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# Harnessing Crowdsourcing Data for Comprehensive Green Window View Analysis

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## 1 ABSTRACT

The paradigm of sustainable resilient cities underscores the importance of how to withstand and rapidly recover from natural disasters, pandemics, or chronic stresses associated with increasing urbanization, environmental degradation, and climate change through the use of advanced technologies and data analytics. Access to urban green spaces is a key requirement for developing and maintaining a sustainable, resilient, and healthy city, as described in Sustainable Development Goal 11.7 and the Sendai Framework. Due to necessary triple inner urban development processes that creates multifunctional spaces in urban areas, the resulting vertical and horizontal densification often leads to an impairment of visual access to urban green spaces. Green window views, which reveal visual access to green spaces from buildings, provide a significant impact on multidimensional aspects of urban dwellers. Still, few studies present how this form of access, in its quantitative and qualitative complexity, should be operationalized into a tool for urban planning. Given socio-technical advances, crowdsourcing, as an increasingly popular participatory method for collecting and managing data, has the potential to contribute to the realization of inclusive planning by incorporating passive and active participatory processes and open-source standards. Therefore, this study aims to integrate key aspects of crowdsourced-based approach and window view accessibility analysis. By leveraging the power of crowdsourcing, we investigate the potential of Volunteered Window View Imagery (VWVI) for green window view analysis. Incorporating VWVI enables informed decisions by urban planners, ensuring resilient, inclusive, and accessible urban green spaces. This integration of VGI and window view analysis advances sustainable and resilient urban development.

Keywords: sustainable resilient cities, urban green spaces, crowdsourcing, spatial planning, visibility analysis

## 2 INTRODUCTION

Owing to their multiple ecosystem services to urban populations, planning and ensuring high quality and accessible urban green spaces are crucial for a sustainable and resilient city, as SDG 11.7 requires (Semeraro et al., 2021; United Nations, 2017). In addition to the availability (number, size, and ratio) and accessibility (distance, travel time, and buffer zones), visibility gains a key role in ensuring accessible urban green spaces due to spatial and access consequences of natural disasters like floods or pandemics on the urban space and the urban population (Amerio et al., 2020; Hobeica & Hobeica, 2018; Labib et al., 2021; Yin et al., 2023). Additionally, increasing urbanization and the implementation of necessary triple inner urban development processes, which focus not only on built-up redensification but also on the planning of mobility offers and the increase of urban green spaces quantity and quality, lead to two- and three-dimensional changes of urban space and thus to a changed visual access to urban green spaces (Haaland & Konijnendijk van den Bosch, 2015; Umweltbundesamt, 2022). In order to meet these challenges and to guarantee a sufficiently accessible provision of urban green spaces, it is necessary to measure, evaluate, and investiagte the status quo situation as well as planned scenarios of built-up and urban green spaces. For this purpose, smart approaches, such as the use of digital twins or big data, are increasingly being used to gain the necessary insights (Farkas et al., 2023). In the digital era, leveraging alternative data sources like social sensing, crowdsourcing, and Volunteered Geographic Information (VGI) can enhance data capabilities. Accessing near-real-time geospatial information can lead to better-informed decisions, driving innovation in geospatial technology, improving the quality and applicability of spatial data, overcoming institutional barriers, and strengthening community resilience through enhanced access to geospatial information services (FIG, 2019; UNISDR, 2017; World Bank, 2020).

In this paper, recognizable limitations in the use of these approaches in the quantification of visible access will be addressed by the presentation of an integrated framework that leverages the power of crowdsourcing for visibility analysis of urban green spaces (Lei et al., 2023). The paper first presents the research context of visible urban green spaces and crowdsourcing including their methodologiocal state of the art as well as challenges and research gaps and links both research areas into an integrated approach for using crowdsourcing to collect and evaluate Volunteered Window View Imagery (VWVI). The paper concludes with an outlook for planning practice and research.

## 3 RESEARCH CONTEXT

### 3.1 Visibility of Urban Green Spaces

The visibility of urban green spaces can be understood as the visible connection between the urban dweller and urban vegetated areas (adapted from Wang et al. (2017)). Depending on the location of the observer, the observation level can be on the street (street view) or in the building (window view) (Bolte et al., 2019). Streets are primarily publicly accessible and can therefore be used by the general public, whereas in the case of buildings a distinction needs to be made between publicly accessible and usable (such as schools, and hospitals) or privately accessible and used (e.g. residential buildings or workplaces). In both access cases, the visibility of urban green spaces matters. The exemplary studies in Fig. 1 serve to illustrate the complex research field of visibility analysis of urban green spaces.

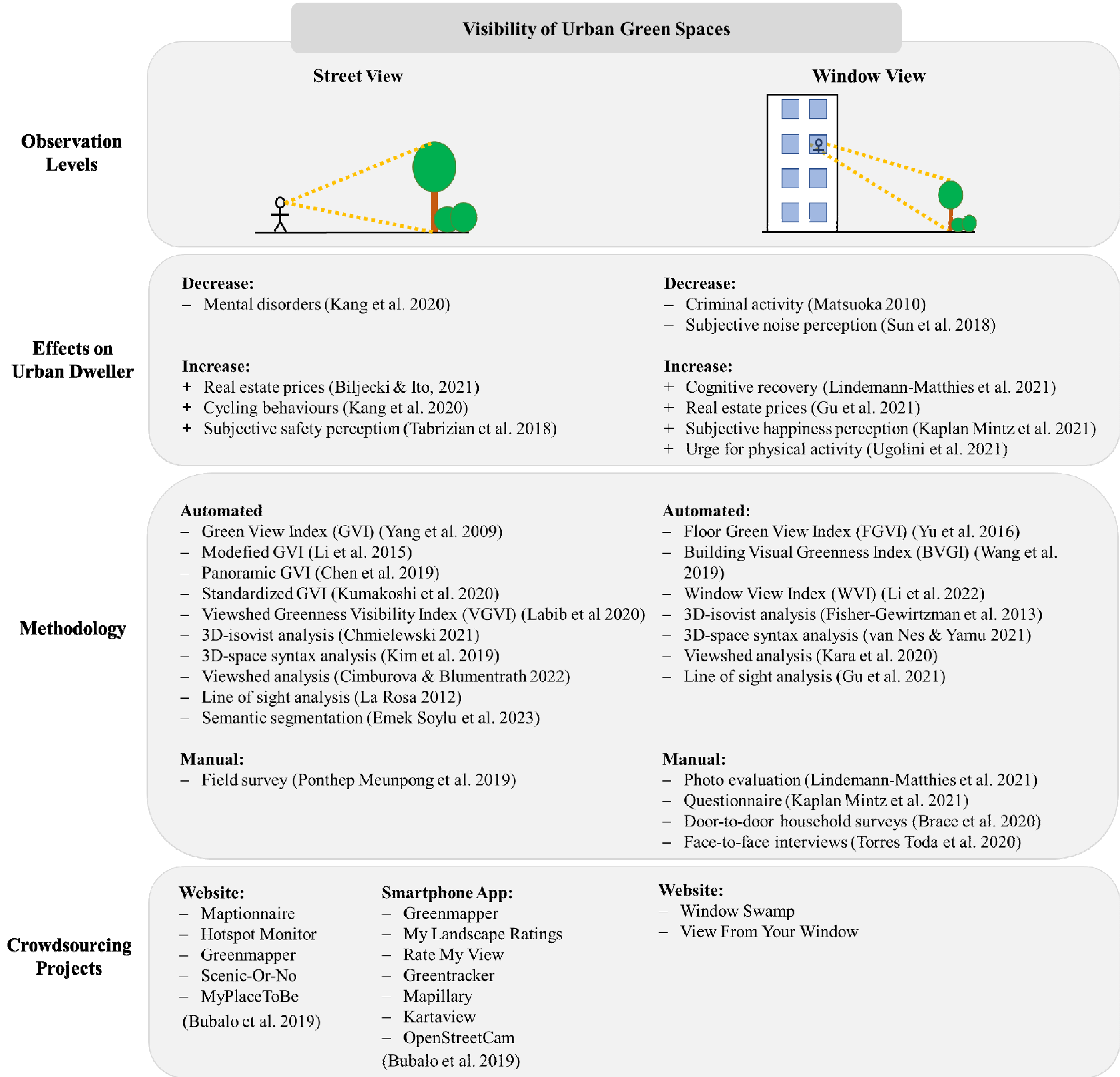


Fig. 1: Visibility of urban green spaces. Source: Own illustration.

#### 3.1.1 Multidimensional Effects on Urban Dweller

Independent of the level of observation, the view of urban green spaces has significant positive effects on urban dwellers. Effect areas concerning the psyche or cognitive recovery as well as the subjective noise, and safety perception, for example are positively influenced (Kang et al., 2020; Kaplan Mintz et al., 2021; Lindemann-Matthies et al., 2021; Sun et al., 2018; Tabrizian et al., 2018). The view of green spaces leads to an increase in physical activity or in real estate values and to a decrease in criminal activity (Biljecki & Ito, 2021; Gu et al., 2021; Kang et al., 2020; Matsuoka, 2010; Ugolini et al., 2021). The consequently illustrated relevance for the integration of visibility analysis into planning practice includes street planning as well as building planning.

#### 3.1.2 Methodology to Measure Quantity and Quality of Visible Urban Green Spaces

A variety of automated or manual methods can be applied by now in order to measure the quantity and quality of visible urban green spaces (Brace et al., 2020; Chen et al., 2019; Chmielewski, 2021; Cimburova & Blumentrath, 2022; Emek Soylu et al., 2023; Fisher-Gewirtzman et al., 2013; Gu et al., 2021; Kaplan Mintz et al., 2021; Kara et al., 2020; KIM et al., 2019; Kumakoshi et al., 2020; La Rosa, 2012; Labib et al., 2020; M. Li et al., 2022; X. Li et al., 2015; Lindemann-Matthies et al., 2021; Ponthep Meunpong et al., 2019; Torres Toda et al., 2020; van Nes & Yamu, 2021; Wang et al., 2019; Yang et al., 2009; Yu et al., 2016). The majority of automated indices to quantify urban green spaces on the street level rely on semantic segmentation of Street View Imagery (SVI), in which Google Street View® plays a key role as data provider (Biljecki & Ito, 2021; Chen et al., 2019; Emek Soylu et al., 2023; Kumakoshi et al., 2020; X. Li et al., 2015; Yang et al., 2009). For window view quantification, the majority of automated approaches are based on three-dimensional environment modeling and use viewshed analyses or line of sight analyses(Gu et al., 2021; Kara et al., 2020; Wang et al., 2019; Yu et al., 2016). Concerning manual quantification approaches to investigate window views, there is a noticeable focus on surveying the inhabitants or users of buildings. Especially these manual approaches are also used for the assessment of window views (Brace et al., 2020; Kaplan Mintz et al., 2021; Lindemann-Matthies et al., 2021; Torres Toda et al., 2020).

### 3.2 Crowdsourcing and Voluneteered Geographic Information (VGI)

The rapid progress in geospatial technologies, fueled by emerging data sources such as Digital Twins, Web 2.0, mobile communications, volunteer crowdsourcing, digital volunteering, georeferencing, and geotagging, has led to profound changes in urban studies. These advancements have prompted urban initiatives to reevaluate their core principles and approaches. By harnessing the power of these technological capabilities, urban initiatives can proactively reshape planning and practices. However, this requires embracing the potential of these technologies to adapt and effectively respond to evolving challenges, thereby optimizing the overall resilience and sustainability of urban areas for a livable city (Goodchild, 2007; Haworth & Bruce, 2015; Porto de Albuquerque et al., 2021).

Over a decade ago, VGI was defined by Goodchild (2007) as the utilization of tools to voluntarily create, compile, and distribute geographic data contributed by individuals. Since then, the landscape of VGI activities has expanded, encompassing a wide range of contributions such as online crowdsourced mapping and location-related posts on social media. This, coupled with the advent of digital transformation, has transformed the acquisition and provision of geospatial data, significantly impacting established authoritative systems and fostering new avenues of public engagement through voluntary contributions (Fernandes et al., 2020; Foody et al., 2017). Noteworthy attributes of VGI include its ability to capture the temporal dynamics of spatial information, enabling multidirectional communication, enhancing situational awareness, and harnessing collective intelligence, potentially surpassing the capabilities of traditional geospatial datasets (Haworth et al., 2018; Kankanamge et al., 2019).

Hence, incorporating VGI into sustainable green space initiatives offers numerous advantages. It not only helps bridge the data gap in geospatial information related to green spaces by involving volunteers in the collaborative creation, curation, and dissemination of free, up-to-date, and near-real-time geospatial data (Givoni, 2016; Solís et al., 2021), but also fosters self-organization within the digital volunteer network. This empowers remote citizens and volunteers to actively contribute their technical expertise, local knowledge, and on-site insights to enhance sustainable green space initiatives (Capineri et al., 2016; Johnson & Sieber, 2013). Furthermore, leveraging these collaborative data ecosystems can promote the accessibility of geospatial information and associated techno-social tools for all individuals, while also facilitating the development of innovative customized tools that contribute to assess visibility and accessibility of green spaces (Arsanjani et al., 2015).

### 3.2.1 Existing Cowdsourcing Projects for Quantifying and Assessing Visible Urban Green Spaces

The integration of the mentioned potentials and strengths of crowdsoucing and VGI is mainly considered in the street view analysis (see Fig. 1, p.2). A plurality of projects focus on the collection of Volunteered Street View Imagery (VSVI), view locations, and view ratings and are operated through websites or smartphone apps (Bubalo et al., 2019; Hou & Biljecki, 2022; Mahabir et al., 2020; Qiu et al., 2023). The existing number of different projects initiates the quality check of data and information in terms of subjectivity and objectivity, as well as the comparison of applications, complementing the investigation of individual visibility effects at the street level with VSVI (Hou & Biljecki, 2022; Mahabir et al., 2020; Qiu et al., 2023). Considering crowdsourcing for window views, VWVI is collected via websites or on request in a blog forum and presented with further information about the location and time of VWVI. The artistic focus of both projects, with no discernible claim to research utility, is unifying.

# 4 UTILIZAZING CROWDSOURCING IN WINDOW VIEW ANALYSIS

## 4.1 Information Bundling from Volunteered Window View Imagery (VWVI)

Despite the wide range of multidimensional effect areas of visible urban green spaces, the low level of integration of crowdsourcing to quantify and evaluate window views so far highlights the need to design an appropriate crowdsourcing application to benefit from a broad and comparable VWGI basis for research and planning pracise. By collecting VWVI, detailed information that was previously collected separately by automated or manual methodologies in window view analysis can be bundled together while maintaining consistent and transparent data resolution and quality. The information concerns the a) observer, b) location, c) environment, and d) window view (see Fig. 2.). They are explained in more detail below and are based on the insights of the studies mentioned in Fig. 1., p. 2:

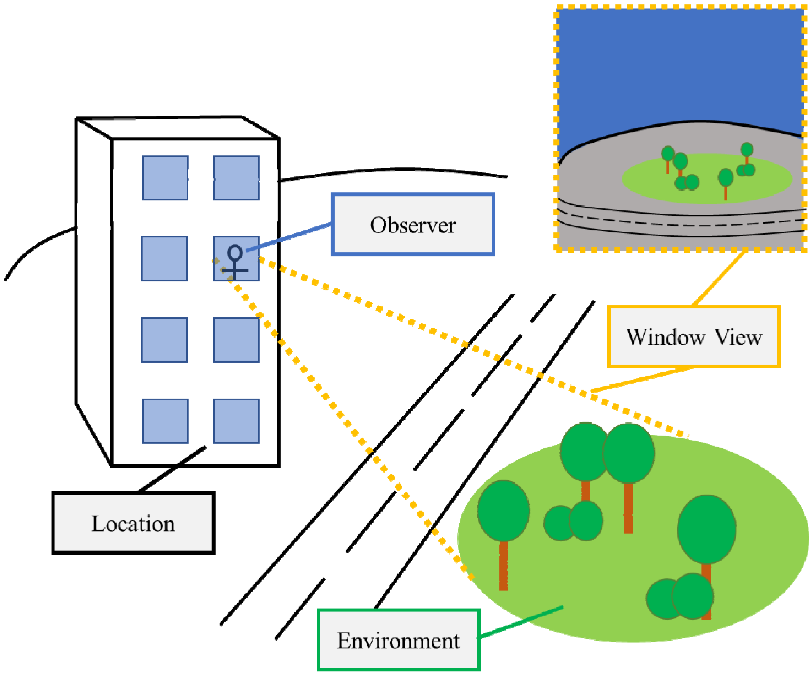


Fig. 2: Information bundling from VWVI. Source: Own illustration.

### 4.1.1 Observer

The observer can be characterized in terms of age, gender, occupation and/or reason for staying in the building (Brace et al., 2020; Gu et al., 2021; Kaplan Mintz et al., 2021; Lindemann-Matthies et al., 2021; Matsuoka, 2010; Sun et al., 2018; Torres Toda et al., 2020; Ugolini et al., 2021).

#### 4.1.2 Location

The location can be described spatially and functionally: This includes the geographical localization and information concerning the building, such as the floor number where the observer is standing, as well as the observer's position in the room and their distance to the window. The primary function of the building should not be mistaken for the occupation or the observers's reason for staying, since different functions can be performed in the same building (e.g. hospital: work of the nurse and recovery of the patient) (Brace et al., 2020; Fisher-Gewirtzman et al., 2013; Gu et al., 2021, 2021; Kaplan Mintz et al., 2021; Kara et al., 2020; M. Li et al., 2022; Lindemann-Matthies et al., 2021; Matsuoka, 2010; Sun et al., 2018; Torres Toda et al., 2020; Ugolini et al., 2021; van Nes & Yamu, 2021; Wang et al., 2019; Yu et al., 2016).

#### 4.1.3 Environment

The environment is described by the characteristics of the topography as well as the type, phenological characteristics, shape, and height of the urban green area and the distance of the area to the location (Brace et al., 2020; Fisher-Gewirtzman et al., 2013; Gu et al., 2021, 2021; Kaplan Mintz et al., 2021; Kara et al., 2020; M. Li et al., 2022; Lindemann-Matthies et al., 2021; Matsuoka, 2010; Sun et al., 2018; Torres Toda et al., 2020; Ugolini et al., 2021; van Nes & Yamu, 2021; Wang et al., 2019; Yu et al., 2016).

#### 4.1.4 Window View

The window view is first described technically. This includes the window size, the observer's personal field of view (FOV), the window's direction and the time. Information on the quantity and quality of the window view describes the amount and type of visible targets in the view. Reduced visibility due to smog or weather conditions may also fall under this category. In addition to vegetated areas, other elements such as, sky or built-up as well as sealed structures could also be mentioned. Furthermore, the observer's personal assessment of the window view's content as well as their multidimensional effects on him need to be adressed (Brace et al., 2020; Fisher-Gewirtzman et al., 2013; Gu et al., 2021, 2021; Kaplan Mintz et al., 2021; Kara et al., 2020; M. Li et al., 2022; Lindemann-Matthies et al., 2021; Matsuoka, 2010; Sun et al., 2018; Torres Toda et al., 2020; Ugolini et al., 2021; van Nes & Yamu, 2021; Wang et al., 2019; Yu et al., 2016).

### 4.2 Key Aspects of Utilizing Crowdsourcing and VGI

Adapted from Moghadas et al. (2022) core crowdsourcing and VGI aspects related to visibility analysis of urban green spaces were identified as below (see Fig. 3 for an overview):

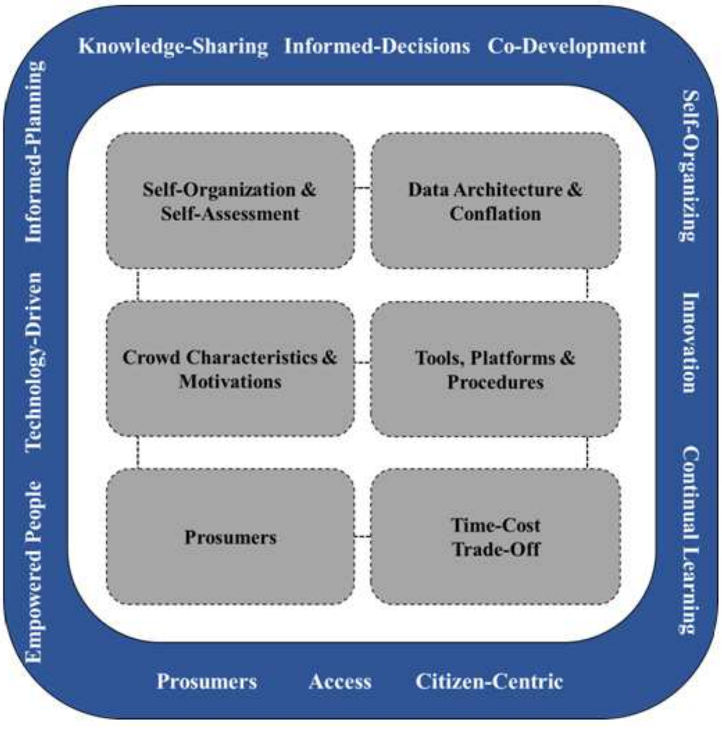


Fig. 3: Key aspects of utilizing crowdsourcning and VGI for assessment of urban green spcae visibility. Source: Own illustration.


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#### 4.2.1 Self-Organization and Self-Assessment

The potential for self-organization and self-assessment becomes evident within VGI-based communities through the active engagement of citizens, community-led organizations, and digital technologies that promote e-participation (Malek et al., 2021). Self-organization, which involves internal reorganization and increased self-awareness, enables innovative problem-solving based on collective intelligence (Palen et al., 2020). Community platforms like OSM, Mapathons, and Missing Maps serve as channels through which local communities and remote volunteers collaborate in collecting, validating, analyzing, and sharing information, thereby fostering a people-centric approach to humanitarian efforts (Givoni, 2016).

#### 4.2.2 Crowd Characteristics and Motivations

Within the realm of visibility of green spaces, VGI platforms can engage participants with diverse levels of expertise, experience, and responsibilities (Coleman et al., 2010). Motivations for contributing to crowdsourcing and VGI initiatives also vary, ranging from positive and altruistic motivations like social recognition, personal reputation, professional interest, community connection, and skill development (Elwood et al., 2012), to potential detrimental contributions such as the spread of misinformation or mass deletions (Coleman et al., 2010). Understanding the characteristics of the crowd and formulating effective motivational strategies play a crucial role in shaping the outcomes of VGI initiatives focused on assessing the visibility of green spaces (Senaratne et al., 2017). Since the nature of a crowd can be relative, it is essential to identify contribution patterns, types, and roles within the initiative's goals and roadmap at an early stage (Yan et al., 2020).

#### 4.2.3 Prosumers

Prosumers, individuals who actively engage as both producers and consumers (Rifkin, 2015), have emerged as key contributors in assessing the visibility of green spaces. Enabled by VGI platforms and associated processes, citizens and remote volunteers can participate as prosumers, generating geospatial content that specifically addresses the assessment of green space visibility based on their own needs and community requirements. By bringing together prosumers, collaborative production and utilization of geospatial data for assessing green space visibility becomes possible. This empowers real-time access to information and minimizes duplication of effort, optimizing the use of resources (Yan et al., 2020) in the pursuit of assessing and enhancing visibility and accessibility of green spaces.

#### 4.2.4 Data Architecture and Conflation

Data architecture plays a vital role in governing the standardized processes of data collection, analysis, and utilization within organizations (Steiniger et al., 2016). To effectively analyze the visibility of green spaces using VGI, it is essential for researchers to adopt a systematic approach that guides contributors in creating, curating, and analyzing relevant data. Establishing practical guidelines for data architecture, considering the potential absence of standardized metadata in VGI, is crucial to ensure a comprehensive understanding of green space visibility. VGI, as a socially constructed epistemology, encompasses distinct labor, reference, and governance relationships that should be treated independently (Sieber & Haklay, 2015). It serves as a valuable complement to authoritative datasets in analyzing the visibility of green spaces, addressing challenges such as cost, outdated information, and restrictive licenses (Grinberger et al., 2019). By incorporating VGI into a formalized data collection and collaboration process, initiatives can meet specific requirements, including real-time updates, additional attribute information, community engagement, and cost-effectiveness (FIG, 2019). Embracing hybrid epistemologies and data conflation processes, integrating VGI into the analysis of green space visibility, offers significant opportunities for data-driven decision-making (Yan et al., 2020). This shift enables the effective utilization of VGI alongside authoritative data, empowering stakeholders with valuable insights to assess and enhance the visibility of green spaces in a meaningful and impactful way.

#### 4.2.5 Tools, Platforms, and Procedures

Location-based and GPS-based services, such as maps, social media apps, and tracking tools, offer valuable support in assessing the visibility of green spaces (Mooney & Minghini, 2017). By collecting user data and providing actionable information through map interfaces, these services aid in evaluating and the visibility of green spaces. Volunteer-driven methods, including OSM, WikiMapia, and Geo-Wiki, along with smartphone apps enable the collection and sharing of geospatial data (Haworth & Bruce, 2015; Moreri et al., 2018). These tools empower citizens to contribute to the assessment of green space visibility, improving the availability and accuracy of information. Urban dashboards or urban digital twin platforms can serve as centralized platforms to aggregate various data sources, such as social sensing, facilitating real-time visibility assessment and promoting transparency and efficiency (Moghadas et al., 2023). To ensure effective assessment of green space visibility, practices like organizing community mapping events (Mapathons) and employing planning checklists, workflows, and data catalogs are crucial (Givoni, 2016). These practices enable the contextualization of visibility assessment initiatives based on specific goals, local values, and community needs.

#### 4.2.6 Time-Cost Trade-Offs

In the realm of assessing green space visibility, the power of modern communication technologies allows individuals known as prosumers to share their location-based knowledge, goods, and services at reduced costs (Rifkin, 2015). VGI plays a pivotal role in this context, enabling the rapid and cost-effective sharing of diverse geographic information (Haworth & Bruce, 2015) related to green spaces. By engaging digital and on-site volunteers, internet-based platforms facilitate the real-time collection and dissemination of large volumes of geospatial data, contributing to better assessment of green space visibility (Moreri et al., 2018). These advancements, including crowdsourcing, digital volunteering, and mobile communications, empower dynamic monitoring and multidirectional communication, driving advancements in green space visibility assessments beyond traditional and costly methods (Pan et al., 2016).

## 5 OUTLOOK AND CONCLUSION

To cope with sudden shocks and chronic stresses that change the visual access to required urban green spaces, advanced technologies and data analytics must be used to ensure sustainable and resilient urban planning. The increasing popularity and importance of crowdsourcing as a participatory method for data collection and management is indispensable for the realization of inclusive urban planning. The introduced approach, which integrates crowdsourcing into window view analysis, effectively addresses these issues and presents the current state of the art. It not only identifies the research gaps in visibility analysis and crowdsourcing but also emphasizes the multifaceted potentials for an integrated planning application. Future research will focus on exploring concrete technical implementation possibilities to facilitate a comprehensive collection of Volunteered Window View Imagery (VWVI) to derive planning recommendations for planning buildings of private and public purposes and to strengthen both research and practical planning purposes. By utilizing crowdsourced data, consequently, planners gain insights into the visibility of green spaces from various vantage points, enabling them to make informed decisions about land use and development. Moreover, this approach aligns with the goal of designing accessible and livable spaces, promoting inclusive planning that considers the needs of diverse communities. The insights derived from crowdsourced data facilitate the creation of urban environments that positively impact residents' well-being. Moreover, the integration of crowdsourcing in urban planning strategies, such as the Urban Green Space Network, allows for smart growth and development. Planners can strategically connect green spaces, considering their visibility and accessibility, thus optimizing land usage and fostering sustainable urban expansion. In this way, crowdsourced window view data not only enriches urban planning processes but also contributes substantially to the evaluation of land suitability and its potential for enhancing the overall urban experience.

## 6 REFERENCES

Amerio, A., Brambilla, A., Morganti, A., Aguglia, A., Bianchi, D., Santi, F., Costantini, L., Odone, A., Costanza, A., Signorelli, C., Serafini, G., Amore, M., & Capolongo, S. (2020). COVID-19 Lockdown: Housing Built Environment's Effects on Mental Health. International Journal of Environmental Research and Public Health, 17(16), 5973–5982. https://doi.org/10.3390/ijerph17165973

Arsanjani, J. J., Zipf, A., Mooney, P., & Helbich, M. (2015). OpenStreetMap in GIScience Experiences, Research, and Applications. http://www.springer.com/gb/book/9783319142791

Biljecki, F., & Ito, K. (2021). Street view imagery in urban analytics and GIS: A review. Landscape and Urban Planning, 215, 104217:1-104217:20. https://doi.org/10.1016/j.landurbplan.2021.104217

Bolte, A.-M., Kötter, T., & Schuppe, S. (2019). Can you see green or blue? On the necessity of visibility analysis of urban open spaces using Remote Sensing techniques and Geographic Information Systems. 2019 Joint Urban Remote Sensing Event (JURSE), 1–4. https://doi.org/10.1109/JURSE.2019.8808936

Brace, O., Garrido-Cumbrera, M., Foley, R., Correa-Fernandez, J., Suarez-Caceres, G., & Lafortezza, R. (2020). Is a View of Green Spaces from Home Associated with a Lower Risk of Anxiety and Depression? INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH, 17(19). https://doi.org/10.3390/ijerph17197014

Bubalo, M., van Zanten, B. T., & Verburg, P. H. (2019). Crowdsourcing geo-information on landscape perceptions and preferences: A review. Landscape and Urban Planning, 184(April 2019), 101–111. https://doi.org/10.1016/j.landurbplan.2019.01.001

Capineri, C., Haklay, M., Huang, H., Antoniou, V., Kettunen, J., Ostermann, F., & Purves, R. (2016). European Handbook of Crowdsourced Geographic Information. Ubiquity Press. http://dx.doi. org/10.5334/bax

Chen, X., Meng, Q., Hu, D., Zhang, L., & Yang, J. (2019). Evaluating Greenery around Streets Using Baidu Panoramic Street View Images and the Panoramic Green View Index. Forests, 10(12), 1109. https://doi.org/10.3390/f10121109

Chmielewski, S. (2021). Towards Managing Visual Pollution: A 3D Isovist and Voxel Approach to Advertisement Billboard Visual Impact Assessment. ISPRS International Journal of Geo-Information, 10(10), 1–19. https://doi.org/10.3390/ijgi10100656

Cimburova, Z., & Blumentrath, S. (2022). Viewshed-based modelling of visual exposure to urban greenery – An efficient GIS tool for practical planning applications. Landscape and Urban Planning, 222(June 2022), 1–11. https://doi.org/10.1016/j.landurbplan.2022.104395

Coleman, D. J., Sabone, B., & Nkhwanana, N. J. (2010). Volunteering geographic information to authoritative databases: Linking contributor motivations to program characteristics. Geomatica, 64(1), 383–396. https://doi.org/10.5623/geomat-2010-0004

Elwood, S., Goodchild, M. F., & Sui, D. Z. (2012). Researching Volunteered Geographic Information: Spatial Data, Geographic Research, and New Social Practice. Annals of the Association of American Geographers, 102(3), 571–590. https://doi.org/10.1080/00045608.2011.595657

Emek Soylu, B., Guzel, M. S., Bostanci, G. E., Ekinci, F., Asuroglu, T., & Acici, K. (2023). Deep-Learning-Based Approaches for Semantic Segmentation of Natural Scene Images: A Review. Electronics, 12(12), 1–49.

Farkas, J. Z., Hoyk, E., de Morais, M. B., & Csomós, G. (2023). A systematic review of urban green space research over the last 30 years: A bibliometric analysis. Heliyon, 9(2), 1–14. https://doi.org/10.1016/j.heliyon.2023.e13406

Fernandes, V. O., Elias, E. N., & Zipf, A. (2020). INTEGRATION OF AUTHORITATIVE AND VOLUNTEERED GEOGRAPHIC INFORMATION FOR UPDATING URBAN MAPPING: CHALLENGES AND POTENTIALS. Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLIII-B4-2020, 261–268. https://doi.org/10.5194/isprs-archives-XLIII-B4-2020-261-2020

FIG (Ed.). (2019). New Trends in Geospatial Information: The Land Surveyors Role in the Era of Crowdsourcing and VGI: Current State and Practices Within the Land Surveying, Mapping and Geo-Science Communities.

Fisher-Gewirtzman, D., Shashkov, A., & Doytsher, Y. (2013). Voxel based volumetric visibility analysis of urban environments. Survey Review, 45(333), 451–461. https://doi.org/10.1179/1752270613Y.0000000059

Foody, G., See, L., Fritz, S., Mooney, P., Olteanu-Raimond, A. M., Fonte, C. C., & Antoniou, V. (2017). Mapping and the Citizen Sensor. In Mapping and the Citizen Sensor (pp. 1–12).

Givoni, M. (2016). Between micro mappers and missing maps: Digital humanitarianism and the politics of material participation in disaster response. Environment and Planning D: Society and Space, 34(6), 1025–1043. https://doi.org/10.1177/0263775816652899

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

Grinberger, A. Y., Schott, M., Raifer, M., Troilo, R., & Zipf, A. (2019). The Institutional Contexts of Volunteered Geographic Information Production: A Quantitative Exploration of OpenStreetMap Data. Proceedings of the "Geographical and Cultural Aspects of Geo-Information: Issues and Solutions," 4–9.

Gu, J., Wang, X., & Liu, G. (2021). Rediscovering the amenity value of urban landscapes in the mountainous areas with high-rise buildings from the perspective of 3D vertical urban systems. Urban Forestry & Urban Greening, 60, 127018:1-. https://doi.org/10.1016/j.ufug.2021.127018

Haaland, C., & Konijnendijk van den Bosch, C. (2015). Challenges and strategies for urban green-space planning in cities undergoing densification: A review. Urban Forestry & Urban Greening, 14(4), 760–771. https://doi.org/10.1016/j.ufug.2015.07.009

Haworth, B., & Bruce, E. (2015). A Review of Volunteered Geographic Information for Disaster Management. Geography Compass, 9(5), 237–250. https://doi.org/10.1111/gec3.12213

Haworth, Bb., Bruce, E., Whittaker, J., & Read, R. R. (2018). The Good, the Bad, and the Uncertain: Contributions of Volunteered Geographic Information to Community Disaster Resilience. Frontiers in Earth Science, 6, 1–15. https://doi.org/10.3389/feart.2018.00183

Hobeica, L., & Hobeica, A. (2018). Flood-prone urban parks: Linking flood adaptation and risk awareness. Territorium, 25(2), 143–160. https://doi.org/10.14195/1647-7723_25-2_12

Hou, Y., & Biljecki, F. (2022). A comprehensive framework for evaluating the quality of street view imagery. International Journal of Applied Earth Observation and Geoinformation, 115(December 2022), 1–15. https://doi.org/10.1016/j.jag.2022.103094

Johnson, P. A., & Sieber, R. E. (2013). Situating the Adoption of VGI by Government. In Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice (pp. 65–81).

Kang, Y., Zhang, F., Gao, S., Lin, H., & Liu, Y. (2020). A review of urban physical environment sensing using street view imagery in public health studies. Annals of GIS, 26(3), 261–275. https://doi.org/10.1080/19475683.2020.1791954

Kankanamge, N., Yigitcanlar, T., Goonetilleke, A., & Kamruzzaman, M. (2019). Can volunteer crowdsourcing reduce disaster risk? A systematic review of the literature. International Journal of Disaster Risk Reduction, 35(February), 101097. https://doi.org/10.1016/j.ijdrr.2019.101097

Kaplan Mintz, K., Ayalon, O., Nathan, O., & Eshet, T. (2021). See or Be? Contact with nature and well-being during COVID-19 lockdown. Journal of Environmental Psychology, 78, 101714:1-101714:13. https://doi.org/10.1016/j.jenvp.2021.101714

Kara, A., van Oosterom, P., Çağdaş, V., Işıkdağ, Ü., & Lemmen, C. (2020). 3 Dimensional data research for property valuation in the context of the LADM Valuation Information Model. Land Use Policy, 98, 104179:1-104179:1. https://doi.org/10.1016/j.landusepol.2019.104179

KIM, G., KIM, A., & KIM, Y. (2019). A new 3D space syntax metric based on 3D isovist capture in urban space using remote sensing technology. Computers, Environment and Urban Systems, 74(March 2019), 74–87. https://doi.org/10.1016/j.compenvurbsys.2018.11.009

Kumakoshi, Y., Chan, S. Y., Koizumi, H., Li, X., & Yoshimura, Y. (2020). Standardized Green View Index and Quantification of Different Metrics of Urban Green Vegetation. Sustainability, 12(18), 7434. https://doi.org/10.3390/su12187434

La Rosa, D. (2012). The observed landscape: Map of visible landscape values in the province of Enna (Italy). Journal of Maps, 7(1), 291–303. https://doi.org/10.4113/jom.2011.1183

Labib, S. M., Huck, J. J., & Lindley, S. (2020). Modelling and mapping eye-level greenness visibility exposure using multi-source data at high spatial resolutions. Science of The Total Environment, 755(1), 1–14. https://doi.org/10.1016/j.scitotenv.2020.143050

Labib, S. M., Lindley, S., & Huck, J. J. (2021). Estimating multiple greenspace exposure types and their associations with neighbourhood premature mortality: A socioecological study. Science of The Total Environment, 789(147919), 1–14. https://doi.org/10.1016/j.scitotenv.2021.147919

Lei, B., Janssen, P., Stoter, J., & Biljecki, F. (2023). Challenges of urban digital twins: A systematic review and a Delphi expert survey. Automation in Construction, 147(March 2023), 1–15. https://doi.org/10.1016/j.autcon.2022.104716

Li, M., Xue, F., Wu, Y., & Yeh, A. G. O. (2022). A room with a view: Automatic assessment of window views for high-rise high-density areas using City Information Models and deep transfer learning. Landscape and Urban Planning, 226(October 2022), 104505. https://doi.org/10.1016/j.landurbplan.2022.10450

Li, X., Zhang, C., Li, W., Ricard, R., Meng, Q., & Zhang, W. (2015). Assessing street-level urban greenery using Google Street View and a modified green view index. Urban Forestry & Urban Greening, 14(3), 675–685. https://doi.org/10.1016/j.ufug.2015.06.006

Lindemann-Matthies, P., Benkowitz, D., & Hellinger, F. (2021). Associations between the naturalness of window and interior classroom views, subjective well-being of primary school children and their performance in an attention and concentration test. Landscape and Urban Planning, 214, 104146:1-. https://doi.org/10.1016/j.landurbplan.2021.104146

Mahabir, R., Schuchard, R., Crooks, A., Croitoru, A., & Stefanidis, A. (2020). Crowdsourcing Street View Imagery: A Comparison of Mapillary and OpenStreetCam. ISPRS International Journal of Geo-Information, 9(6), 1–22. https://doi.org/10.3390/ijgi9060341

Malek, J. A., Lim, S. B., & Yigitcanlar, T. (2021). Social Inclusion Indicators for Building Citizen-Centric Smart Cities: A Systematic Literature Review. Sustainability, 13(1), 376. https://doi.org/10.3390/su13010376

Matsuoka, R. H. (2010). Student performance and high school landscapes: Examining the links. Landscape and Urban Planning, 97(4), 273–282. https://doi.org/10.1016/j.landurbplan.2010.06.011

Moghadas, M., Fekete, A., Rajabifard, A., & Kötter, T. (2023). The wisdom of crowds for improved disaster resilience: A near-real-time analysis of crowdsourced social media data on the 2021 flood in Germany. GeoJournal, 1–27. https://doi.org/10.1007/s10708-023-10858-x

Moghadas, M., Rajabifard, A., Fekete, A., & Kötter, T. (2022). A Framework for Scaling Urban Transformative Resilience through Utilizing Volunteered Geographic Information. ISPRS International Journal of Geo-Information, 22(114). https://doi.org/10.3390/ijgi11020114

Mooney, P., & Minghini, M. (2017). A Review of OpenStreetMap Data. In Mapping and the citizen sensor (pp. 37–59). biquity Press.

Moreri, K., Fairbairn, D., & James, P. (2018). Issues in developing a fit for purpose system for incorporating VGI in land administration in Botswana. Land Use Policy, 77(November 2017), 402–411. https://doi.org/10.1016/j.landusepol.2018.05.063

Palen, L., Anderson, J., Bica, M., Castillos, C., Crowley, J., Díaz, P., Finn, M., Grace, R., Hughes, A., & Imran, M. (2020). Crisis Informatics: Human-Centered Research on Tech & Crises: A Guided Bibliography Developed by Crisis Informatics Researchers.

Pan, Z., Yu, H., Miao, C., & Leung, C. (2016). Efficient collaborative crowdsourcing. Thirtieth AAAI Conference on Artificial Intelligence, 4248–4249.

Ponthep Meunpong, P., Buathong, S., & Kaewgrajang, T. (2019). Google Street View virtual survey and in-person field surveys: An exploratory comparison of urban tree risk assessment. Arboricultural Journal, 41(4), 226–236. https://doi.org/10.1080/03071375.2019.1643187

Porto de Albuquerque, J., Anderson, L., Calvillo, N., Coaffee, J., Cunha, M. A., Degrossi, L. C., Dolif, G., Horita, F., Klonner, C., Lima-Silva, F., Marchezini, V., Martins, M. H. da M., Pajarito-Grajales, D., Pitidis, V., Rudorff, C., Tkacz, N., Traijber, R., & Zipf, A. (2021). The role of data in transformations to sustainability: A critical research agenda. Current Opinion in Environmental Sustainability, 49(June), 153–163. https://doi.org/10.1016/j.cosust.2021.06.009

Qiu, W., Li, W., Liu, X., Zhang, Z., Li, X., & Huang, X. (2023). Subjective and objective measures of streetscape perceptions: Relationships with property value in Shanghai. Cities, 132(January 2023), 1–29. https://doi.org/10.1016/j.cities.2022.104037

Rifkin, J. (2015). he Zero Marginal Cost Society: The Internet of Things, the Collaborative Commons, and the Eclipse of Capitalism. Griffin.

Semeraro, T., Scarano, A., Buccolieri, R., Santinoano, A., & Aarrevaara, E. (2021). Planning of Urban Green Spaces: An Ecological Perspective on Human Benefits. Land, 105(10), 1–25. https://doi.org/10.3390/land10020105

Senaratne, H., Mobasheri, A., Ali, A. L., Capineri, C., & Haklay, M. (Muki). (2017). A review of volunteered geographic information quality assessment methods. International Journal of Geographical Information Science, 31(1), 139–167. https://doi.org/10.1080/13658816.2016.1189556

Sieber, R., & Haklay, . (2015). The epistemology(s) of volunteered geographic information: A critique. Geo: Geography and Environment, 2(2), 122–136. https://doi.org/10.1002/geo2.10

Solís, P., Anderson, J., & Rajagopalan, S. (2021). Open geospatial tools for humanitarian data creation, analysis, and learning through the global lens of YouthMappers. Journal of Geographical Systems, 23(0123456789), 599–625. https://doi.org/10.1007/s10109-020-00339-x

Steiniger, S., Poorazizi, M. E., & Hunter, A. J. S. (2016). Planning with citizens: Implementation of an e-planning platform and analysis of research needs. Urban Planning, 1(2), 49–64. https://doi.org/10.17645/up.v1i2.607

Sun, K., Echevarria Sanchez, G. M., De Coensel, B., Van Renterghem, T., Talsma, D., & Botteldooren, D. (2018). Personal Audiovisual Aptitude Influences the Interaction Between Landscape and Soundscape Appraisal. Frontiers in Psychology, 9, 780:1-780:15. https://doi.org/10.3389/fpsyg.2018.00780

Tabrizian, P., Baran, P. K., Smith, W. R., & Meentemeyer, R. K. (2018). Exploring perceived restoration potential of urban green enclosure through immersive virtual environments. Journal of Environmental Psychology, 55(February 2018), 99–109. https://doi.org/10.1016/j.jenvp.2018.01.001

Torres Toda, M., Miri, M., Alonso, L., Gómez-Roig, M. D., Foraster, M., & Dadvand, P. (2020). Exposure to greenspace and birth weight in a middle-income country. Environmental Research, 189, 109866. https://doi.org/10.1016/j.envres.2020.109866

Ugolini, F., Massetti, L., Pearlmutter, D., & Sanesi, G. (2021). Usage of urban green space and related feelings of deprivation during the COVID-19 lockdown: Lessons learned from an Italian case study. Land Use Policy, 105, 105437:1-105437:11. https://doi.org/10.1016/j.landusepol.2021.105437

Umweltbundesamt (Ed.). (2022). Dreifache Innenentwicklung—Definition, Aufgaben und Chancen für eine umweltorientierte Stadtentwicklung (Triple inner urban development—Definition, tasks, and opportunities for environmentally oriented urban development). https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/221208_uba_hg_dreifacheinnenentwicklung.pdf

UNISDR (Ed.). (2017). Sendai Framework Data Readiness Review 2017, Disaster-related Data for Sustainable Development. In Journal of Personality and Social Psychology (1st ed., Vol. 1, pp. 1188–1197). United Nations Office for Disaster Risk Reduction.

United Nations. (2017). Resolution adopted by the General Assembly on 6 July 2017 Work of the Statistical Commission pertaining to the 2030 Agenda for Sustainable Development.

van Nes, A., & Yamu, C. (2021). Introduction to Space Syntax in Urban Studies (1st ed.). Springer.

Wang, W., Lin, Z., Zhang, L., Yu, T., Ciren, P., & Zhu, Y. (2019). Building visual green index: A measure of visual green spaces for urban building. Urban Forestry & Urban Greening, 40, 335–343. https://doi.org/10.1016/j.ufug.2018.04.004

Wang, W., Tang, B., Fan, X., Mao, H., Yang, H., & Zhu, M. (2017). Efficient visibility analysis for massive observers. Procedia Computer Science, 111, 120–128. https://doi.org/10.1016/j.procs.2017.06.018

World Bank (Ed.). (2020). Solid Ground, Increasing Community Resilience through Improved Land Administration and Geospatial Information Systems. http://hdl.handle.net/10986/33706

Yan, Y., Feng, C. C., Huang, W., Fan, H., Wang, Y. C., & Zipf, A. (2020). Volunteered geographic information research in the first decade: A narrative review of selected journal articles in GIScience. International Journal of Geographical Information Science, 34(9), 1765–1791. https://doi.org/10.1080/13658816.2020.1730848

Yang, J., Zhao, L., Mcbride, J., & Gong, P. (2009). Can you see green? Assessing the visibility of urban forests in cities. Landscape and Urban Planning, 91(2), 97–104. https://doi.org/10.1016/j.landurbplan.2008.12.004

Yin, C., Peng, N., Li, Y., Shi, Y., Yang, S., & Jia, P. (2023). A review on street view observations in support of the sustainable development goals. International Journal of Applied Earth Observation and Geoinformation, 117(March 2023), 1–11.

Yu, S., Yu, B., Song, W., Wu, B., Zhou, J., Huang, Y., Wu, J., Zhao, F., & Mao, W. (2016). View-based greenery: A three-dimensional assessment of city buildings' green visibility using Floor Green View Index. Landscape and Urban Planning, 152, 13–26. https://doi.org/10.1016/j.landurbplan.2016.04.004