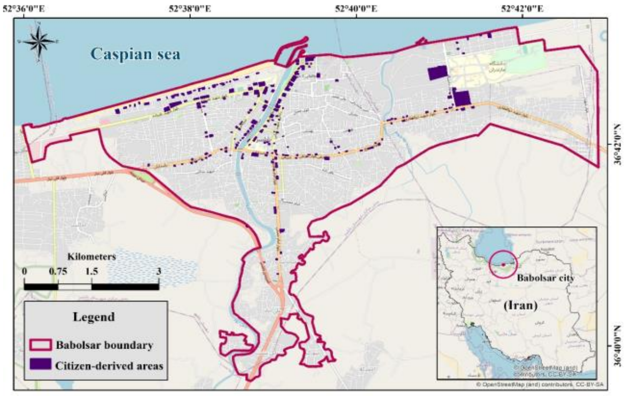

Figure 5. The location of the city of Babolsar and the citizen-proposed areas for the restaurant's establishment.

Many of the areas proposed by citizens overlap in terms of geography, and up to seven persons can agree on the selection of some areas. These areas are proposed by many people at the same time because they contain tourist attractions or are located on the main streets or crowded routes. Figure (6) depicts the frequency of citizen-generated areas. According to this figure, about half of the indicated areas were proposed by citizens just once, while some areas were proposed by many people. The high frequency of proposed areas demonstrates how close citizens' opinions are. This can show the spatial similarity of the proposed areas or the citizens' common consensus.

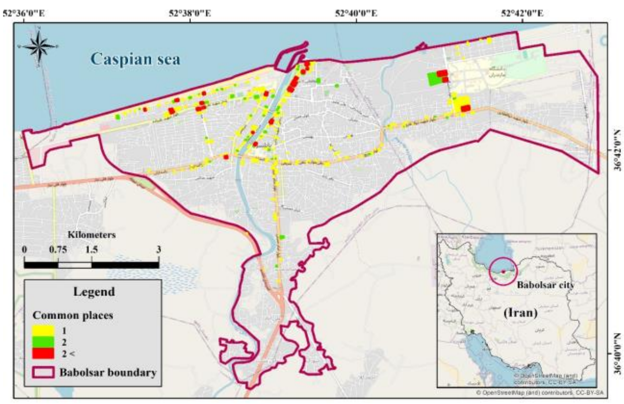

Figure 6. The frequency of citizen-proposed areas.

In the following section, the degree of spatial similarity of the citizens' proposed areas was analyzed using spatial indexes, and the findings are provided in tables (1) to (3). According to these tables, the quantity of area, perimeter, and minimum central distance of the proposed areas with a frequency of 2 to 4 people have the maximum value. As the frequency of proposed areas increases, the standard deviation in the area, perimeter, and minimum central distance of the intersection areas reduce from 4645 to 15.4, 134.5 to 21.6, and 42.4 to 4.2 respectively. The coefficient of variation of spatial indexes is shown in Figure (7) in the paragraphs that follow. The figure shows that when the frequency of areas suggested by citizens rises, the spatial indexes' coefficients of variation, particularly the Intersection area and Minimum central distance, considerably decline. As a result, when the standard deviation and the coefficients of variation decrease, the spatial dispersion of citizens' proposed areas reduces, and their opinions become closer together. This can demonstrate the high spatial similarity of the areas offered by citizens to establish a restaurant in Babolsar city.

Frequency	Intersection area (m^2)			
	Maximum	Minimum	Average	SD
2	50975.7	0.004	829.8	4645
3	3307.6	0.006	422.8	780.3
4	6272.5	0.01	701.7	1650.9
5	911.3	0.0006	139.5	281.3
6	308.6	0.08	27	76
7	58.4	0.003	7.6	15.4

Table 1. Evaluation of the area index in the intersection areas proposed by citizens.

Frequency	Intersection perimeter (m)			
	Maximum	Minimum	Average	SD
2	1261.3	0.9	103.6	134.5
3	446.3	0.8	101.9	105.8
4	372.4	1.8	80.9	95.2
5	166.5	0.2	45.2	48
6	82	3.8	22.9	23.2
7	81.5	0.5	18.9	21.6

Table2. Evaluation of the perimeter index in the intersection areas proposed by citizens.

Frequency	Minimum central distance (m)			
	Maximum	Minimum	Average	SD
2	344.6	0.4	18.2	42.4
3	117.6	0.4	11.3	22
4	110.2	0.4	11.2	22.1
5	107.8	0.7	10	21.3
6	16.1	0.7	4.4	5.5
7	16.1	0.7	3.7	4.2

Table 3. Evaluation of minimum central distance index in intersection areas proposed by citizens.

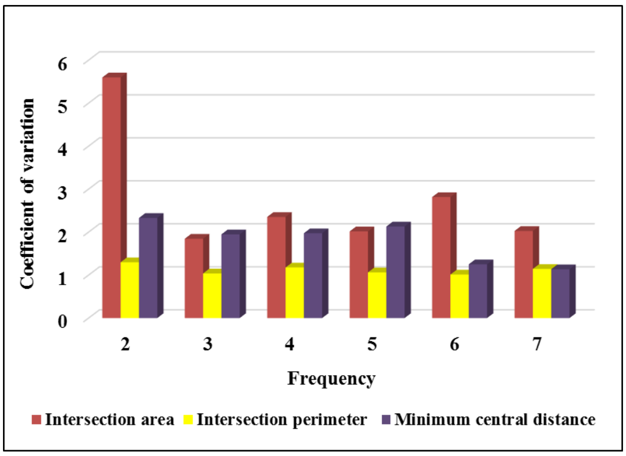

Figure 7. Coefficient of variation of spatial indexes.

In the final word, in this study, the proposed areas of citizens to establish a restaurant in the tourist city of Babolsar were gathered in the form of VGI using a Web-GIS system. Users have drawn their proposed areas as polygons by enrolling in the system. Following that, the degree of spatial similarity of the areas proposed by citizens was assessed using some spatial indexes. The findings of the studies revealed that when the frequency of the proposed areas increases, their spatial dispersion reduces, and their spatial similarity increases.

REFERENCES

Allam, Z. (2020). The emergence of voluntary citizen networks to circumvent urban health data sharing restrictions during pandemics. *Surveying the COVID-19 Pandemic and its Implications*, 81. doi.org/10.1016/B978-0-12-824313-8.00005-X.

Anshori, R. M., Samodra, G., Mardiatno, D., & Sartohadi, J. 2022. Volunteered geographic information mobile application for participatory landslide inventory mapping. Computers & Geosciences, 161, 105073. doi.org/10.1016/j.cageo.2022.105073.

Apostolopoulos, K., & Potsiou, C. 2022. Consideration on how to introduce gamification tools to enhance citizen engagement in crowdsourced cadastral surveys. *Survey Review*, 54(383), 142-152. doi.org/10.1080/00396265.2021.1888027.

Astaburuaga, J., Martin, M. E., Leszczynski, A., & Gaillard, J. 2022. Maps volunteered geographic information (VGI) and the spatial-discursive construction of nature. *Digital Geography and Society*, 100029. doi.org/10.1016/j.diggeo.2022.100029.

Calcagni, F., Amorim Maia, A. T., Connolly, J .J. T., & Langemeier, J. 2019. Digital co-construction of relational values: Understanding the role of social media for sustainability. *Sustainability Science*, 14(5), 1309-1321. doi.org/10.1007/s11625-019-00672-1.

Chen, Q., Wang, L., Waslander, S. L., & Liu, X. 2020. An end-to-end shape modeling framework for vectorized building outline generation from aerial images. *ISPRS Journal of Photogrammetry and Remote Sensing*, 170, 114-126. doi.org/10.1016/j.isprsjprs.2020.10.008.

Dixon, B., Johns, R., & Fernandez, A. 2021. The role of crowdsourced data, participatory decision-making, and mapping of flood-related events. *Applied Geography*, 128, 102393. doi.org/10.1016/j.apgeog.2021.102393.

Fontes, D., Fonte, C., & Cardoso, A. 2017. Integration of VGI and sensor data in a Web GIS-based platform to support emergency response. *In 2017 4th Experiment@ International Conference*. 214-219. IEEE. doi.org/10.1109/EXPAT.2017.7984345.

Giuffrida, N., Le Pira, M., Inturri, G., & Ignaccolo, M. 2019. Mapping with stakeholders: An overview of public participatory GIS and VGI in transport decision-making. *ISPRS International Journal of Geo-Information*, 8(4), 198. doi.org/10.3390/ijgi8040198.

Goetz, M., Lauer, J., & Auer, M. 2012. An algorithm-based methodology for the creation of a regularly updated global online map derived from volunteered geographic information. *In Proceedings of the Fourth International Conference on Advanced Geographic Information Systems, Applications, and Services, Valencia*, Spain 30, 50-58.

Goodchild, M. F. 2007. Citizens as sensors: the world of volunteered geography. *GeoJournal*, 69(4), 211-221. doi.org/10.1007/s10708-007-9111-y.

Gosztonyi, G. 2022. Aspects of the History of Internet Regulation from Web 1.0 to Web 2.0. JEHL, 13, 168.

Hashemi Dare Badami, S., OmidiPour, M., Jelokhani Niaraki, M., & Mahmoudi, S. 2021. Development of a VGI-based Participatory Spatial Decision-making System to Distribute Relief Aids in the Event of Natural Disasters. *Journal of Geomatics Science and Technology*, 10(4), 57-71.

Jelokhani-Niaraki, M. 2021. Collaborative spatial multicriteria evaluation: A review and directions for future research. International Journal of Geographical Information Science, 35(1), 9-42. doi.org/10.1080/13658816.2020.1776870.

Johnson, P. A., & Sieber, R. E. 2013. Situating the adoption of VGI by the government. *In Crowdsourcing geographic knowledge*, 65-81. Springer, Dordrecht. doi.org/10.1007/978-94-007-4587-2_5.

Khan, Z. T., & Johnson, P. A. 2020. Citizen and government co-production of data: Analyzing the challenges to government adoption of VGI. *The Canadian Geographer/Le Géographe canadien*, 64(3), 374-387. doi.org/10.1111/cag.12619.

Kollmann, T., Lomberg, C., & Peschl, A. (2016). Web 1.0, Web 2.0, and Web 3.0: The development of e-business. *In Encyclopedia of e-commerce development, implementation, and management*, 1139-1148. doi.org/10.4018/978-1-4666-9787-4.ch081.

LI, Z., ZHAI, J., & WU, F. (2019). A Shape Similarity Assessment Method for Linear Feature Generalization. 44(12), 1859-1864. doi.org/10.13203/j.whugis20180164.

Mirkatooli, J., Ghadami, M., Mahdian, M., & Mohamadi, S. 2011. Study and survey of trend and physical-space expansion of Babolsar city using Shannon's Entropy and Holden models. *Journal of Studies of Human Settlements Planning*, 6(16), 115-133.

Neis, P. 2015. Measuring the reliability of wheelchair user route planning based on volunteered geographic information. *Transactions in GIS*, 19(2), 188-201. doi.org/10.1111/tgis.12087.

Niaz, S., Buriro, G. A., & Soomro, N. H. 2022. Web-based English Language Learning: A Review from Web 1.0 to Web 3.0. *Pakistan Journal of Humanities and Social Sciences*, 10(2), 813-821. doi.org/10.52131/pjhss.2022.1002.0246.

Sadeghi-Niaraki, A., Jelokhani-Niaraki, M., & Choi, S.-M. 2020. A volunteered geographic information-based environmental decision support system for waste management and decision making. Sustainability, 12(15), 6012. doi.org/10.3390/su12156012.

Schmidt, F., Dröge-Rothaar, A., & Rienow, A. 2021. Development of a Web GIS for small-scale detection and analysis of COVID-19 (SARS-CoV-2) cases based on volunteered geographic information for the city of Cologne, Germany, in July/August 2020. *International journal of health geographics*, 20(1), 1-24. doi.org/10.1186/s12942-021-00290-0.

Johnson, P. A., Robinson, P. J., & Philpot, S. 2020. Type, tweet, tap, and pass: How smart city technology is creating a transactional citizen. *Government Information Quarterly,* 37(1), 101414. doi.org/10.1016/j.giq.2019.101414.

Vanolya, N. M., Jelokhani-Niaraki, M., & Toomanian, A. 2019. Validation of spatial multicriteria decision analysis results using public participation GIS. *Applied Geography*, 112, 102061. doi.org/10.1016/j.apgeog.2019.102061.

Verplank, J., McCall, M. K., Uberhuaga, C., Rambaldi, G., & Haklay, M. 2016. A shared perspective for PGIS and VGI. *The Cartographic Journal*, 53(4), 308-317. doi.org/10.1080/00087041.2016.1227552.