INTEGRATION OF AUTHORITATIVE AND VOLUNTEERED GEOGRAPHIC INFORMATION FOR UPDATING URBAN MAPPING: CHALLENGES AND POTENTIALS

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ABSTRACT:

This paper provides a bibliometric review between integration of authoritative and volunteered geographic information for the purpose of cartographic updating of urban mappings. The adopted methodology was through a bibliometric survey of the literature published by Web of Science and Science Direct. The period was evaluated from 2005 to 2020 and the keywords used were: integration of authoritative data, volunteered geographic information, VGI, large scale topographic mapping, Authoritative urban mapping. The number of publications found was small for the topic that deals with this integration, totalizing 14 articles at Web of Science and 23 at Science Direct. 38% of them were published in the International Journal of Geo Information (ISPRS), 16% in the International Journal of Geographical Information Science. 5% were published in the Cartography and Geographic Information Science and the Computer Geosciences respectively. The other 36% is shown in several other journals, approximately 3% each. Regarding the origin of publications, 25% are in Germany (University of Heidelberg), 14% in the UK (New Castle University), 13% in China (Wuhan University), 11% in Canada (Calgary University), and other countries show percentages between 3% and 5%. Among the research, areas are physical geography, remote sensing, computer science, information science, engineering, and public administration. Among themes addressed in the articles, potentials can be pointed out as existence of models which institutions can implement management of information received collaboratively, existence of several methodologies for quality control of this information so that they can be integrated into authoritative data that are called as data conflation. Methodologies for handling big data and semantic interoperability, as well as automation of processes. This data potential is not only on platforms such as OpenStreetMap, but also on data collected through scraping from social networks such as twitter, sites, and others. Among the challenges, there are still somethings to investigate regarding consideration of temporal, historic, political, and economic aspects, as well as the consideration of legal aspects. The integration of this volunteered geographic information is necessary, mainly in cities with economic and cultural difficulties to maintain their mapping up to date, as well as the difficulty of accessing information that allows access to authoritative data

1. INTRODUCTION

Technological computer advances of the last decades have allowed any individual who has a computer or smartphone with internet access to generate geoinformation. This feature is associated with web 2.0, a concept defined by O'Reilly in 2007; where it is established users to become fundamental elements in generation and management of certain information, besides being consumers of it. In this context, there are Volunteered Geographic Information (VGI) in which geospatial data are stored on online platforms and can be edited at any time by users. It is important to emphasize that these users do not need to have technical knowledge in cartography, but only local knowledge of the edited features. VGI platforms have become fundamental in generating updated geospatial data. This aspect can be exemplified by observing information inherent to OpenStreetMap (OSM) platform since in 2020 it was found that there are more than 6.2 million registered users and more than 6.4 billion features stored. However, despite efficiency presented and constant updating of information in the geographical scenario, there are still limitations to use VGI data sources in cartographic products, since these do not characterize authoritative cartography with known and controlled quality parameters

Authoritative mapping is generated by official mapping agencies with the purpose of representing all visible features in the landscape. This mapping has been produced by mapping organizations to represent territorial features for general use in ways that serve a variety of uses (KENT, 2009).

This type of classic cartographic knowledge information was for a long time the only approach referring to concepts associated with the generation of cartographic representations (ELWOOD et al. 2012). However, computational advances, already discussed, allowed users without knowledge in cartography to also become generators of special data. Connors et al. (2012) state that with the growing participation of non-specialist users in elaboration and dissemination of spatial information, challenges associated with the quality and truthfulness of these data have arisen, since it can vary according to type of information, area of study and group of contributors evaluated. The evaluation of quality in geospatial data has its importance associated with investigation of the truthfulness of information, so it is possible to measure and document these characteristics associated with the cartographic product

It is then allowed to characterize aspects related to discrepancies, omissions, uncertainties, and assign characteristics associated with the purpose that will be given to data according to the results obtained. (GOODCHILD, 2010).

According to Machado and Camboim (2019), many governments are studying the possibility of interacting with collaborative mapping and accepting the contribution of geospatial data produced by common citizens, mainly through

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platforms such as OSM. Among main motivations are: on one hand, the potential of citizens to act as sensors in environment where they live and the reduction in mapping costs; and, on other hand, use of population's knowledge to support decision making and land management. In latter, citizens are seen as partners, the opposite of the vision of citizens as sensors (Olteanu-Raimond et al., 2017; Goodchild, 2007).
Studies that explore the possibilities of use and integration of data from IGVs become important, especially for regions that have difficulties in keeping their mappings updated, an important characteristic of VGI.

2. RESEARCH SELECTION METHOD

Andery et al. (2004), considers that research methodologies focus on a set of norms and procedures, which the academic community accepts, seek the development of scientific knowledge. Therefore, having a broad and well-defined repertoire of research methods may contribute to the emergence of new work proposals, theories, and practical experiences that, as a consequence, leverage the production of knowledge in certain areas.
According to Kitchenham (2004), systematic literature review (SRL) is an important tool to identify, evaluate and interpret research questions, whether they are thematic, specific or phenomena of interest, thus evaluating what is already available and relevant, as well as the discovery of new research gaps. Thus, its evaluation process involves verifying the behavior of an artifact in environment for which it was designed with explicit propositions, rules for testing, and statements of results.
The criteria adopted in the review involve the following procedures: (i) review planning; (ii) conducting the review; and (iii) analysis of results.

2.1 Review Planning

The review planning was structured to identify the multiple sources of evidence, aiming to discriminate: (i) study commitments; (ii) main objective; (iii) search strategies; (iv) list of researched bases (v) criteria for inclusion and exclusion; (vi) summarization of results. Papers should be published based on scientific journals and contemplate the time interval from 2005 to 2020 and searches were performed in Web of Science and Science Direct database. The terms used were: integration of authoritative data, volunteered geographic information, VGI, large scale mapping, authoritative urban mapping.
Some criteria were defined for inclusion of selected papers: (i) papers that portray an application associated with VGI integration and authoritative mapping; (ii) works with the search term at least in title, abstract, or keywords; (iii) online papers published between 2005 and 2020. As exclusion criteria, it was defined: (i) literature review studies (ii) repeated articles and (iii) unavailability for a complete download of papers. Figure 1 schematically presents the adopted criteria.

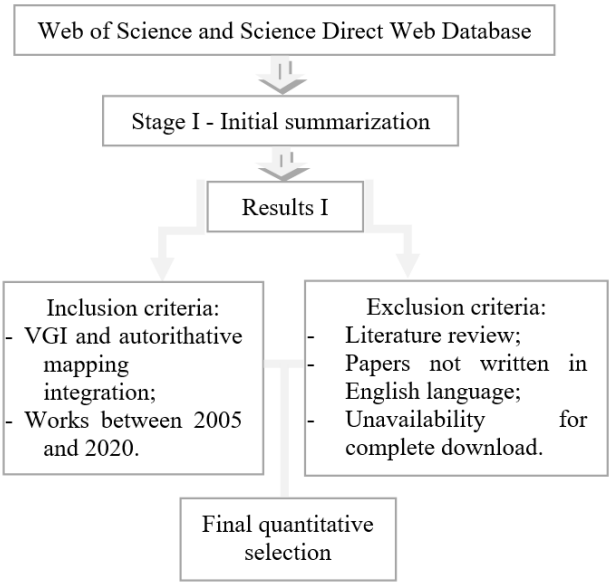

Figure 1: Criteria used for research selection.

2.2 Technical Selection

To obtain integrated literature, the following keywords were used: integration of authoritative data “AND” volunteered geographic information and/or VGI.
Then, the terms authoritative urban mapping “AND” large scale mapping “AND” VGI was used, and finally authoritative urban mapping “AND” VGI.
Initially, 189 publications were found and all associated with full papers or expanded abstracts, shown in Table 1.

INITIAL SUMMARIZATION			
Stage 1	Database and quantitative	Science Direct	Web of Science
		112	77
Total samples		**189 publications**	

Table 1: Inicial summarization, Stage I.

After this initial survey, the factors of exclusion and inclusion were applied and with refined research, this sample reduced to 37 publications.

SUMMARIZATION OF SLR			
STAGE 2	Restrictive Filter	Science Direct	Web of Science
	Review papers	21	25
	Repeated papers	40	26
	Download access	26	12
	Total samples	**23**	**14**

Table 2: Refined research, Stage II.

3. RESULTS

Among the journals where the largest number of publications were found 38% of these were published in the International Journal of Geo Information (ISPRS), 16% in the International Journal of Geographical Information Science. 5% were published in the Cartography and Geographic Information Science and the Computer Geosciences respectively. The other 36% displayed in various other periodic approximately 3% each. Figure 2 shows these results.

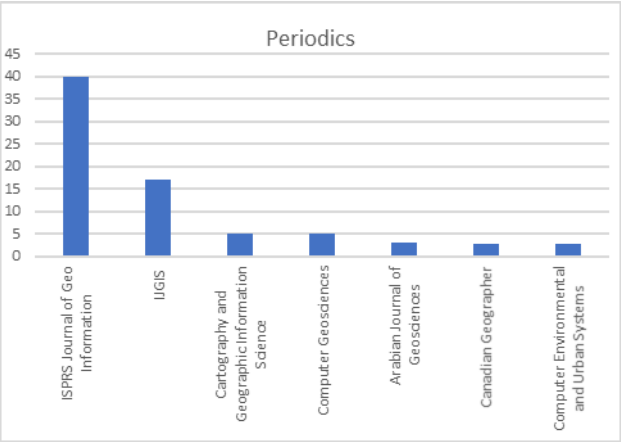

Figure 2: Main periodic

Regarding the origin of publications, 25% are in Germany (University of Heidelberg), 14% in the UK (New Castle University), 13% in China (Wuhan University), 11% in Canada (Calgary University), and other countries show percentages between 3% and 5%. Figure 3 shows these results.

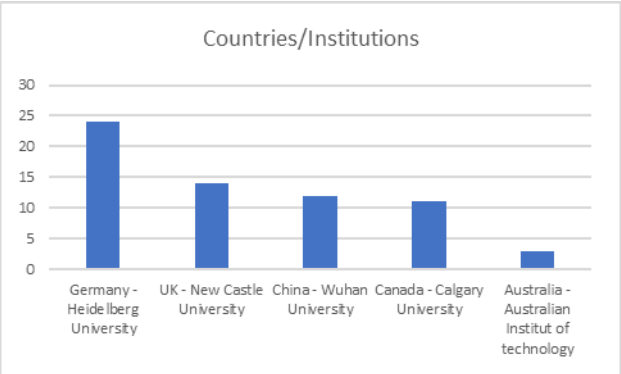

Figure 3: Origin of publications

Among the research, areas are physical geography, remote sensing, computer science, information science, engineering, and public administration.

4. ANALYSIS OF RESULTS

Among the analyzed papers, some interesting themes were chosen to be analyzed and presented below.

4.1 WORD CLOUD

One of the analyses that were performed was the keywords presented in the analyzed articles. Among the words that were repeated the most were: VGI, Data, GIS, Geographic, Mapping, Evaluation, Geospatial, Openstreetmap, Precision, Semantic, Urban, being represented with greater size in world cloud. In figure 5 this word cloud is presented.

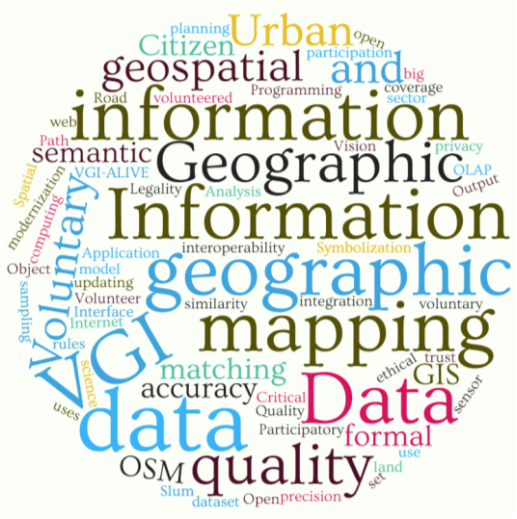

Figure 4: Word Cloud

4.2 QUALITY CONTROL MODELS FOR VALIDATION OF GEOSPATIAL INFORMATION

Johnson (2017) proposes four models that can define how a government can perform quality control in acceptance of direct edits and feedback on geospatial data. A form that can be applied to collaborative information or not. Four models are a "status quo" of open data provision, data curation, data mirroring, and crowdsourcing. These models are placed in continuous government control, which ranges from high levels of control over data creation to a low level of control. Each model is discussed, with relevant challenges highlighted. These four models present an initial set of options for governments that wish to accept direct editions of end-users of data and can be framed as a partial realization of many principles of open government. Despite the varied potential of these approaches, they bring about a change in the control location away from the government, creating various areas of risk for the government. Of these models, short-term interest may focus on curating and mirroring data as evolutionary, rather than revolutionary steps that expand on the simple provision of open data.

4.3 GEOSPATIAL DATA INTEGRATION INITIATIVES

Many governments already work with information from VGI, mainly through platforms, such as OSM (Olteanu-Raimond et al., 2017; Johnson & Sieber, 2013). Among the main motivations are: on the one hand, the potential of citizens to act as sensors in environment in which they live and the reduction in mapping costs; and, on the other hand, the use of population's knowledge to support decision making and land management. In the latter, citizens are seen as partners, opposite of the view of citizens as sensors (Olteanu-Raimond et al., 2017; Goodchild, 2007).

It is possible to mention some institutions that already perform integrations between mappings, according to a study carried out by Olteanu-Raimond et al. (2017): Federal Agency for Cartography and Geodesy and Bavarian Agency for Surveying and Geographical Information (Germany), National Geographic Institute of Belgium (Belgium), Centre for Topographic Information (Canada), Lands and Surveys of Cyprus (Cyprus), National Geographic Institute of Spain (Spain), United States Geological Survey (United States), National Land Survey of Finland (Finland), National Institute for Geographic Information and Forestry (France), Ordnance Survey of Great Britain (United Kingdom), 1 Hellenic Military Geographical Service (Greece), Greenland Survey (Greenland), Ordnance

Survey Ireland and Land and Property Services, Northern Ireland (Ireland), National Land Survey of Iceland (Iceland), National Land Survey of Iceland (Iceland), Bruno Kessler Foundation (Italy), General Directorate of the Territory (Portugal), Federal Office of Topography-Swisstopo (Switzerland). Figure 5 provides an overview of the use of VGI in NMA.

An almost universal characteristic in this study by Olteanu-Raimond, et al. (2017) was that each agency that was actively involved with VGI verified the information received using a variety of information sources, including those acquired by its team from these institutions, need to undergo an assessment of the quality of these data received. It was also found that mapping agencies are significantly involved with VGI and that several organizations that currently do not explore VGI plan to get involved shortly future because they assume the importance of this information. It is also apparent that, in most cases, current involvement is limited to detecting changes and correcting errors.

Figure 5: The use of VGI in the European NMAs (Olteanu-Raimond, et al., 2017)

4.4 CHARACTERISTICS OF ASSESSED PUBLICATIONS AND RELEVANT CONTEXT IN INTEGRATION PROCESS

	Title	Context
1	Using geometric properties to evaluate the possible integration of authoritative and volunteered geographic information. FAIRBAIRN, D., & AL-BAKRI, M. (2013).	Evaluation of the quality of information from OSM, Ordnance Survey (UK), and General Directorate of Research (Iraq) for possible integration.
2	Models of direct editing of government spatial data: challenges and constraints to the acceptance of contributed data. JOHNSON (2017).	Four models that can define how the government accepts direct edits and feedback on geospatial data.
3	VGDI – Advancing the Concept: Volunteered Geo-Dynamic Information and its Benefits for Population Dynamics Modelling. AUBRECHT et al (2016)	Difficulties in integrating time-space information.
4	Challenges in Crowdsourcing Geospatial Data to Replace or Enhance Official Sources. DAVIS (2018)	Challenges of integrating geospatial data from government or corporate sources into crowdsourcing data
5	A new spatial OLAP approach for the analysis of volunteered geographic information. BIMONTE et al (2014)	Aggregation based on VGI credibility and a filter based on historical accuracy.
6	Semantic interoperability of sensor data with volunteered geographic information: a unified model.	It proposes a framework for the semantic interoperability of sensor and VGI data for integration.
7	Dynamically integrating OSM data into a borderland database. ZHOU et al. (2015)	The method used to dynamically integrate OSM data into the borderland database.
8	The potential for using volunteered geographic information in pervasive health computing applications. MOONEY et al. (2013)	Integrates information from OSM and twitter with health-related information, particularly in areas where access to information about health services is limited or difficult.
9	An automatic data integration approach to enrich ATKIS with the VGI of outdoor-sports data. ZHANG et al (2018)	Data integration between (a) ATKIS topographic data set maintained by German research and mapping agencies and (b) the Alpstein outdoor sports data (AOSD)
10	A polygon-based approach for matching Openstreetmap road networks with regional transit authority data. FAN et al (2015)	Polygon-based approach to combine OpenStreetMap road network with official data
11	Some basic mathematical constraints for the geometric conflation problem. CASADO (2006)	Procedures between its 1:25000 series, the cadastral cartography 1:1000 and the street guide information 1:1000 collected by the INE (National Statistical Institute) for integration
12	Digital map conflation: a review of the process and a proposal for classification. RUIZ et al (2011)	State-of-the-art analysis of conflation processes applied to geospatial databases (GDBs) from heterogeneous sources. The term conflation is used to describe the procedure for the integration of different data.
13	An iterative road-matching approach for the integration of postal data ZHANG & MANG (2007)	This paper reports a special case of data matching between road layer from the digital landscape model "Basis DLM" maintained by German surveying and mapping agencies and road database supplied by TeleAtlas Corp.
14	Volunteered Geographic Information constructions in a contested terrain: A case of OpenStreetMap in China. LIN (2018).	This paper traces political-economic transitions concerning OSM constructions and examines OSM contributors' experiences
15	Towards an Automated Comparison of OpenStreetMap with Authoritative Road Datasets. BROVELLI et al (2016)	Methodology for comparing data geometry of OSM road network with other road data sets.
16	OpenStreetMap history for intrinsic quality assessment: Is OSM up-to-date? MINGHINI & FRASSINELLI (2019)	The paper presents "Is OSM up-to-date?", an open-source web application addressing the need of OSM contributors, community leaders, and researchers to quickly assess OSM intrinsic quality based on the object history for any specific region.

17	Improving Volunteered Geographic Data Quality Using Semantic Similarity Measurements. VANDECASTEELE & DEVILLERS (2013)	This paper proposes an approach for both improving the semantic quality and reducing the semantic heterogeneity of VGI data sets.
18	Improving the quality of citizen contributed geodata through their historical contributions: the case of the road network in Openstreetmap. NASIRI ET AL (2018)	This study aims to present a new approach to improve the positional accuracy and integrity of the OSM road network with the integration of historical information to be taken into account.
19	The Value of OpenStreetMap Historical Contributions as a Source of Sampling Data for Multi-Temporal Land Use/Cover Maps. VIANA et al (2019)	The study used historical OSM data to support LULC's multitemporal regional and rural mapping (source of mapping and visualization of land use).
20	Using geometric properties to evaluate the possible integration of authoritative and volunteered geographic information. MINGHINI & FRASSINELLI (2019)	Methodology for assessing positional and form quality of large-scale authorized data, such as data from the UK Ordnance Survey (OS) and data from the Iraqi General Directorate of Research (GDS) and (VGI), such as OpenStreetMap (OSM), with intention of evaluating a possible integration.
21	Integrating and generalizing volunteered geographic information. SESTER et al (2014)	This paper describes approaches for the integration of official and informal sources and discusses the impact of integrating user-generated data on automated generalization and visualization.
22	Data privacy and ethical uses of volunteered geographic information. BLATT A.J. (2015)	The goal of this chapter is to explore these important issues of patient privacy, ethics, and liability, as they pertain to the use of VGI
23	VGTrust: measuring trust for volunteered geographic information. SEVERINSEN (2019)	This research presents a formulaic model that addresses VGI quality issues, by quantifying trust in VGI.
24	Action and interaction in volunteered geographic information: a workshop review. MOONEY (2013)	This paper summarizes the important outcomes of workshop presentations and key discussion statements from participant contributions to an open-floor discussion on the most pertinent issues in Volunteered Geographic Information (VGI) research
25	Comparison of matching methods of user-generated and authoritative geographic data. ABDOLMAJIDI et al (2014)	To study the progress of the VGI data it is of interest to compare it with authority data. This study presents an assessment of two commonly-used approaches consisting of Segment-based and Node-based for matching two linear datasets
26	Geospatial Information Integration for Authoritative and Crowd-Sourced Road Vector Data. DU et al (2012)	This article describes results from a research project undertaken to explore the technical issues associated with integrating unstructured crowdsourced data with authoritative national mapping data.
27	Developing an interactive mobile volunteered geographic information platform to integrate environmental big data and citizen science in urban management. TANG et al (2017)	This paper evaluates the strengths, weaknesses, opportunities, and threats for the selected real cases: "Field Photo," "CoCoRaHS," "OakMapper," "What's Invasive!", "Leafsnap," "U.S. Green Infrastructure Reporter", and "Nebraska Wetlands". Based on these case studies, the results indicate that active, loyal, and committed users are key to ensuring the success of citizen science projects. Online and offline activities should be integrated to promote the effectiveness of public engagement in environmental management.
28	Geometric-based approach for integrating VGI POIs and road networks. YANG & LU (2014)	The method integrates both the POIs from VGI and the POIs from official mapping agencies with the associated road networks effectively and validly, providing a promising solution for enriching professional road networks by integrating VGI POIs.
29	Applications of Volunteered Geographic Information in Surveying Engineering: A First Approach. SOFOS et al (2015)	This paper aims to suggest a framework that will support data sharing in Surveying Engineering by creating an online Spatio-temporal information repository for land surveying projects. A data model to meet the needs of Surveying Engineering applications and accuracy requirements are introduced to facilitate the sharing of VGI information among Surveying Engineers.
30	Integrating Authoritative and Volunteered Geographic Information for spatial planning. MASSA & CAMPAGNA (2016)	This contribution concerns ongoing research by the authors on the integrated use of Social Media Geographic Information (SMGI) and Authoritative Geographic Information (A-GI) as support in urban and regional planning.
31	Potential Contributions and Challenges of VGI for Conventional Topographic Base-Mapping Programs. COLEMAN (2013)	This chapter introduces the context and characteristics implicit in conventional digital topographic mapping programs and then contrasts them to important underlying assumptions regarding volunteered geographic information. It defines the term "authoritative data" and challenges its use in the context of comprehensive topographic base-mapping programs. After examining prevailing cultures and assumptions that must be adjusted and workflows that must be modified to manage risk and make the best use of VGI in this role
32	Crowdsourcing, Citizen Science, or Volunteered Geographic Information? SEE ET AL (2016)	In this article, the expressions used to describe citizen sensing of geographic information are reviewed and their use over time explored, before categorizing them and highlighting key issues in the current state of the subject.
33	Collaborative mapping as a data source for urban planning: challenges and potentialities. MACHADO & CAMBOIM (2019)	This article describes the main considerations regarding the integration of collaborative mapping to the urban reference mapping
34	Integrating Spatial Data Infrastructures (SDIs) with Volunteered Geographic Information (VGI) for creating a Global GIS platform. DEMETRIOU (2017)	this chapter discusses the challenges of integrating VGI with INSPIRE and outlines a generic framework for a globally integrated GIS platform, similar in concept to Digital Earth and Virtual Geographic Environments (VGEs)
35	Situating the adoption of VGI by government	Were identified three ways that governments can situate themselves

	JOHNSON (2012)	to accept VGI—by formalizing the VGI collection process, through encouraging collaboration between levels of government, and by investigating the participatory potential of VGI.
36	The scale of VGI in map production: a perspective on European national mapping agencies. OLTEANU-RAIMONd (2017)	The potential role of citizen sensing and so its current scale of use by European National Mapping Agencies (NMAs) is limited by a series of concerns, notably relating to issues of data quality, the nature and motivation of the contributors, legal issues, the sustainability of data source, and employment fears of NMA staff.
37	VGI in National Mapping Agencies: Experiences and Recommendations. OLTEANU-RAIMOND (2017)	This chapter aims to give an overview of the experiences of some European NMAs in engaging with VGI.

Table 3: Publications and relevant context in the integration process

4.5 INTEGRATION CHALLENGES

Among the challenges and integration from VGI and authoritative mapping, it occurs due to the growth of open data platforms and the increasing share of geospatial data across portals regarding geospatial issues. VGI creates an opportunity for government institutions to get updated information.
Open data encourages transparency in government activities and reduces the cost of data sharing between government agencies, encourages innovation in civic services, thereby supporting economic development. Another possibility is to use information from open data platforms like Openstreetmap is to check the behavior of updates in urban space. evaluate which areas are growing and which is the vector of growth or not of cities. Another possibility that is being researched by the main authors of this article is the creation of a method that proposes indicators to evaluate the outdated authoritative mapping. By systematizing this method, it is possible to verify which areas of mapping need updating. The proposal deals with a targeted update, without the need for new mapping.

5. CONCLUSION

In this paper, the main considerations regarding the integration of collaborative mapping with reference mapping through a bibliometric review were addressed. The characteristics of each of the mappings were addressed, involving issues related to their production, legal, and quality issues, as well as examples of international initiatives in which integration between them has already taken place. This information supported a synthesis point out the main challenges and potentialities for the integration of the mappings. It has been demonstrated that integration of voluntary mapping can enrich, update and complement official mapping, but it poses several challenges, requiring methods of analysis, compatibility, and automation of processes inherent to mapping and integration, in addition to procedures for documentation of the quality of collaborative data through metadata.

REFERENCES

BELMONTE, S; BOUCELMA, O; SELLAMI, S., 2014. A new spatial OLAP approach for the analysis of volunteered geographic information. Computers, environment, and urban systems. volume 48, 2014. doi.org/j.compenvurbsys.2014.07.006

Bakillah, M., Liang, S. H. L., Zipf, A., & Jokar Arsanjani, J. 2013. Semantic interoperability of sensor data with volunteered geographic information: a unified model. *ISPRS International Journal of Geo-Information*, *2*(3), 766-796. https://doi.org/10.3390/ijgi2030766

Ferdiansyah, H. 2015. Finding a New Approach for Participatory Mapping Organization and National Mapping Agency Relation in Indonesia. *j. Cartogr. Geogr. inf.* 65, 230–237. https://doi.org/10.1007/BF03545145

Blatt A.J. (2015) Data Privacy and Ethical Uses of Volunteered Geographic Information. In: Health, Science, and Place. Geotechnologies and the Environment, vol 12. Springer, Cham

Brovelli, M.; Minghini, M.; Molinari, M. Mooney, P. 2016. Towards An Automated Comparison Of Openstreetmap With Authoritative Road Datasets. Transactions in GIS. VOLUME 21, ISSUE 2.

Casado, M.L. 2006. Some basic mathematical constraints for the geometric conflation problem. In: M Caetano, M Painho (eds) Proc. of 7th international symposium on spatial accuracy assessment in natural resources and environmental sciences, July 5–7 2006.

Chan, K.L., Qin K., 2017: Biomass burning related pollution and their contributions to the local air quality in Hong Kong. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci*., XLII-2/W7, 29-36. doi.org/10.5194/isprs-archives-XLII-2-W7-29-2017.

Coleman D.J. 2013 Potential Contributions and Challenges of VGI for Conventional Topographic Base-Mapping Programs. In: Sui D., Elwood S., Goodchild M. (eds) Crowdsourcing Geographic Knowledge. Springer

Connors, J.P., Lei, S., Kelly, M., 2012. Citizen science in the age of neogeography: Utilizing volunteered geographic information for environmental monitoring. Annals of the Association of American Geographers 102, 1267–1289. DOI: https://doi.org/10.1080/00045608.2011.627058

Demetriou, D, Campagna, M, Racetin, I, Konecny, M. 2017. Integrating Spatial Data Infrastructures (SDIs) with Volunteered Geographic Information (VGI) for creating a Global GIS platform. In: Foody, G, See, L, Fritz, S, Mooney, P, OlteanuRaimond, A-M, Fonte, C C and Antoniou, V. (eds.) Mapping and the Citizen Sensor. Pp. 273–297. London: Ubiquity Press. DOI: https://doi.org/10.5334/bbf.l. License: CC-BY 4.0

ELWOOD, Sarah; GOODCHILD, Michael F.; SUI, Daniel Z. 2012. Researching volunteered geographic information: Spatial data, geographic research, and new social practice. Annals of the Association of American Geographers, v. 102, n. 3, p. 571-590

E. Abdolmajidi1, J. Will1, L. Harrie1, A. Mansourian. 2014. Comparison of matching methods of user-generated and authoritative geographic data. 17th ICA Workshop on Generalization and Multiple Representation, Vienna, Austria

Fairbairn, D., & Al-Bakri, M. 2013. Using geometric properties to evaluate the possible integration of authoritative and volunteered geographic information. ISPRS International Journal of Geo-Information, 2(2), 349–370. https://doi.org/10.3390/ijgi2020349

Fairbairn, D.; Al-Bakri, M. 2013. Using Geometric Properties to Evaluate Possible Integration of Authoritative and Volunteered Geographic Information. *ISPRS Int. J. Geo-Inf.* 2013, *2*, 349-370.

Fan H, Yang B, Zipf A, Rousell A. 2015. A polygon-based approach for matching Openstreetmap road networks with regional transit authority data. Int J Geogr Inf Sci 30(4):748–764. https://doi.org/10.1080/13658816.2015.1100732

Heshan, D.; Morley, J.; Hart, G., Leibovici, D.; Jackson, M.; Ware, Mark. Geospatial Information Integration for Authoritative and Crowd-Sourced Road Vector Data. Transactions in GIS, 2012, 16(4): 455–476.

Goodchild, M. F. 2010 "Foreword." In Principles of Modeling Uncertainties in Spatial Data and Spatial Analyses. CRC Press.

Johnson P.A., Sieber R.E. (2013) Situating the Adoption of VGI by Government. In: Sui D., Elwood S., Goodchild M. (eds) Crowdsourcing Geographic Knowledge. Springer, Dordrecht

Ruiz, J.; Ariza, F.; Ureña, M; Blázquez, E. (2011) Digital map conflation: a review of the process and a proposal for classification, International Journal of Geographical Information Science, 25:9, 1439-466, DOI: 10.1080/13658816.2010.519707

Kang H (2001) Spatial Data Integration: A Case Study of Map Conflation with Census Bureau and Local Government Data, University Consortium for Geographic Information Science, Summer Assembly, June 2001, http://www.cobblestoneconcepts.com/ucgis2summer/kang/kang_main.htm.

Kent, A; 2009. Stylistic diversity in European state 1:50 000 topographic maps. The Cartographic Journal 46 179–213

Kitchenham, B. 2004. Procedures for performing systematic reviews. Keele, UK, Keele University, 33(2004):1–26.

MACHADO, A; CAMBOIM, S. 2019.Collaborative mapping as a data source for urban planning: challenges and potentialities. *urbe, Rev. Bras. Gest. Urbana* [online]. 2019, https://doi.org/10.1590/2175-3369.011.e20180142.

Massa, P; Campagna, M. 2016. Integrating Authoritative and Volunteered Geographic Information for spatial planning. In: Capineri, C, Haklay, M, Huang, H, Antoniou, V, Kettunen, J, Ostermann, F and Purves, R. (eds.) European Handbook of Crowdsourced Geographic Information, Pp. 401–418. London: Ubiquity Press. DOI: http://dx.doi.org/10.5334/bax.ac.
Zhang, M; Meng, L. 2007. An iterative road-matching approach for the integration of postal data. Computers, Environment, and Urban Systems. VOLUME 31, ISSUE 5.

Minghini, M., Frassinelli, F. 2019. OpenStreetMap history for intrinsic quality assessment: Is OSM up-to-date?. *Open geospatial data, software. stand.* 4, 9. https://doi.org/10.1186/s40965-019-0067-x

Mooney, P.; Corcoran, P.; Ciepluch, B. 2013. The potential for using volunteered geographic information in pervasive health computing applications. *J Ambient Intell Human Comput* 4, 731–745. https://doi.org/10.1007/s12652-012-0149-4

Mustière, S. 2006. Results of experiments of automated matching of networks at different scales, ISPRS Vol. XXXVI. ISPRS Workshop - multiple representation and interoperability of spatial data, Hannover, Germany

Mustière S, Devogele T 2008 Matching networks with different levels of detail. GeoInformatica 12:435–453. https://doi.org/10.1007/s10707-007-0040-1

Nasiri, A.; Ali Abbaspour, R.; Chehreghan, A.; Jokar Arsanjani, 2018.J. Improving the Quality of Citizen Contributed Geodata through Their Historical Contributions: The Case of the Road Network in OpenStreetMap. *ISPRS Int. J. Geo-Inf. 7*, 253

Olteanu-Raimond, A.-M., Hart, G., Foody, G., Touya, G., Kellenberger, T., & Demetriou, D. (2017). The scale of VGI in map production: A perspective of European National Mapping Agencies. *Transactions in GIS*, 21(1), 74-90. http://dx.doi.org/10.1111/tgis.12189.

Olteanu-Raimond, A-M, Laakso, M, Antoniou, V, Fonte, C C, Fonseca, A, Grus, M, Harding, J, Kellenberger, T, Minghini, M, Skopeliti, A. 2017. VGI in National Mapping Agencies: Experiences and Recommendations. In: Foody, G, See, L, Fritz, S, Mooney, P, Olteanu-Raimond, A-M, Fonte, C C and Antoniou, V. (eds.) Mapping and the Citizen Sensor. Pp. 299–326. London: Ubiquity Press. DOI: https://doi.org/10.5334/bbf.m.

Johnson, P. A. 2017. Models of direct editing of government spatial data: challenges and constraints to the acceptance of contributed data, Cartography and Geographic Information Science, 44:2, 128-138, DOI: 10.1080/15230406.2016.1176536
Peter Mooney, Karl Rehrl & Hartwig Hochmair (2013) Action and interaction in volunteered geographic information: a workshop review, Journal of Location-Based Services, 7:4, 291-311, DOI: 10.1080/17489725.2013.859310

See, L.; Mooney, P.; Foody, G.; Bastin, L.; Comber, A.; Estima, J.; Fritz, S.; Kerle, N.; Jiang, B.; Laakso, M.; Liu, H.-Y.; Milčinski, G.; Nikšič, M.; Painho, M.; Pődör, A.; Olteanu-Raimond, A.-M.; Rutzinger, M. 2016. Crowdsourcing, Citizen Science, or Volunteered Geographic Information? The Current State of Crowdsourced Geographic Information. *ISPRS Int. J. Geo-Inf.* 2016, *5*, 55.

Sester M., Jokar Arsanjani J., Klammer R., Burghardt D., Haunert JH. 2014. Integrating and Generalising Volunteered Geographic Information. In: Burghardt D., Duchêne C., Mackaness W. (eds) Abstracting Geographic Information in a Data-Rich World. Lecture Notes in Geoinformation and Cartography. Springer, Cham

Severinsen, J.; Mairead de R.; Femke, R.; Emir H. 2019. Vgtrust: measuring trust for volunteered geographic information. International Journal of Geographical Information Science. volume 33, 2019 - issue 8

Sofos I., Vescoukis V., Tsakiri M. 2015. Applications of Volunteered Geographic Information in Surveying Engineering: A First Approach. In: Bacao F., Santos M., Painho M. (eds) AGILE 2015. Lecture Notes in Geoinformation and Cartography. Springer, Cham

Tang Z., Zhou Y., Yu H., Gu Y., Liu T. 2017. Developing an Interactive Mobile Volunteered Geographic Information Platform to Integrate Environmental Big Data and Citizen Science in Urban Management. In: Thakuriah P., Tilahun N., Zellner M. (eds) Seeing Cities Through Big Data. Springer Geography. Springer, Cham

Vandecasteele, A., and Devillers, R. 2013. Improving Volunteered Geographic Data Quality Using Semantic Similarity Measurements, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XL-2/W1, 143–148, https://doi.org/10.5194/isprsarchives-XL-2-W1-143-2013

Wen Lin. 2018. Volunteered geographic information constructions in a contested terrain: a case of Openstreetmap in China. Geoforum. Volume 89, February 2018, Pages 73-82

Yang B, Zhang Y, Feng L (2014) Geometric-based approach for integrating VGI Pois and road networks. Int J Geogr Inf Sci 28(1):126–147. https://doi.org/10.1080/13658816.2013.830728

YANG, B. , Lu, F. 2014. Geometric-based approach for integrating VGI POIS and road networks. Journal international journal of geographical information science. Volume 28, 2014 - Issue 1

Zhang M, Meng L. 2007. An iterative road-matching approach for the integration of postal data. Computer Environment Urban System. https://doi.org/10.1016/j.compenvurbsys.2007.08.008

Zhang, M., Zhang, B. & Fan, H. 2018. An automatic data integration approach to enrich ATKIS with the VGI of outdoor-sports data. *Arab Geosci* 11, 486 https://doi.org/10.1007/s12517-018-3849-z

Zhou, X.; Zeng, L.; Jiang, Y.; Zhou, K.; Zhao, Y. Dynamically Integrating OSM Data into a Borderland Database. *ISPRS Int. J. Geo-Inf.* 2015, *4*, 1707-1728.