AGILE: GIScience Series, 3, 71, 2022. https://doi.org/10.5194/agile-giss-3-71-2022
Proceedings of the 25th AGILE Conference on Geographic Information Science, 2022.
Editors: E. Parseliunas, A. Mansourian, P. Partsinevelos, and J. Suziedelyte-Visockiene.
This contribution underwent peer review based on a full paper submission.


# Towards geospatial blockchain: A review of research on blockchain technology applied to geospatial data

Pengxiang Zhao [1], Jesus Rodrigo Cedeno Jimenez [2], Maria Antonia Brovelli [2], and Ali Mansourian [1]

[1]GIS Center, Department of Physical Geography and Ecosystem Science, Lund University, Lund, Sweden
[2]Department of Civil and Environmental Engineering, Politecnico di Milano, Milan, Italy

Correspondence: Pengxiang Zhao (pengxiang.zhao@nateko.lu.se)

**Abstract.**

In recent years, geospatial big data has been generated at a very high speed, and the data volume is becoming increasingly massive. In order to realize the full potential of geospatial big data, there has been a strong requirement and push to embrace the value of open science. However, it is still challenging to preserve the privacy and integrity of geospatial data in data sharing and management. Blockchain as d distributed ledger technology has a series of good characteristics, such as decentralization, trust-free, transparency, tamper-free, consensus and security, etc. These characteristics of blockchain are beneficial for facilitating geospatial data sharing and management, and hence promoting the development of open GIS. In this paper, we provide a comprehensive review on the literature that involves how blockchain technology is applied to geospatial data, especially in geospatial data privacy and integrity preservation. First, the background knowledge on geospatial data privacy and blockchain technology are introduced. Then, we reviewed how blockchain technology is applied to geospatial data, followed by the conclusion of the topic. This review is beneficial for understanding how blockchain technology can be applied to geospatial domain by integrating geospatial technologies like GIS and remote sensing.

**Keywords.** Blockchain, Geospatial data, Open GIS, Data privacy and integrity preservation

## 1 Introduction

With the rapid development of global navigation satellite system (GNSS), information and communication technology (ICT), and sensor technology, various and massive geospatial data have been generated at an unprecedented rate in our daily lives over the past decade, such as remote sensing images, individual trajectories, the data generated by location-based services, and so on (e.g. Lee and Kang, 2015; Zhao et al., 2019; Huang et al., 2021). These geospatial data bring opportunities and challenges in geospatial information science (Chun et al., 2019; Martin and Schuurman, 2020). In recent years, there has been a growing need for the sharing and safe use of reliable spatial information, which can not only motivate innovation in technology and industry, but also break down data barriers between various sectors, thereby generating enormous economic value for a country (e.g. Zhang et al., 2019). In particular, in order to achieve the full potential of geospatial big data, there has been strong requirement and motivation to promote and develop open GIS paradigm (Kitchin et al., 2017; Coetzee et al., 2020). However, there are still several barriers in administration, legislation, business and culture for the full implementation of open science, which are required to be dealt with properly. Currently, there are several definitions on open science (e.g. Fecher and Friesike, 2014; Vicente-Saez and Martinez-Fuentes, 2018; Leible et al., 2019). One of the common definitions is provided by FOSTER [1], which defines open science as the practice of science where research data, lab notes and other research processes are freely available, under terms that enable reuse, redistribution and reproduction of the research and its underlying data and methods. Therefore, it is significant and necessary to be aware of relevant approaches and develop best practices for promoting open science, especially in geospatial domain.

Data privacy, integrity and security play a crucial role in the sharing and storage of geospatial data, which are one of the major barriers in promoting and developing open GIS. Location in geospatial data has always been a key point for visualizing the current location, predicting events and enhancing service delivery (Tohidi and Rustamov, 2020). Especially, the rise of location-based services (e.g., Google maps, social media) has brought geospatial privacy into

[1]https://www.fosteropenscience.eu/foster-taxonomy/open-science-definition

the spotlight. However, it is still challenging to guarantee data privacy and security in geospatial data sharing and management. In addition, data integrity depicts the data consistency and accuracy while sharing or storing the data, which quantifies the validity and fidelity of data (Kumar and Sunitha, 2017). To preserve privacy and integrity of geospatial data, geospatial data should be validated to satisfy the security requirements, and be protected from unauthorized modifications.

Recently, blockchain has emerged as a technology to realize data storage with tamper-proof, traceable, trust-free, transparent, and decentralized characteristics, which has been indicated to be effective in solving various security and privacy issues (e.g. Nofer et al., 2017; Monrat et al., 2019; Lv et al., 2021). Blockchain achieves the decentralization and security by integrating distributed data storage, consensus mechanism, asymmetric cryptographic algorithm, smart contract, and some other technologies. Hence, blockchain technology opens an avenue for dealing with privacy of geospatial data, which has also been applied to GIS field. For instance, Papantoniou (2021) proposed the concept of Geoblockchain via the combination or integration of blcokchain with GIS to support the analysis of spatial-temporal trends of blockchain transactions.

Although geospatial data privacy and integrity preservation, and blockchain technology have been investigated and discussed extensively in previous studies, the research on the combination of them is still less. To the best of knowledge, there is no existing work to review the conjunction of these two important areas. In this situation, the goal of this paper is to review past studies in this area, which can be helpful remarkably in understanding the current situation and provide insights on geospatial data sharing and management in a secure and transparent environment. Moreover, it will also be an attempt of step in facilitating the application of blockchain technology in geospatial data.

The remainder of this paper is organized as follows. Background knowledge regarding privacy and integrity of geospatial data, and blockchain technology are reviewed in section 2. Section 3 presents an overview of the applications of blockchain in geospatial data privacy and integrity preservation and some other applications in geospatial domain. We discuss and conclude this research in section 4.

## 2 Background knowledge

### 2.1 Privacy of geospatial data

Geospatial data privacy has been attracting more attention in recent years. Especially, as location-enabled technologies and location-based services are becoming ubiquitous, users need to share their location with an ever-growing number of external services (e.g., Google maps) (Keßler and McKenzie, 2018). Such geospatial data sharing brings concerns for users' location privacy leakage. Hence, how to satisfy privacy requirements has become one of the most important challenges in geospatial data sharing, which is also crucial to secure users' privacy in context-aware applications (Zurbarán et al., 2018).

Although different types of geospatial data are capable of giving useful feedback and providing valuable information to the involved users and services, it is important and necessary to be able to protect the privacy of the corresponding data before sharing in some ways (e.g., anonymizing, perturbing, encrypting, etc.) (Katsomallos et al., 2019). One recent study on location privacy preservation indicated that 44% of the participants did not want to share their location with online social media (e.g. Twitter, Facebook, Instagram), and 66% did not want to have their location stored, and approximately 88% of the participants were opposed to third parties drawing inferences about them based on their activities (Martin and Nissenbaum, 2020). Different models have been developed to preserve geoprivacy during geospatial data sharing over the last two decades. Location obfuscation mechanisms are commonly used in the models, which aim to protect privacy by deliberately degrading the precision of location information in a way to hide the sensitive information with the precondition that the service can still be conducted to some acceptable extent (e.g. Partovi et al., 2020; Zurbarán et al., 2020; Hojati et al., 2021). For example, Zurbarán et al. (2018) developed an algorithm called Rand-K to minimize the impact of location obfuscation on exploratory spatial data analysis (ESDA). The results show that the algorithm can reduce the impact on the spatial analysis.

### 2.2 Integrity of geospatial data

Geospatial data integrity and quality is a critical issue of creating and maintaining a spatial database for geospatial data storage. The study by Lin et al. (2005) introduces the seven components of spatial data quality that were defined by the ICA Commission of Spatial Data Quality, including lineage, positional accuracy, attributes accuracy, completeness, logical, semantic accuracy and temporal information. These components are important aspects to be considered while preserving geospatial data integrity. An important activity in the design of a spatial database is to identify and impose various integrity constraints into the database that are used to detect and evaluate inconsistencies (Borges et al., 1999). Hence, it is important to verify and preserve the integrity of geographic information based on the database structure.

Moreover, in the geospatial big data era, high volume geospatial data are available for download and usage. For example, the volume of remote sensing (RS) data for a single scene is usually on the gigabyte (GB) level, the data volume in a large ground station is usually on the terabyte (TB) level, the volume of the archive of historical RS data could be on the petabyte (PB) level in some countries and on the exabyte (EB) level in the globe (Liu, 2015). It normally requires cloud infrastructures and environment to maintain, manage and process such RS big data. Such computing environment also brings a series of potential issues, such as the risk of accidental data corruption, data tampering or malicious interference in the databases, etc. Blockchain technology displays potential in preserving data integrity for large-scale geospatial data.

### 2.3 Blockchain technology

Distributed ledger technology (DLT) has attracted notable attention in recent years, which is a transparent, distributed, secure data storage and transfer technology that works without any centralized trusted third party (Xie et al., 2019). Blockchain, as a distributed ledger technology, was first proposed by Nakamoto (2008) in terms of Bitcoin, which provides a novel way to record and save transaction data without the supervision and intervention of a central financial system. This new technology integrates distributed storage, consensus mechanism, smart contract, asymmetric cryptographic algorithm and other technologies (e.g. Yaga et al., 2019; Qiu et al., 2020). Smart contract is a computer program that consists of a set of rules running on the blockchain, the basic idea behind which is that many kinds of terms of agreement can be embedded in the hardware and software (Szabo, 1997). Asymmetric cryptographic algorithms are used to validate and authenticate transactions in blockchain using two mathematically associated keys, known as public and private keys. One key is used for data encryption, and the other is used for decryption of data Gordon and Jeffrey (2004).

A standard blockchain is actually a peer-to-peer network, which is composed of a number of nodes that are connected to each other to maintain a copy of the data. The data in blockchain is stored in the form of blocks, which are chained together in an append-only manner (e.g. Xie et al., 2019). Each block is comprised of a hash pointer to point to the previous block, a timestamp and data regarding transaction details. As shown in Fig. 1, each block is digitally signed by a hash value that is calculated by a hash function based on the transaction data, the timestamp, the nonce and the hash of the previous block. It guarantees that the tamper-free characteristic of blockchain. The computational consensus process, namely proof of work (PoW), is implemented to determine which node can add the new block to blockchain(e.g. Farnaghi and Mansourian, 2020). Any update or change to the data in blockchain must be reviewed and validated by a majority of nodes in a consensus process. Once the data is recorded to blockchain, it is impossible to tamper with the data without altering all the subsequent blocks. Hence, blockchain technology creates an open, transparent, and accountable computational environment.

## 3 Applications of blockchain to geospatial data

Recently, blockchain technology has been gradually used to different aspects of geospatial data, including geospatial data privacy preservation, geospatial data sharing and others. In this section, we review the existing studies and give a summary on how blockchain technology is applied in these aspects.

### 3.1 Preserving geospatial data privacy

Regarding geospatial data privacy preservation, blockchain technology is mainly used to the fields of location-based services. For instance, in response to users' privacy leakage issue while verifying their geographic information in the location-based services, Amoretti et al. (2018) proposed a novel decentralized, infrastructure-independent proof-of-location scheme based on blockchain technology. The evaluation results indicated that the proposed scheme is able to guarantee both location trustworthiness and user privacy preservation. Based on the current privacy issues in the existing spatial crowdsensing system where worker locations are inevitably disclosed during the payment process, Yang et al. (2019) developed a novel blockchain-based privacy-preserving crowdsensing system to prevent the leakage of users' location privacy considering that users' locations are usually exposed during the process of transmitting information to and from the service server. Qiu et al. (2020) developed a novel location privacy protection approach by integrating blockchain technology with a privacy preservation model called k-anonymity (Sweeney, 2002). Compared with the centralized privacy-preservation architecture, the proposed approach is independent on the help of trusted third-party anonymizing servers. In addition, blockchain technology is also used to mitigate the public concern on privacy issues while conducting contact tracing during the COVID-19 pandemic (e.g. Xu et al., 2020; Tahiliani et al., 2021). For example, Xu et al. (2020) presented a blockchain-enabled privacy preserving contact tracing scheme called BeepTrace to combat COVID-19 pandemic.

### 3.2 Preserving geospatial data integrity

Blockchain technology has shown potential in securing storage and information transfer, and promoting integrity (immutability) and ownership of data due to its decentralized characteristic. Since it is built upon the concept of distributed ownership of the node infrastructure, blockchain is suitable for sharing and handling geospatial data more directly and in a more transparent way. For example, the white paper on "Blockchain and Earth Observation" from European Space Agency (2019) proposed that blockchain technology can help to solve existing problems and issues for the earth observation (EO) sector, and open new opportunities for promoting integrity and ownership of EO

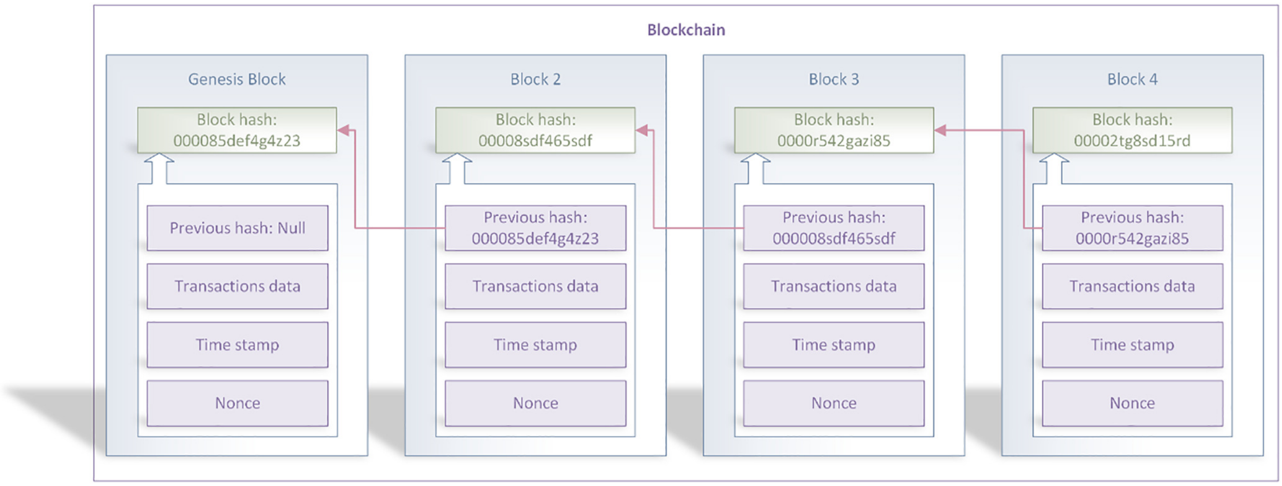


**Figure 1.** One example of blockchain (Farnaghi and Mansourian, 2020).

in data delivery [2]. Another white paper on "Earth Observation Data Provenance with KSI Blockchain" released by ESA (2020) introduced the the Blockchain for Space Activities (BC4SA) project [3]. This project demonstrated how blockchain technology can be used to independently verify the integrity (e.g., data lineage) and provenance of EO data sets at ESA considering that the data is generated, moved across organizational boundaries. Zhang et al. (2019) proposed a blockchain-based remote sensing data sharing model for solving the security problems of data sharing of remote sensing institutions considering the ownership problem in remote sensing data sharing. Pincheira et al. (2020) put forward blockchain-based system to share and retrieve data without the need for a central authority, which can provide trusted data for remote sensing applications and guarantee the data integrity.

### 3.3 Some other applications

There are also some other applications of blockchain based on geospatial data. For instance, the study by Vos et al. (2017) described how the blockchain technology is applied to land administration by considering spatial units/parcel and land rights. Note that some of the principles and requirements of good governance in land administration, such as transparency, accountability, security and rule of law, can be satisfied with blockchain technology. Likewise, Papantonioua and Hilton presented a prototype for land ownership transactions by combining GIS and blockchain, which includes a GIS component and a blockchain component. The blockchain component can support participants (land owners, customers, and other stakeholders) to exchange (buy or sell) land, and the transaction results can be instantly viewed through the GIS component (i.e., a dashboard). Another typical application is FOAM (https://www.foam.space/), which is an open protocol for decentralized geospatial data markets. Specifically, FOAM aims to build a consensus-driven map of the world that can trusted by every application, which secures physical space on the blockchain using a crypto-spatial coordinate (CSC) system. Lynch (2018) introduced how blockchain rewards (Littercoin) is used to motivate people to contribute open data on the geospatial characteristics of litter to OpenLitterMap in response to plastic pollution. Kamel Boulos et al. (2018) discussed the promises, challenges of geospatially-enabled blockchain that uses a crypto-spatial coordinate system to add an immutable spatial context as well as some application scenarios in health and healthcare. Daho (2020) explored the suitability of blockchain technology for the storage, retrieval and processing of vector geospatial data. The concept of CSC from the FOAM protocol was also used to identify spatial features uniquely on the blockchain. Kamali et al. (2021) proposed a spatial crowdsourcing system based on blockchain technology, in which the reward mechanism is used to encourage users' participation in collecting accurate spatial information. In addition, the system also considers the privacy preservation and the security of spatial information.

## 4 Conclusion

This paper provides a review of the existing research on blockchain technology applied to geospatial data, especially in privacy and integrity of preservation of geospatial data. First, the background knowledge of geospatial data privacy and blockchain technology are introduced. Then, how blockchain technologies is applied to geospatial data privacy and integrity preservation is discussed by reviewing the related literature. Besides, we also discuss some other applications of blockchain based on geospatial data, including land administration, consensus-driven

[2]https://eo4society.esa.int/wp-content/uploads/2019/04/Blockchain-and-Earth-Observation_White-Paper-April-2019.pdf

[3]https://eo4society.esa.int/wp-content/uploads/2020/03/EO-data-provenance-with-KSI-blockchain-Feb-2020.pdf

maps, geospatial data storage and retrieval, and crowdsourcing spatial information collection.

In summary, the research on applying blockchain technology to geospatial data has been attracting more attention, but is still relatively limited. This survey is expected to serve as a guideline for further exploring the potential application fields of blockchain technology in geospatial domain towards geospatial blockchain.

## References


Amoretti, M., Brambilla, G., Medioli, F., and Zanichelli, F.: Blockchain-based proof of location, in: 2018 IEEE International Conference on Software Quality, Reliability and Security Companion (QRS-C), pp. 146–153, IEEE, 2018.

Borges, K. A., Laender, A. H., and Davis Jr, C. A.: Spatial data integrity constraints in object oriented geographic data modeling, in: Proceedings of the 7th ACM international symposium on Advances in geographic information systems, pp. 1–6, 1999.

Chun, Y., Kwan, M.-P., and Griffith, D. A.: Uncertainty and context in GIScience and geography: challenges in the era of geospatial big data, 2019.

Coetzee, S., Ivánová, I., Mitasova, H., and Brovelli, M. A.: Open geospatial software and data: A review of the current state and a perspective into the future, ISPRS International Journal of Geo-Information, 9, 90, 2020.

Daho, A. B.: Crypto-spatial: an open standards smart contracts library for building geospatially enabled decentralized applications on the ethereum blockchain, The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 43, 421–426, 2020.

Farnaghi, M. and Mansourian, A.: Blockchain, an enabling technology for transparent and accountable decentralized public participatory GIS, Cities, 105, 102 850, 2020.

Fecher, B. and Friesike, S.: Open science: one term, five schools of thought, in: Opening science, pp. 17–47, Springer, Cham, 2014.

Gordon, A. D. and Jeffrey, A.: Types and effects for asymmetric cryptographic protocols, Journal of Computer Security, 12, 435–483, 2004.

Hojati, M., Farmer, C., Feick, R., and Robertson, C.: Decentralized geoprivacy: leveraging social trust on the distributed web, International Journal of Geographical Information Science, 35, 2540–2566, 2021.

Huang, H., Yao, X. A., Krisp, J. M., and Jiang, B.: Analytics of location-based big data for smart cities: Opportunities, challenges, and future directions, Computers, Environment and Urban Systems, 90, 101 712, 2021.

Kamali, M., Malek, M. R., Saeedi, S., and Liang, S.: A Blockchain-Based Spatial Crowdsourcing System for Spatial Information Collection Using a Reward Distribution, Sensors, 21, 5146, 2021.

Kamel Boulos, M. N., Wilson, J. T., and Clauson, K. A.: Geospatial blockchain: promises, challenges, and scenarios in health and healthcare, 2018.

Katsomallos, M., Tzompanaki, K., and Kotzinos, D.: Privacy, space and time: A survey on privacy-preserving continuous data publishing, Journal of Spatial Information Science, 2019, 57–103, 2019.

Keßler, C. and McKenzie, G.: A geoprivacy manifesto, Transactions in GIS, 22, 3–19, 2018.

Kitchin, R., Lauriault, T. P., and Wilson, M. W.: Understanding spatial media, Sage, 2017.

Kumar, K. M. and Sunitha, N.: Preserving Location Data Integrity in Location Based Servers using Blockchain Technology, in: 2017 2nd International Conference On Emerging Computation and Information Technologies (ICECIT), pp. 1–6, IEEE, 2017.

Lee, J.-G. and Kang, M.: Geospatial big data: challenges and opportunities, Big Data Research, 2, 74–81, 2015.

Leible, S., Schlager, S., Schubotz, M., and Gipp, B.: A review on blockchain technology and blockchain projects fostering open science, Frontiers in Blockchain, p. 16, 2019.

Lin, X., Zhang, Y., Liu, Y., and Gao, Y.: Spatial data integrity ensuring mechanism in SDBMS, in: Proceedings. 2005 IEEE International Geoscience and Remote Sensing Symposium, 2005. IGARSS'05., vol. 1, pp. 4–pp, IEEE, 2005.

Liu, P.: A survey of remote-sensing big data, frontiers in Environmental Science, 3, 45, 2015.

Lv, Z., Qiao, L., Hossain, M. S., and Choi, B. J.: Analysis of using blockchain to protect the privacy of drone big data, IEEE Network, 35, 44–49, 2021.

Lynch, S.: OpenLitterMap. com–open data on plastic pollution with blockchain rewards (littercoin), Open Geospatial Data, Software and Standards, 3, 1–10, 2018.

Martin, K. and Nissenbaum, H.: What is it about location?, Berkeley Tech. LJ, 35, 251, 2020.

Martin, M. E. and Schuurman, N.: Social media big data acquisition and analysis for qualitative GIScience: Challenges and opportunities, Annals of the American Association of Geographers, 110, 1335–1352, 2020.

Monrat, A. A., Schelén, O., and Andersson, K.: A survey of blockchain from the perspectives of applications, challenges, and opportunities, IEEE Access, 7, 117 134–117 151, 2019.

Nakamoto, S.: Bitcoin: A peer-to-peer electronic cash system, Decentralized Business Review, p. 21260, 2008.

Nofer, M., Gomber, P., Hinz, O., and Schiereck, D.: Blockchain, Business & Information Systems Engineering, 59, 183–187, 2017.

Papantoniou, C.: GeoBlockchain: The Analysis, Design, and Evaluation of a Spatially Enabled Blockchain, Ph.D. thesis, The Claremont Graduate University, 2021.

Papantonioua, C. and Hilton, B.: Workflows and Spatial Analysis in the Age of GeoBlockchain: A Land Ownership Example.

Partovi, A., Zheng, W., Jung, T., and Lin, H.: Ensuring privacy in location-based services: a model-based approach, arXiv preprint arXiv:2002.10055, 2020.

Pincheira, M., Donini, E., Giaffreda, R., and Vecchio, M.: A blockchain-based approach to enable remote sensing trusted data, in: 2020 IEEE Latin American GRSS & ISPRS Remote Sensing Conference (LAGIRS), pp. 652–657, IEEE, 2020.

Qiu, Y., Liu, Y., Li, X., and Chen, J.: A novel location privacy-preserving approach based on blockchain, Sensors, 20, 3519, 2020.

Sweeney, L.: k-anonymity: A model for protecting privacy, International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, 10, 557–570, 2002.

Szabo, N.: Formalizing and securing relationships on public networks, First monday, 1997.

Tahiliani, A., Hassija, V., Chamola, V., Kanhere, S. S., Guizani, M., et al.: Privacy-preserving and incentivized contact tracing for covid-19 using blockchain, IEEE Internet of Things Magazine, 4, 72–79, 2021.

Tohidi, N. and Rustamov, R. B.: A review of the machine learning in gis for megacities application, Geogr. Inf. Syst. Geospat. Intell, pp. 29–53, 2020.

Vicente-Saez, R. and Martinez-Fuentes, C.: Open Science now: A systematic literature review for an integrated definition, Journal of business research, 88, 428–436, 2018.

Vos, J., Lemmen, C., and Beentjes, B.: Blockchain based land administration feasible, illusory or a panacea, in: Netherlands Cadastre, Land Registry and Mapping Agency. Paper prepared for presentation at the 2017 World Bank Conference on Land and Povertry. The World Bank, Washington, DC, 2017.

Xie, J., Tang, H., Huang, T., Yu, F. R., Xie, R., Liu, J., and Liu, Y.: A survey of blockchain technology applied to smart cities: Research issues and challenges, IEEE Communications Surveys & Tutorials, 21, 2794–2830, 2019.

Xu, H., Zhang, L., Onireti, O., Fang, Y., Buchanan, W. J., and Imran, M. A.: BeepTrace: blockchain-enabled privacy-preserving contact tracing for COVID-19 pandemic and beyond, IEEE Internet of Things Journal, 8, 3915–3929, 2020.

Yaga, D., Mell, P., Roby, N., and Scarfone, K.: Blockchain technology overview, arXiv preprint arXiv:1906.11078, 2019.

Yang, M., Zhu, T., Liang, K., Zhou, W., and Deng, R. H.: A blockchain-based location privacy-preserving crowdsensing system, Future Generation Computer Systems, 94, 408–418, 2019.

Zhang, L., Gao, Y., Chen, J., Wang, X., Huang, Z., and Wei, D.: Research on Remote Sensing Data Sharing Model Based on Blockchain Technology, in: Proceedings of the 2019 2nd International Conference on Blockchain Technology and Applications, pp. 59–63, 2019.

Zhao, P., Bucher, D., Martin, H., and Raubal, M.: A clustering-based framework for understanding individuals' travel mode choice behavior, in: International Conference on Geographic Information Science, pp. 77–94, Springer, 2019.

Zurbarán, M., Wightman, P., Brovelli, M., Oxoli, D., Iliffe, M., Jimeno, M., and Salazar, A.: NRand-K: Minimizing the impact of location obfuscation in spatial analysis, Transactions in GIS, 22, 1257–1274, 2018.

Zurbarán, M. A., Salazar, A., Brovelli, M. A., and Wightman, P. M.: An evaluation framework for assessing the impact of location privacy on geospatial analysis, IEEE Access, 8, 158 224–158 236, 2020.