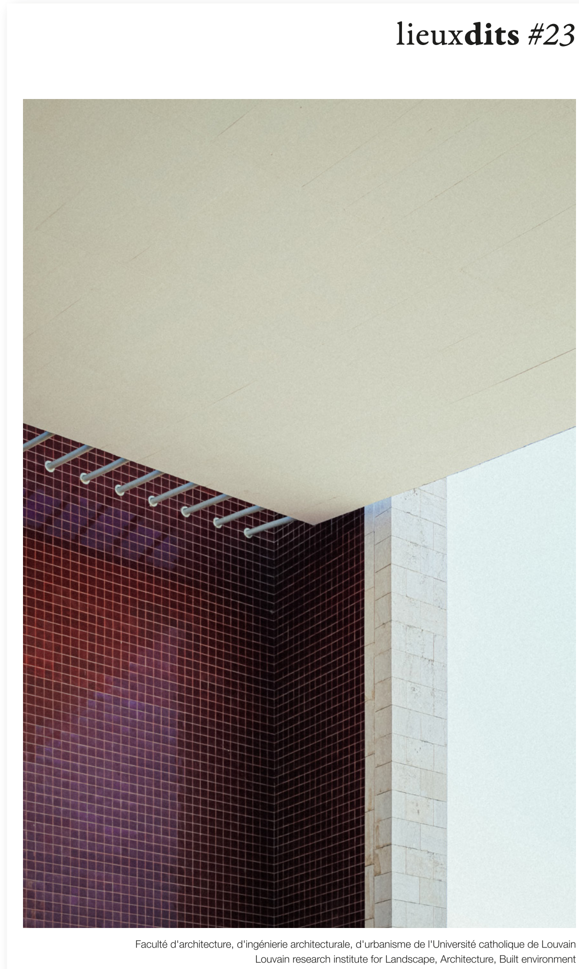
photo de couverture
Articulation, Lisbonne, 2022.
Architecte : Alvaro Siza.
Photo Louis Beeuswaert, Master 1, LOCI Tournai.

lieux**dits** *#23*
Avril 2023



Référence bibliographique :
Maider Llaguno-Munitxa "Site surveying", *lieuxdits#23,* avril 2023, pp.14-21

SEMESTRIEL

ISSN 2294-9046
e-ISSN 2565-6996

Éditeur responsable : Le comité éditorial, place du Levant, 1 - 1348 Louvain-la-Neuve (lieuxdits@uclouvain.be)

Conception graphique : Nicolas Lorent
Imprimé en Belgique

LOCI
Faculté d'architecture d'ingénierie architecturale d'urbanisme

LAB
Louvain research institute for Landscape, Architecture, Built environment

www.**uclouvain.be/loci**
www.**uclouvain.be/lab**

Site-surveying

Architecture and it's local ecology

Author

Maider Llaguno-Munitxa
architect, professor
Architecture et Climat
LOCI+LAB
UCLouvain
0000-0002-5592-8901

Prof. Maider Llaguno-Munitxa is an architect with expertise on environmental and computational design, building information technologies, and urban environmental modelling. Her research work focuses on the study of novel design practices to improve urban environmental quality and health.

Abstract. *Regarded as both a science and an art, site-surveying has become one of the most fascinating and arguably important tasks in the fields of architecture, urban design and planning. This is particularly the case today, in our post-truth society, where questions of urban sustainability, ecology, and inequality have become central to our agendas as designers, and the search for evidence has become imperative. This paper highlights the advantages of detailed site-surveying practices – i.e. the documentation of geographic, topographic, environmental, and social factors – for the construction of local urban ecologies.*

Keywords. *site-surveying · architecture · urban design · urban digitalization · site scanning*

Résumé. *Considéré à la fois comme une science et un art, l'étude de sites est devenue l'une des tâches les plus fascinantes et sans doute les plus importantes dans le domaine de l'architecture ainsi que de la conception et de la planification urbaines. C'est particulièrement le cas aujourd'hui, dans notre société de la post-vérité, où les questions de durabilité urbaine, d'écologie et d'inégalité sont devenues centrales dans nos agendas de concepteurs, et où la recherche de preuves est devenue impérative. Cet article met en évidence les avantages des pratiques d'étude détaillée des sites – c'est-à-dire la documentation des facteurs géographiques, topographiques, environnementaux et sociaux – pour la construction d'écologies urbaines locales.*

Mots-clés. *étude des sites · architecture · design urbain · numérisation urbaine · numérisation de site*

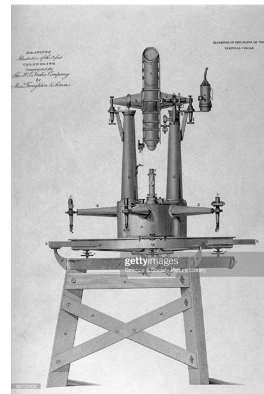
The site

The *Cambridge Dictionary of the English Language* defines a site as "a place where something is, was, or will be built, or where something happened, is happening, or will happen". The *Collins Dictionary* describes it similarly as "a piece of ground that is used for a particular purpose, or where a particular thing happens". In short, a site is characterized by its physical and non-physical condition. In addition, a site can encompass extensive territory, or be limited to a small area on which a single building is erected. It can thus vary in terms of space and time. As Henri Lefebvre observes in *Rhythmanalysis, Space, Time, and Everyday Life* (Lefebvre, 2004), a site is subject to time-sensitive patterns, such as the rhythms of the inhabitants conditioned by the design of its space and their preferences and habits. These days, site-surveying practices enable us to gather detailed evidence of both the tangible reality of a physical environment and the intangible reality of its socio-ecological setting. Moreover, the incorporation of combined objective and subjective surveying protocols and technologies – e.g. geospatial analysis and 3D scanning, citizen questionnaires, bioenvironmental sensing, and dynamic behavior observations – can provide us with insights into citizen preferences and occupational patterns, amongst other things, and help us evaluate how these relate to the geometric, material, and environmental conditions of a given site. Although many of these site-surveying technologies and protocols have been on the market for decades, it is now easier to integrate them into the design workflow of architects, planners, or urban stakeholders, thanks to the increasing availability of computational resources and the affordability of sensing and scanning technologies. Today we have the means to engage with these technologies and protocols and develop spatio-temporal site surveys that more effectively address local ecological knowledge and potentialities.

Site-surveying practices

Site surveying has been used to track the traces of floods and define the boundaries of property since the time of the ancient Egyptians. Architectural markings on tombs and shrines of the New Kingdom (~1100 BCE) indicate that surveyors – known back then as "rope sketchers" – studied constructions with the help of a calibrated rope (Fig.1) (Wilson et al., 2021). Today, site-surveying generally involves the use of a theodolite, an optical precision instrument for measuring vertical and horizontal angles between points invented in 1571 by English mathematician Leonard Digges (1571). In the early 19th century, theodolites were commercialized by the instrument makers Troughton & Simms, who, at the time, were the world's leading sup-


1


2a


2b

plier of this device. It was with the help of a Troughton & Simms theodolite that in 1849 the survey officer James Nicolson established that Mount Everest was the highest peak in the world (Fig.2). The theodolite is also associated with the tragic story of the death in 1843 of the superintendent Ferdinand Hassler, who had been ordered by Thomas Jefferson to conduct a territorial survey of the US East Coast. To do so, Hassler had used a Troughton & Simms theodolite, which he so treasured that he prioritized it over the safety of his own life (Hassler, 2010). Looking at Hassler's camp illustrations, we can observe the dominating presence of the theodolite, an instrument deemed by him irreplaceable, and for which he had long waited and repeatedly fought, both to secure the money for its purchase and protect it from attack (Fig.3).

The theodolite remains the most widely used geometric site-surveying tool. Today, however, surveys involving heritage buildings, for example, also rely on Light Detection and Ranging (LiDAR) technologies. Capable of determining the geometric properties of buildings, cities, and territories, such technologies use laser infrared technology to capture the millions of data points needed to generate a detailed 3D point cloud (Gonzalez-Aguilera et al., 2013). The dataset of such a point cloud includes geolocation – X, Y, and Z coordinates – as well as color/RGB and luminance values. The specific type of LiDAR scanning protocols deployed depends on the site surveyed. Territorial or city-to-neighborhood scaled scans, for example, are conducted with the help of airborne LiDAR technologies, which involve installing a sensor on an aircraft to collect geospatial data. Airborne LiDAR can be further broken down into topographical and bathymetric LiDAR, which provide detailed information on the qualities of topography, riverbeds, soil, and subsoil (di Stefano et al., 2021). An alternative to airborne LiDAR is photogrammetry, which uses high-resolution RGB cameras to reconstruct models through image overlap rather than data intensive point-cloud datasets. Photogrammetry is particularly well suited for mapping large urban areas. Terrestrial LiDAR (either static or mounted on a moving vehicle), in turn, can be used to capture point-cloud datasets at street level (Wang et al., 2019). ScanLAB Projects, amongst others, uses LiDAR technologies for site surveying. Their ongoing contemplative art installation FRAMERATE (ScanLAB Projects, 2022), displayed at the UN Climate Conference COP26 in Glasgow and at SXSW 2022, uses point-cloud dataset visualizations to document spatial and temporal changes in the urban forest. Another of their projects, the Dream Life of Driverless Cars (ScanLAB Projects, 2015), took LiDAR technology

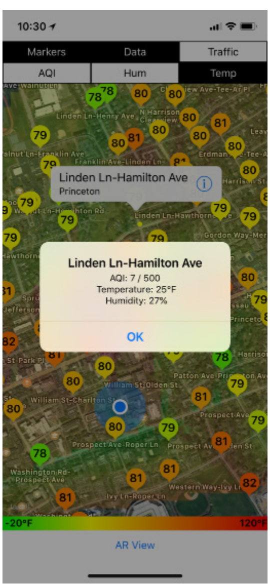

3

1 Rope stretching to measure property dimensions in Ancient Egypt, Facsimile, Menna (TT 69). Image Source/ Courtesy: Reproduction, The Metropolitan Museum of Art in New York City.

2a Everests three-foot theodolite made by Troughton & Simms, 1825-1830 and designed to the specification of Colonel Sir George Everest (1790-1866). Image source/courtesy: Science Museum / Science & Society Picture Library.

2b The three-foot theodolite made by Cary for the Great Survey of India, 1802. © Getty images

3 Hasserl's camp. Image courtesyPrinciple Documents Relating to the Survey of the Coast of the United States, Vol. II (pp. 22-23 and 40). National Institute of Standards and Technology Virtual Museum. Image source/courtesy: Hassler, F.R. (1820).



(4)

(4) City Reader mobile urban sensing technology. Deployment of MUST in NYC and Princeton. Image source/ courtesy: Llaguno-Munitxa, M., Bou-Zeid, E. (2021). Sensing the Environmental Neighborhoods. In: Yuan, P.F., Yao, J., Yan, C., Wang, X., Leach, N. (Eds) Proceedings of the 2020 DigitalFUTURES. CDRF 2020. Springer, Singapore. https://doi.org/10.1007/978-981-33-4400-6_12

into the streets of London to document how driverless vehicles might perceive the city. LiDAR technology has also been used by Jorge Otero-Pailos to document environmental traces on buildings. His project, The Atlas of Dust, which he developed at Columbia University's GSAPP's Preservation Technology Lab, aims to conduct interactive 3D scans of buildings to visualize the patterns of pollution deposited on facades and reflect upon urban pollution and climate change (Otero-Pailos, 2021).

Environmental site surveying, too, is a practice with a long history. Interestingly, Leon Battista Alberti is credited with having invented the wind anemometer in the 15th century. In his opinion, such an instrument was needed to develop site-surveying techniques so that they could document local microclimatic conditions, assess exposure to noxious fumes, and thus enhance wellbeing (Alberti, [c.1450] 1988). In addition to 3D-scanning technologies, environmental monitoring campaigns that rely on affordable sensing technologies to collect data on urban pollution (i.e. air, heat, light, soil, water, and noise pollution) and microclimate parameters (i.e. air and surface temperature, relative humidity, wind speed and direction) are now used to survey the environmental spatio-temporal gradients at sites and translate them into active and passive approaches to design (Llaguno-Munitxa et al., 2022; Rahm, 2009). Low-cost sensing technologies are also empowering citizens to pursue city-wide environmental surveying initiatives. CurieuzenAir, one of the world's largest citizen science projects, for example, has relied on the effort of 3 000 people to assess air quality in the Brussels-Capital Region (Lauriks and Meysman, 2022). A US equivalent of this initiative is the Purple Air project, which has been extensively deployed in California (Tryner et al., 2020; Llaguno-Munitxa et al., 2022). Biometric sensing technologies have also become more affordable and part of our everyday life. They are used in everything from sports instruments such as smartwatches that monitor heart rate variability and recovery to wearable medical monitors that generate electrocardiograms or measure blood pressure. Wearable electroencephalography (EEG) devices that document brain activity during navigation through space (Zou et al., 2019; Su et al., 2014) have also become available. Thanks to these devices, measuring psychological and physiological responses to stressors such as heat or noise has become possible and can inform us about their impact on human health.

Advances in scanning and bioenvironmental sensing technologies have been accompanied by the increasing availability of urban imaging and video recordings (i.e. Google Street View, open-access video surveillance repositories). Noteworthy too are geospatial and remote sensing datasets that are openly available on the web or provided by municipalities or regional bodies. Geolocated data on environmental and socio-economic conditions, citizen health, or land use can provide site studies with additional citywide datasets. Furthermore, due to urban health concerns, several municipalities have started implementing extensive environmental monitoring networks and publishing the collected datasets (Breathe London, 2021; Ricaurte, 2021; Lauriks and Meysman, 2022). The Brussels-Capital Region is an especially data-rich context, where not only geospatial data but also aerial point-cloud datasets are available on request. However, as the availability of data depends very much on the political will and investment capabilities of municipalities and regions, data on most cities, especially those of the Global South, remains scarce.

Given that each site is subject to distinct geographical, environmental, and socio-economic stressors, and that the availability of data varies according to geography, site-surveying protocols must be tailored to site conditions as well as informed by an initial assessment of the available data and local concerns. Another thing to consider is that the evidence gathered by a surveying campaign can potentially inform urban policies, political agendas or citizen initiatives. Surveying can generate the evidence (most likely hitherto unknown) needed to highlight urban environmental inequalities, for example, or advocate for environmental justice.
The following sections introduce three ongoing research projects in which distinct site-surveying protocols have been tested. The first, *City Reader*, collects high spatio-temporal resolution urban environmental data. The second, *Green Squares*, documents human perception of urban green infrastructure. The third, *Site Scan*, proposes that LiDAR scanning technologies be used to develop detailed urban topographical models.

City Reader – Urban Environmental Survey

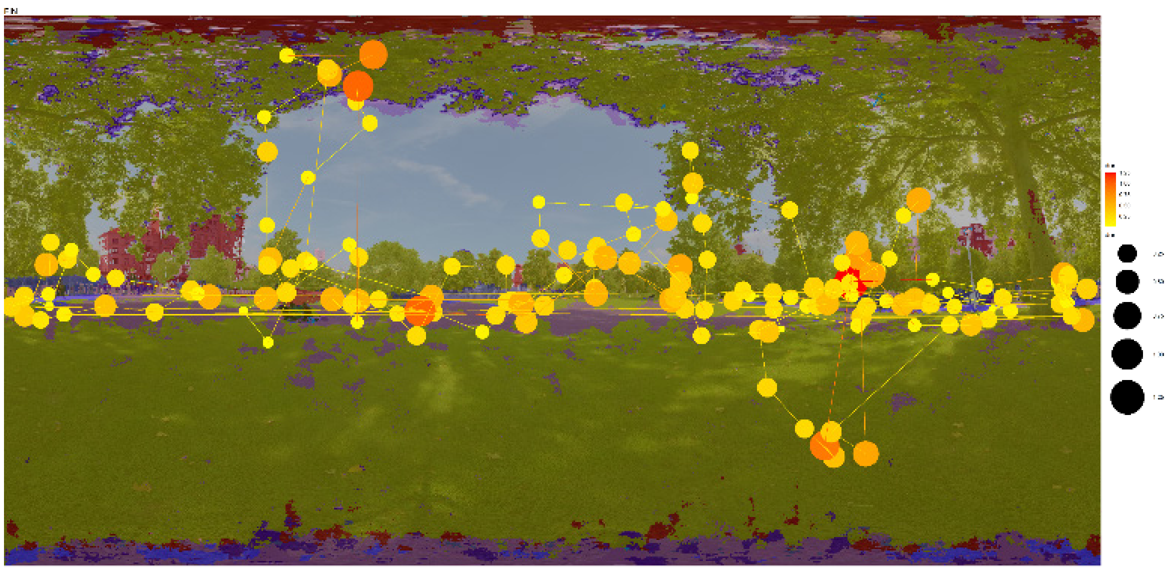
In collaboration with Elie Bou-Zeid

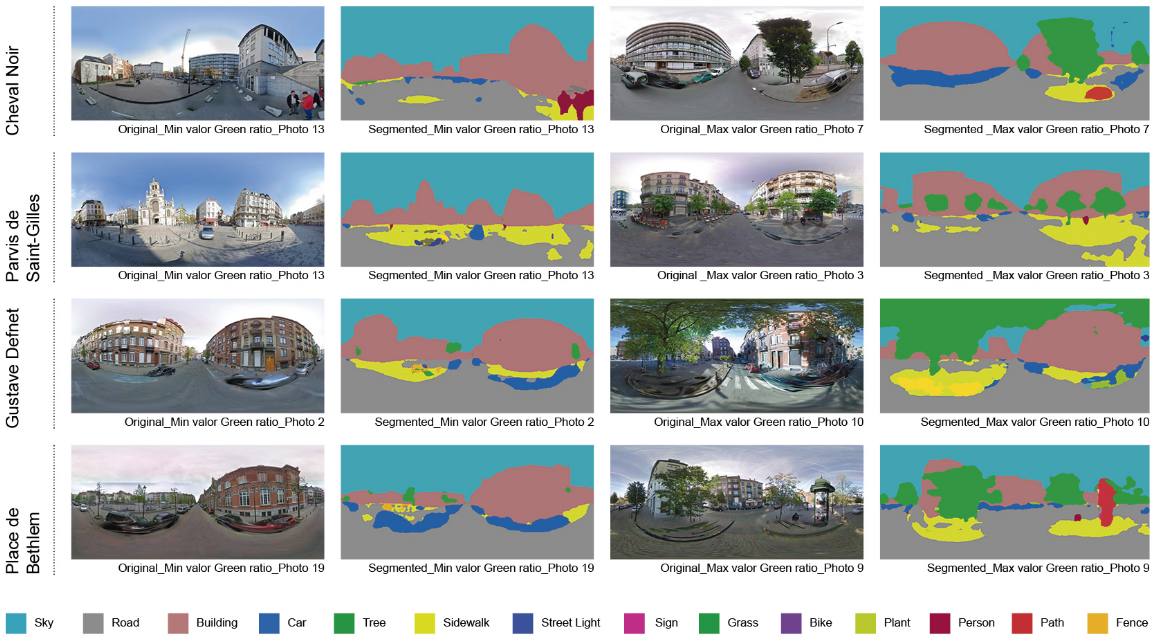
City Reader is a project developed to capture neighborhood-scale environmental gradients in an affordable manner. It is becoming increasingly evident that heat stress and air contaminant concentrations impact the streets we live in as well as our home-to-work trajectories. Recent studies have shown that the concentration of air contaminants within a street canyon can vary and rise by 600% (Apte et al., 2017). However, our understanding of how distinct urban characteristics play into urban environmental gradients remains unclear. Several City Reader prototypes have been developed and tested in the cities of Seoul, New York, and Princeton. The goal of these surveys is to evaluate differences in air temperature and contaminant concentrations within a given neighborhood and relate them to urban design features, such as building geometry or the presence of green infrastructure. An understanding of such environmental gradients can for instance help cities devise cost-effective approaches to tree planting that aim at environmental equality.
In order to minimize the costs of urban environmental surveying, City Reader uses a Mobile Urban Sensing Technology (MUST) designed to be deployable on any mobile platform, including private and public vehicles (Llaguno-Munitxa and Bou-Zeid, 2021). While the reliability of low-cost sensing technologies remains in question, if they follow the necessary QA/QC protocols, they can provide us with data that is "just good enough" (Gabrys et al., 2016) to monitor urban environmental gradients on a neighborhood scale. Urban environmental data is generally collected by regulatory and fixed weather stations that are often located at airports or in parks. Such air quality and weather networks, however, offer low spatial resolution coverage, which makes it difficult to distill intra-urban spatio-temporal gradients. However, low-cost sensing technologies can be used to map a large urban area if sensing kits are coupled with mobile platforms, such as pedestrians, bicycles, delivery trucks… Figure 4 shows MUST sensing kits designed for use on cars, trucks, and buses. A portable and lightweight MUST kit was also designed to be paired with pedestrian backpacks. Additionally, Figure 4 displays some of the results obtained from a survey conducted in Princeton, New Jersey. These were discussed in relation to the campus-planning strategies of Princeton University and were made available to members of its campus community through a web and mobile application designed to help them navigate the city with an awareness of environmental exposure gradients.

Green Squares – Pedestrian Perception Survey

In collaboration with Martin Edwards, Stephan Grade, Marie Vander Meulen, Clement Letesson, Elena Agudo-Sierra, Sergio Altomonte, Émilie Lacroix, Biayna Bogosian, Kris Mun, Eduardo Macagno

The Green Squares project in Brussels was based on detailed surveys of pedestrians' perception of urban squares in the neighborhoods of Saint Gilles and Molenbeek (Fig.5). The project's main aim was to diagnose citizens' perception of greenery. While the benefits of contact with nature for our well-being are widely acknowledged, the precise types and features of urban green infrastructure and the ratio of green to non-green infrastructure that can bring about such positive physiological and psychological effects are not yet fully understood. Given the ongoing transformation of urban mobility driven by the transition to electric vehicles and vehicle sharing, and the strategies for implementing urban green infrastructure proposed alongside such transformations, we must be able to evaluate and understand the benefits of urban green infrastructure on the pedestrian level.
The Green Squares project was run as an image and video-based survey of select urban squares. 360 Google Street View images and locally captured images shot with a 360 camera were gathered and segmented to evaluate




Cheval Noir
Original_Min valor Green ratio_Photo 13
Segmented_Min valor Green ratio_Photo 13
Original_Max valor Green ratio_Photo 7
Segmented _Max valor Green ratio_Photo 7
Parvis de Saint-Gilles
Original_Min valor Green ratio_Photo 13
Segmented_Min valor Green ratio_Photo 13
Original _Max valor Green ratio_Photo 3
Segmented _Max valor Green ratio_Photo 3
Gustave Defnet
Original_Min valor Green ratio_Photo 2
Segmented_Min valor Green ratio_Photo 2
Original_Max valor Green ratio_Photo 10
Segmented_Max valor Green ratio_Photo 10
Place de Bethlem
Original_Min valor Green ratio_Photo 19
Segmented_Min valor Green ratio_Photo 19
Original_Max valor Green ratio_Photo 9
Segmented_Max valor Green ratio_Photo 9
Sky
Road
Building
Car
Tree
Sidewalk
Street Light
Sign
Grass
Bike
Plant
Person
Path
Fence

the relative position and characteristics of green infrastructure in relation to the position of the pedestrian in order to compute the latter's accessibility to green infrastructure. The on- and off-site research methodologies deployed made use of immersive media technologies to collect eye-tracking data and measure heart-rate variability. In addition, pedestrians were given questionnaires in which they could evaluate their subjective perception of the local green infrastructure. The preliminary results indicate that the squares with higher ratios of green infrastructure were preferred by the participants in the study, and that urban squares with large trees generated greater pleasure and were more effective at reducing stress.

Site Scan – Geometric and Material Survey

In collaboration with Chiara Cavalieri, Damien Claeys, Philipp Urech, Frédéric Andrieux, Alexandre Bossard, Marie Vander Meulen, Elena Agudo-Sierra, Pietro Manaresi, Nawri Khamallah, Lylian Kubiak

Site scanning, which uses photogrammetry and LiDAR technologies, provides us with highly detailed urban point clouds - geometric and material data - that can be used in the study of urban environmental flows. In the case of the Brussels-Capital Region, for example, the aerial urban point-cloud dataset can be provided by CIRB Brussels (Le Centre d'Informatique pour la Région Bruxelloise). However, due to the obstruction caused by trees and urban topographical elements, aerial scans often fail to provide the data needed to accurately model urban topography. The site-scan project thus entailed pedestrian-level scanning of urban squares in the neighborhoods of Saint Gilles, Auderghem, and Woluwe-Saint-Pierre.
This practice was also explored in two courses at LOCI UCLouvain (Questions d'architecture : architecture et numérique - LTARC/LBARC2080[1], and Atelier 1 : Projet approfondi : architecture, ville, paysage, développement durable - LICAR2601[2]). Figure 6 shows the scan compiled for one of the squares selected, Place Dumon, located in Woluwe-Saint-Pierre. Once the scan of the square was compiled, the local urban green infrastructure, urban surface, and topographical characteristics were analyzed with the help of point-cloud datasets. Figure 6 also shows the point-cloud elevation color-coding of the topography to highlight those areas of the square with the lowest elevation values and thus greatest susceptibility to flooding.

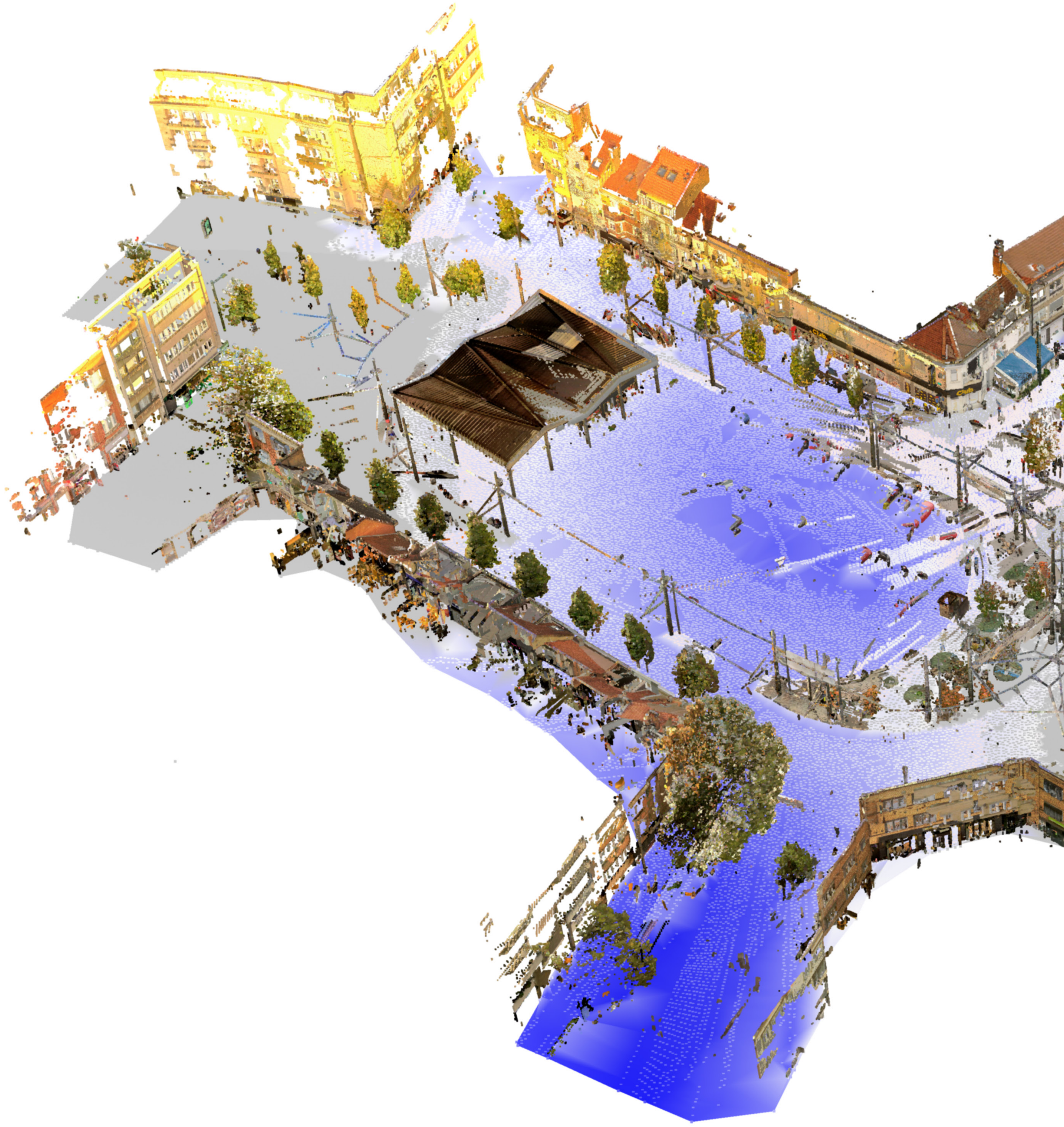
Conclusions

The aim of this paper has been to discuss the site analyses and design potentials induced by recent transformations in site-surveying protocols and technologies. Presented here have been three site-surveying projects that document the environmental, geometric, and material features of sites along with citizens' perception of these. Also discussed have been the benefits of developing detailed surveys that include citizen feedback on urban and geometric features as well as microclimate. These, in turn, can lead us to better informed urban investment strategies for enhancing urban resilience, comfort, and well-being.
While the benefits of using newly available software and hardware technologies for site-surveying are undeniable, we must not forget the dark side of such practices. Citizen surveillance is transforming the way in which we inhabit urban spaces, and the limitations and biases introduced by both surveying technologies and data-analysis algorithms often lead to problematic results. The Living's *Twin Mirror* project was meant to expose the hidden biases of machine-learning technologies used in smart city design. The Living used two different face-recognition models trained on two different sets of data to reveal that the biases depended on the training data and AI (The Living 2018). As the use of surveying practices and AI technologies in urban decision-making seems imminent, it is necessary to acknowledge their challenges and limitations. Moreover, as we gain access to more and more data, so too do we become aware of the existence of ever more layers of urban complexity that we are still incapable of rationalizing. In sum, although the opportunities offered by contemporary site-surveying technologies are manifold, their limitations must be acknowledged. ■

(5) Green Squares study of the Place Morichar in Saint-Gilles in the Brussels-Capital Region.
(top)
Eye-tracking data superimposed over segmented 360° image. Image source/courtesy: Llaguno-Munitxa, Maider; Edwards, Martin; Grade, Stephan; Vander Meulen, Marie, Letesson, Clement; Agudo-Sierra Elena, Altomonte, Sergio, Lacroix, Émilie; Bogosian, Biayna; Mun, Kris; Macagno, Eduardo. Quantifying stress level reduction induced by urban greenery perception SBEFIN 2022.
(bottom)
Green infrastructure point-cloud elevation study. Image source/courtesy: Llaguno-Munitxa, Maider; Vander Meulen, Marie; Agudo-Sierra Elena, Burgueño-Diaz Alejandro. Aerial and pedestrian level green infrastructure survey of 12 squares located in the Brussels-Capital Region, UFFU Conference 2022, KU Leuven, from 25/07/2022 to 27/07/2022.

1 - https://uclouvain.be/cours-2021-ltarc2080

2 - https://uclouvain.be/en-cours-2021-licar2601



Médiagraphie

Alberti, L. B. ([c.1450] 1988). *De re aedificatoria. On the Art of Building in Ten Books*. J. Rykwert, R. Tavernor, & N. Leach (Eds). Cambridge, Massachusetts: MIT Press.

Apte, J. S.,Messier, K.P., Gani, S., Brauer, M., Kirchstetter, T. W., Lunden, M. M., ... Hamburg, S. P. (2017). High-Resolution Air Pollution Mapping with Google Street View Cars: Exploiting Big Data. *Environmental Science & Technology 51*(12). https://doi.org/10.1021/acs.est.7b00891

Breathe London. (2021). Breathe London Technical Report.

Digges, L. (1571). *A Geometrical Practise Named Pantometria*.

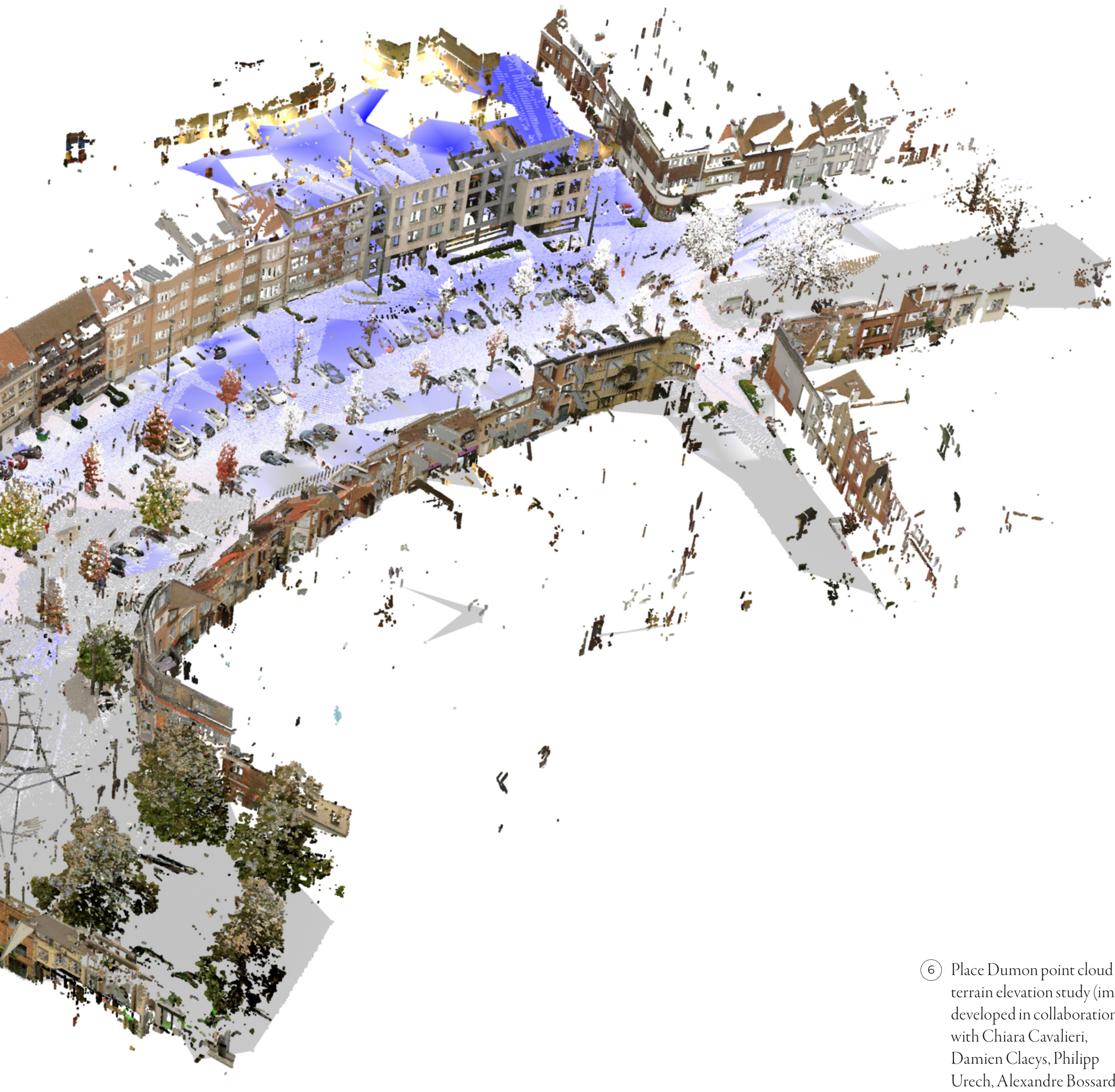
Francesco di, S., Chiappini, S., Gorreja, A., Balestra, M., & Pierdicca, R. (2021). Mobile 3D Scan LiDAR: A Literature Review. *Geomatics, Natural Hazards and Risk 12*(1): 2387–2429. https://doi.org/10.1080/19475705.2021.1964617

Gabrys, J., Pritchard H., & Barratt, B. (2016). Just Good Enough Data: Figuring Data Citizenships through Air Pollution Sensing and Data Stories. *Big Data & Society 3*(2). https://doi.org/10.1177/2053951716679677

Gonzalez-Aguilera, D., Crespo-Matellan, E., Hernandez-Lopez E., & Rodriguez-Gonzalvez, P. (2013). Automated Urban Analysis Based on LiDAR-Derived Building Models. *IEEE Transactions on Geoscience and Remote Sensing 51*(3): 1844–51. https://doi.org/10.1109/TGRS.2012.2205931.

Hassler, F. R. (2010). *Principal Documents Relating to the Survey of the Coast of the United States ...: From November 1835 to November 1836*. Nabu Press.

Jacobs, L. D., & Meysman, F. J. R. (2022). Curieuzenair - Data Collection, Data Analysis and Results.



⑥ Place Dumon point cloud and terrain elevation study (image developed in collaboration with Chiara Cavalieri, Damien Claeys, Philipp Urech, Alexandre Bossard, Marie Vander Meulen, Nawri Khamallah).

Lefebvre, H. (1992). *Rhythmanalysis: Space, Time and Everyday Life*. S. Elden, G. Moore trans. New York : Continuum.

Llaguno-Munitxa, M., & Bou-Zeid, E. (2021). Sensing the Environmental Neighborhoods. *Proceedings of the 2020 DigitalFUTURES*. Singapore: Springer Singapore. https://doi.org/10.1007/978-981-33-4400-6_12

Llaguno-Munitxa, M., Bou-Zeid E., Rueda P., & Shu X. (2022). Citizen-Science Urban Environmental Monitoring for the Development of an Inter-Urban Environmental Prediction Model for the City of Los Angeles. *EGU General Assembly*.

Otero-Pailos, J. (2021). The Atlas of Dust.Reterieved from https://www.Arch.Columbia.Edu/Summer-Workshops/46-an-Atlas-of-Dust. 2021

Rahm, P., et al. (2009). *Architecture Météorologique*. Paris: Archibooks.

Ricaurte, L. (2021). The Array of Things, Chicago. *Urban Planning for Transitions*. Wiley. https://doi.org/10.1002/9781119821670.ch11

ScanLAB Projects. (2015). Dream Life of Driverless Cars. *New York Times*.

ScanLAB Projects. (2022). Frame rate. Retrieved from https://Scanlabprojects.Co.Uk/Work/Framerate/. 2022.

Su, X., Tong, H., & Ji, P. (2014). Activity Recognition with Smartphone Sensors. *Tsinghua Science and Technology 19*(3): 235–49. https://doi.org/10.1109/TST.2014.6838194

Tryner, J., L'Orange, C., Mehaffy J., Miller-Lionberg, D., Hofstetter J. C, Wilson, A., & Volckens J. (2020). Laboratory Evaluation of Low-Cost PurpleAir PM Monitors and in-Field Correction Using Co-Located Portable Filter Samplers. *Atmospheric Environment 220* (January). https://doi.org/10.1016/j.atmosenv.2019.117067

Wang, Y., Chen, Q., Zhu, Q., Liu, L., Li, C.& Zheng, D. 2019. A Survey of Mobile Laser Scanning Applications and Key Techniques over Urban Areas. *Remote Sensing 11*(13): 1540. https://doi.org/10.3390/rs11131540

Wilson D. A., Nettleman, C. A., & Walter G. Robillard. (2021). *Evidence and Procedures for Boundary Location*. 7th edition. Hoboken, NJ: Wiley.

Zou, Z., Xinran, Y., & Ergan, S. (2019). Integrating Biometric Sensors, VR, and Machine Learning to Classify EEG Signals in Alternative Architecture Designs. *Computing in Civil Engineering 2019*, 169–76. Reston, VA: American Society of Civil Engineers. https://doi.org/10.1061/9780784482421.022