Digital Landscape Architecture Education – Where Do We Stand and Where Should We Go?

Pia Fricker[1], Ulrike Wissen Hayek[2], Rosalea Monacella[3]

[1]Aalto University, School of Arts, Design and Architecture, Espoo/Finland · pia.fricker@aalto.fi
[2]ETH Zurich, Planning of Landscape and Urban Systems, Zurich/Switzerland
[3]Harvard University, Graduate School of Design & Center for the Environment, Boston/USA

Abstract: Landscape architecture has a crucial role in designing landscapes to influence how they perform in a desired manner and provide more resilient and adaptive environments. Sophisticated analytical and design tools and techniques exist along with data from a range of allied disciplines that have the capacity to inform and transform the way landscape design approaches are conceived. However, these are not widely embraced across landscape architectural design schools as a status quo. This paper aims to provide a prompt to initiate a critical theoretical discussion on the future pedagogical foci for digital landscape architecture education discourse at the forthcoming DLA conference in 2023. The critical question is, what is the future direction of digital landscape architecture education to address the pressing and complex challenges of the climate crisis? For the purpose of this paper and the conference, we have limited the focus to three streams of digital landscape architecture: approaches, tools, and techniques. These critical streams of the discipline are framed through a brief synopsis capturing lineages from the 1960s to identify their influence on landscape architecture design education. Patterns and processes that lead to shortcomings in implementing the approaches are discussed. This is concluded with a set of questions derived from identified gaps to stimulate a targeted discussion on the future trajectories of digital landscape architecture education.

Keywords: Landscape architecture design pedagogy, digital landscape architecture education, theory development, critical discussion frameworks, design techniques and tools

1 Introduction

In the face of climate change, we are confronted with accelerated urbanization and environmental degradation. The transformation of our landscape and urban systems toward more equitable, resilient and adaptive environments is urgently required, imbuing the capacity to repair and respond to future crises and to adapt to unpredictable futures (ELMQVIST et al. 2019, SHEARER et al. 2021, FRICKER 2022a).

Digital design education in landscape architecture that considers scales of action from the planetary to the regional and microbial, has a crucial role in equipping students with the design capabilities to generate alternative typologies of aesthetics and performance (MEYER 2008, FRICKER et al. 2020). This includes landscape transformations that perform in a desired manner (STEINITZ 2012, URECH et al. 2020, GRÊT-REGAMEY et al. 2021). To this end, the discipline has developed sophisticated design and analytical tools, such as 3D point clouds, as a basis for urban design and algorithmic analysis of energy absorption, wind flow, and shadow provision (URECH et al. 2020, 2022). They support an integrated analysis across scales and feedback loops, as evidenced in several recent projects, like the example of a river rehabilitation project at the local scale that consequently explores the larger catchment area (VOLLMER et al. 2015, GRÊT-REGAMEY 2017). An illustrative overview of tools and approaches for responsive landscape design is provided by WALLIS & RAHMANN (2016), as well as by CANTRELL & HOLZMANN (2016). The publications provide a comprehensive over

Journal of Digital Landscape Architecture, 8-2023, pp. 576-584. © Wichmann Verlag, VDE VERLAG GMBH · Berlin · Offenbach. ISBN 978-3-87907-740-3, ISSN 2367-4253, e-ISSN 2511-624X, doi:10.14627/537740060.

view of design projects and responsive technologies that frame performance as a generative design approach. Furthermore, heterogeneous data on environmental and socio-economic aspects are available with unprecedented detail to inform design approaches. For example, urban sustainability transformation projects that use passively sensed geospatial data of land use, service networks etc., may be augmented by active sensing of stakeholder perceptions and behaviour with participatory methods and technologies (GRÊT-REGAMEY et al. 2021). However, although increasingly more tools and datasets are developed, and the agency of their application is demonstrated in prototypes (CANTRELL & HOLZMAN 2015), they are not widely used across landscape architectural design schools. We postulate that a critical discussion on digital design education is lacking in the discipline of digital landscape architecture (FRICKER 2022b). Therefore, we propose to investigate this in the forthcoming 2023 Digital Landscape Architecture conference.

This paper acts as a precursor for the future conference dialogue to interrogate where Digital Design Education is positioned and how to advance the pedagogical approaches of digital landscape architecture. For this, we want to highlight some of the existing theories of the discipline in the discussion, describe the status quo, and point out recent "streams of consciousness". This demonstrates that the landscape architecture discipline has constantly been influenced by and porous to other disciplines, thinking, tools and techniques that have constructed amorphous streams and trajectories continually being made and positioned (FRICKER 2021). A complete review of the theoretical streams in digital landscape architecture is beyond the scope of this paper. However, we reflect on specific critical theories and associated tools and processes from the 1960s to today that have significantly influenced current educational practice in digital landscape architecture. The intention is not to give a comprehensive history of digital landscape architecture, but a framing of various digital design approaches in landscape architecture as a departure point for a discussion on future tools and techniques. We use this review to discuss recurring patterns and processes in how new approaches and tools are used and how the gap in implementation manifests (ERVIN 2018). This leads us to formulate concrete questions to specify further: How do students need to be taught digital approaches? Where should we focus on enhancing our students' teaching? Furthermore, what needs to be taught in digital landscape architecture education?

2 A Synopsis of Computational Lineages

2.1 From System Thinking to Artificial Intelligence

This chapter aims to reflect on a selection of relevant concepts and workflows developed mainly during the 1960s and 1970s, which strongly influenced a pedagogy for the computational realm and demonstrated a radical approach to creatively interact with diverse data sets across scales. The purpose of this brief historical reflection is to unveil concepts to be revisited within the current discussion on defining possible avenues for adjusting the present trajectory of the digital pedagogy in the field of landscape architecture. Due to the richness of historical references, the discussion is focused on key examples, inviting for an extended discussion towards the future of the digital landscape architecture education and implementation within practise. Note: the selected examples in this paper address only male scientists. We want to acknowledge that in these known lineages, female leaders in the field often need to be discussed as being more instrumental to the development. We aim to capture and slowly rectify this familiar narrative in future discussions.

Already towards the end of the 60s, computational design thinking pioneers recognized the potential of machine-human interaction to sound out new potentials within architecture and landscape architecture. Almost 25 years later, the integration of "computation" in teaching ushered a fundamental pedagogic change in direction for design teaching, research, and a form making language. In addition, a parallel stream "Digital Design Education" established itself with a focus primarily on the visualization applications of digital tools and the teaching of new software (ERVIN & HASBROUCK 2001, FRICKER 2021). The presented historical overview allows for a discussion in order to shift the focus from a merely tool-based approach towards holistic computational design thinking.

The history of computation goes far beyond the development of computing technology and relates to the "interaction between internal rules and (morphogenetic) pressures that, themselves, originate in other adjacent forms (ecology)" (MENGES & AHLQUIST 2011, 8). This complex theory and framework of relationships is based upon theories from disciplines like mathematics, computer science, cybernetics, biology and philosophy. The integration of information technological developments into the landscape architectural curriculum accelerated especially during the 1960s and 1970s through an intensive exchange between cybernetics and its influence on architecture (MENGES & AHLQUIST 2011). This first manifestation was driven by a deep theoretical discourse and led to the first integration of Artificial Intelligence (AI) in design methodology. The fusion of these two areas lay in new questions related to the rise of global ecological challenges, which also changed our relationship to data and our interaction with the information it contained (FULLER 1969, MEADOWS et al. 1972). The theories developed in the area of cybernetics allowed a new computational design method to be established mainly within architecture, which describes this complex network of relationships through the integration of System Theory and Patterns (FRAZER 1993). In the late 1960s, Jay Forrester, a computer engineer and system scientist by education, strongly engaged in describing the "systemic structure responsible for the dynamics of urban development and decay", founded the Urban System Group at MIT (FORRESTER 1973).

The themes discussed between cybernetics and architecture influenced simultaneous developments in landscape architecture with respect to the domain of system thinking in the field of spatial data handling. This is because both the fields of architecture and landscape architecture were called to address issues of rapid urbanization. Though the field of landscape architecture recognized the necessity of developing new approaches for handling data, it did not develop meaningful questions or further research with AI.

2.2 Emerging Pedagogical Principles

One of the pioneering academic institutions, introducing a new form of design education with special focus on computational design thinking, was the Ulm School of Design (Hochschule für Gestaltung in Ulm, HfG), active from 1953 until 1968. Already 17 years before the foundation of the Architecture Machine Group by Nicholas Negroponte and Leon Groisser, at a time "computers were only available at a few research centres, (…) their capabilities were widely recognised and the subject of much broader theorisation and influence, opening up the field of logic and computer science to the social sciences and arts" (NEVES et al. 2013, 292). The new pedagogical approach of the HfG is understood as a research-based activity, strongly engaged in theoretical discourse focusing on a new understanding of design, which is based on thinking in connections and networks.

The "pioneered heuristic procedures that were related to the power of the new computational methods" (NEVES et al. 2013, 299) developed at the HfG can be seen in strong relation to the computational education developed by Negroponte. Negroponte recognized that problem-based learning concepts and the opportunity to work together with the computer for direct feedback significantly increased students' motivation. Programming was understood as a new way of thinking! Negroponte experimented with the potential of formal descriptions of architectural solutions, implemented through a program and deployed as Computer Aided Participatory Design. Thus, he laid the foundation for current methods in the field of AI and emphasized, "However, remember that these systems assume the driver to be an architect" (NEGROPONTE 1975, 365). The influence of the early computational design development in the education of architecture has had very little impact on the area of landscape architecture education. The only traces of limited integration of computational design can be observed at the newly founded Laboratory of Computer Graphics at Harvard Graduate School of Design in 1965. Contrary to the radical development and interaction with data for generative purposes at the Arch MAC Group at MIT, landscape architecture education at Harvard's GSD concentrated mainly on layered data-mapping methods.

2.3 The Evolution of Spatial Thinking: From GIS-based Layering towards Mapping

The field of landscape architecture focused its emerging computational possibilities on research and application in teaching during the 60s and 70s on problems related to Big Spatial Data. The pressure to develop new methods to process the complex relations of nature-based processes was strengthened by the new arising "Ecological Awareness". The idea of layering spatial information and its use for evaluating designs was presented 1971 in the book "Design with Nature" by Ian McHarg (LEE et al. 2014). Based on this idea, Geographic Information Systems (GIS) originated largely at Harvard GSD enabled to geographically allocate digital data and create maps (FOSTER 2016). Further developments in the 1970s and 1980s focused on spatially analysing the system from different aspects. In the following period the user interfaces, data processing capabilities and data interoperability were enhanced, and with this, its applicability for many user groups (LEE at al. 2014). This development enabled easier access to digital geodata and simulations for assisting in a design process, and in 2012, Carl Steinitz published a "Framework for Geodesign", which presents an iterative process of integrating stakeholders' knowledge, needs and desires, geospatial modelling, impact simulation and rapid feedback on the degree of achieving a desired goal to facilitate an informed, responsive design (FOSTER 2016, STEINITZ 2012).

3 Current "Streams of Consciousness"

Streams of consciousness describe time infused recursively in the material reality of the landscape through states of formation, from those that signify stability to sequences that are predictable and observable processes of change to those that are uncertain and instantaneous. MASSUMI (2002) suggests that our own "human" sensing of the world experienced through sensation involves a "backward referral in time". Therefore, a sensation is organised recursively prior to being part of our conscious chain or actions and reactions. In this process, the smoothing over of the anomaly is made to fit our conscious requirements of continuity and linear causality.

The act of measuring and making the landscape is not a neutral activity; therefore, the process, techniques, and tools of representing form are rooted in a specific understanding of ecosystems and their processes. "Actant is a term from semiotics covering both humans and nonhumans; an actor is any entity that modifies another entity in a trial; of actors it can only be said that they act; their competence is deduced from their performances; the action in turn is always recorded in the course of a trial and by an experimental protocol, elementary or not" (LATOUR 2004). Tools for measuring the landscapes, and the techniques by which we deploy them, have their own constraints that translate and transform information. The representations we make are constructed from a set of instruments, codes, techniques, and a lineage of conventions. Consequently, the worlds they describe, and project are derived only from those aspects of reality susceptible to those techniques. These acts of measuring, analysing and making the landscape can formulate a view of what already exists and set conditions for new worlds to emerge. Below are three examples of what we refer to as porous, constantly evolving "streams of consciousness".

Entangled Knowledge Systems: STEINITZ'S (2012) framework provides a clear structure on how to design a design process for multi-disciplinary collaboration to better address the complexity of environmental problems across scales (FOSTER 2016). Along with the emergence of the new field of Geodesign, geodesign education programs were launched (WILSON 2014) and today, universities worldwide participate in the International Geodesign Collaboration (https://www-igcollab.hub.arcgis.com). A major challenge in the education of Geodesign, however, are the strict disciplinary silos at the universities that hinder cross-disciplinary collaboration (WILSON 2014). Further, recent evaluation of geodesign processes reveal that not all projects implement the full structure and particularly the analysis of spatial relationships and impact analysis across scales are often not well performed (GU et al. 2020).

The emergence of geodesign and other GIS-based methodologies coincided with the critical discourse on big data and the development of open-source systems that enabled collective contribution and alternative algorithms to reveal bias in large data sets. In landscape architecture education, students were educated on the ethical and responsible use of big data to critically address the inherent power that data has had historically in producing unjust actions and policies on the oppressed. The emergence of "hacking" data approaches and the creation of alternative data sets as a public good and public service consequently emerged (GABRYS 2016, WILLIAMS & PROQUEST 2020).

Emergent Patterns: In another stream, contemporary research in landscape architecture addresses, in particular, the technical challenge of best-representing geo-data and environmental factors to foster an understanding of information and making sense of it (URECH et al. 2020). For example, a collection of drawing types, such as diagrams, axonometry and mappings, has been assembled (AMOROSO 2015). In response to more complex landscape relationships and organizational patterns in landscape architecture education, digital syntax, such as codes and patterns, is used to establish quantitative correlations between the landscape and data processing. These approaches are utilized as a generative component for design production (M'CLOSKEY & VANDERSYS 2017, CANTRELL & MEKIES 2018).

International Fields: With the environment globally changing more rapidly than ever before, in the first two decades of the 21st century the awareness of urgency for an immediate response for solving problems increased. This gave rise to the use of point clouds recorded in the field with a terrestrial laser scanner to rapidly replicate the physical landscape with high resolution and fidelity and as basis for analysis and design (GIROT 2019, URECH et al.

2020). The point cloud models provide a common ground between architects, engineers, and scientists to develop informed landscape design (GRÊT-REGAMEY et al. 2021, GRÊT-REGAMEY 2017, VOLLMER et al. 2015). By performing geospatial analyses using the geometry of the point cloud model, spatial configuration parameters can be investigated and enhanced employing simulation models, e. g., for improving climate conditions through altering building and vegetation patterns (URECH et al. 2020). In this way, the point cloud models and immersive data interaction allow for more dynamic and versatile forms of landscape design through all scales involving aesthetic and performance considerations (GIROT 2019, URECH et al. 2022). But the approach is still very experimental and has not yet found widespread use in digital design education in landscape architecture.

4 Discussion and Conclusion: How to Consolidate the Gap?

When we look at the outlined examples, there are some recurring patterns that suggest a gap in the implementation of tools and approaches. A major concern is that often the full understanding is left out of what the process behind a generated solution is. In particular, this is evident in three crucial pitfalls of tool implementation, which we exemplarily point out as: (1) using "black box" digital tools, (2) improper calibration, and linear processes (3) focusing on single aspects rather than interactions and processes across systems.

Concerning the first pitfall with the tremendously fast development of cutting-edge tools, designers become mere users without an understanding of the underlying processes and the inherent critical distance to the results. Looking back in the history of digital landscape architecture, the invention and use of digital tools in the design process (such as Grasshopper) led to concerns of employing a "black-box" optimization, taking the output as a goal in itself and lacking a more holistic systems thinking (FRICKER et al. 2020).

Second, not understanding the complex relationships of the defined parameters of a model and making uninformed choices of input data can also lead to wrong design decisions and optimization processes. For example, a data set is assembled only in the beginning of a design project and often neither updated nor further data is collected according to the generated simulation outputs (FRICKER 2021). Overall, a critical engagement with the collected and generated data across scale and fields is missing.

Third, there is a risk of justifying a design through simulation results on single aspects or on one specific scale while the design solution actually is not solving the problem when examined at a large scale because of mutual interactions of single aspects on various scales (FRICKER et al. 2020). Disregarding aspects can lead to undesired developments, for example, focusing only on the design site for river rehabilitation one might overlook effects of developments in the catchment area still leading to severe flooding (VOLLMER et al. 2015). An urban densification that helps minimize urban sprawl can increase the urban heat island effect and negatively affect a series of services provided by the urban ecosystem such as the provision of recreational area, storm water infiltration and retention, or habitat for species (GRÊT-REGAMEY 2017, WISSEN HAYEK & GRÊT-REGAMEY 2021). There is a lack of understanding of system dynamics, spatial patterns and relationships (WOOD 2017).

Landscape architecture as a discipline is evolving rapidly as it responds to both broadening and intensifying changes in environmental, social and political conditions. These changing conditions require development and innovation in the digital competencies of landscape architects. What approaches, digital skills and technologies are needed by landscape architects to equip them to deal with the complexities brought forth by the climate crisis? Then comes a critical consequential question: how can we design the education of future practitioners (MONACELLA & KEANE 2023).

The transformation of the digital landscape architectural education must involve profound reconfiguration of, and innovation in, discrete knowledge systems within the pedagogical framework of the curriculum, including the course's techniques, approach and nature of the way students are taught and learn. In conclusion we posit the following questions for discussion:

1) What is the current status of pedagogical approaches to digital landscape architecture techniques, tools and approaches? What are the former "streams of consciousness"? We argue that streams of consciousness are porous lineages and trajectories historically influenced by broader contextual innovations and pursuits.
2) What are the recent critical developments in digital landscape architecture and related approaches? What are the current "streams of consciousness and potential challenges in relation to emerging fields like Artificial Intelligence and Machine Learning"?
3) What are the gaps in the technological-based technique developments in digital landscape architecture utilized to address the climate change related issues and their translation in advancing pedagogical approaches?

References

AMOROSO, N. (2015), Representing landscapes: digital. Routledge, London/New York. doi:10.4324/9781315731858,

CANTRELL, B. & HOLZMAN, J. (2016), Responsive Landscapes, Strategies for responsive technologies in landscape architecture. Routledge, London/New York, USA. doi:10.4324/9781315757735.

CANTRELL, B. & MEKIES, A. (2018), Codify: Parametric and computational design in landscape architecture. Routledge, Abingdon/Oxon/New York.

ELMQVIST, T., ANDERSSON, E., FRANTZESKAKI, N., MCPHEARSON, T., OLSSON, P., GAFFNEY, O., TAKEUCHI, K. & FOLKE, C. (2019), Sustainability and resilience for transformation in the urban century. Nature Sustainability, 2, 267-273. doi:10.1038/s41893-019-0250-1.

ERVIN, S. M. (2018), Turing Landscapes. In: Codify: Parametric and Computational Design in Landscape Architecture (edited by CANTRELL, B. E. & MEKIES, A.), 88-115. Routledge. doi:10.4324/9781315647791.

ERVIN, S. M. & HASBROUCK, H. (2001), Landscape Modeling: Digital Techniques for Landscape Visualization. McGraw-Hill Professional Architecture. McGraw-Hill, New York.

FORRESTER, J. W. (1973), Urban Dynamics. 4th printing. The MIT press, Cambridge, Mass.

FOSTER, K. (2016), Geodesign parsed: Placing it within the rubric of recognized design theories. Landscape and Urban Planning, 156, 92-100. doi:10.1016/j.landurbplan.2016.06.017.

FRAZER, J. H. (1993), The Architectural Relevance of Cybernetics. Systems Research, 10 (3), 43-48. doi:10.1002/sres.3850100307.

FRICKER, P., KOTNIK, T. & BORG, K. (2020), Computational Design Pedagogy for the Cognitive Age. eCAADe, 38, 685-692. http://papers.cumincad.org/data/works/attecaade2020_255.pdf (15.03.2023).

FRICKER, P. (2022a), Augmented Co-Design Methods for Climate Smart Environments: A Critical Discourse and Historical Reflection. In: UGLIOTTI, F. M. & OSELLO, A. (Eds.), Handbook of Research on Implementing Digital Reality and Interactive Technologies to Achieve Society 5.0, 156-183. doi:10.4018/978-1-6684-4854-0.ch008.

FRICKER, P. (2022b), Computing with nature: Digital design methodologies across scales. In: MONACELLA, R. & KEANE, B. (Eds.), Designing Landscape Architectural Education: Studio Ecologies for Unpredictable Futures Routledge. doi:10.4324/9781003145905.

FRICKER, P. (2021), The Relevance of Computational Design Thinking in Landscape Architecture: A Pedagogy of Data-Informed Design Processes across Scales. Diss. ETH No. 27393, ETH Zurich, Zurich.

FULLER, R. B. (1969), Operating Manual for Spaceship Earth. Southern Illinois University Press, Carbondale.

GABRYS, J. (2016), Program earth: environmental sensing technology and the making of a computational planet. University of Minnesota Press.

GIROT, C. (2019), "Cloudism": Towards a new Culture of Making Landscapes. In: BRAAE, E. & STEINER, H. (Eds.), Routledge Research Companion to Landscape Architecture. Routledge, London, 113-124. https://www.taylorfrancis.com/chapters/edit/10.4324/9781315613116-12/cloudism-christophe-girot (accessed 15.03.2023).

GRÊT-REGAMEY, A. (2017), Six Key Conditions for Successfully Implementing a Responsive Landscape Planning Approach. Journal of Digital Landscape Architecture 2-2017, 2-9. doi:10.14627/537629001.

GRÊT-REGAMEY, A., SWITALSKI, M., FAGERHOLM, N., KORPILO, S., JUHOLA, S., KYTTÄ, M., KÄYHKÖ, N., MCPHEARSON, T., NOLLERT, M., RINNE, T., SOININEN, N., TOVONEN, T., RÄSÄNEN, A., WILLBERG, E. & RAYMOND, C. M. (2021), Harnessing sensing systems towards urban sustainability transformation. npj Urban Sustain 1, 40. doi:10.1038/s42949-021-00042-w.

GU, Y., DEAL, B., ORLAND, B. & CAMPAGNA, M. (2020), Evaluating Practical Implementation of Geodesign and its Impacts on Resilience. Journal of Digital Landscape Architecture, 5-2020, 467-475. doi:10.14627/537690048.

LATOUR, B. (2004), Politics of nature: how to bring the sciences into democracy. Harvard University Press.

LEE, D. J., DIAS, E. & SCHOLTEN, H. J. (2014), Introduction to Geodesign Developments in Europe. In: LEE, D. J., DIAS, E. & SCHOLTEN, H. J. (Eds.), Geodesign by Integrating Design and Geospatial Sciences, GeoJournal Library 1, 3-11. doi:10.1007/978-3-319-08299-8_1.

MASSUMI, B. (2002), Parables for the Virtual: Movement, Affect, Sensation. Duke University Press, Durham, NC. doi:10.1215/9780822383574.

M'CLOSKY, K. & VANDERSYS, K. (2017), Dynamic Pattern. Visualizing Landscapes in a Digital Age. Routledge, New York.

MEADOWS, D. H., MEADOWS, D. L., RANDERS, J. & BEHRENS, W.W. (1972), Limits to Growth. New American Library.

MENGES, A. & AHLQUIST, S. (2011), Computational Design Thinking, Wiley & Sons, London.

MEYER, E. K. (2008), Sustaining beauty. The performance of appearance. Journal of Landscape Architecture, 3 (1), 6-23. doi:10.1080/18626033.2008.9723392.

MONACELLA, R. & KEANE, B. (2023), Designing Landscape Architectural Education : Studio Ecologies for Unpredictable Futures. Routledge.

NEGROPONTE, N. (1975), Soft Architecture Machines. The Massachusetts Institute of Technology MIT, Cambridge, Mass; MIT Press, London.

NEVES, I. C., ROCHA, J. & DUARTE. J. P. (2013), The Legacy of the Hochschule für Gestaltung of Ulm for Computational Design Research in Architecture. In: Proceedings of the 18th International Conference on Computer-Aided Architectural Design Research in Asia (edited by STOUFFS, R., JANSSEN, P., ROUDAVSKI, B. & TUNÇER, B.), 18, 292-302. NUS Singapore.

SHEARER, A. W., KILCULLEN, D. J. & PENDLETON, G. (2021), Conceptualizing a Model of Antifragility for Dense Urban Areas. Journal of Digital Landscape Architecture, 6-2021, 75-84. doi:10.14627/537705004.

STEINITZ, C. (2012), A framework for geodesign: changing geography by design. Esri Press, Redlands, CA.

URECH, P. R. W., DISSEGNA, M. A., GIROT, C. & GRÊT-REGAMEY, A. (2020), Point cloud modeling as a bridge between landscape design and planning. Landscape and Urban Planning 203, 103903. doi:10.1016/j.landurbplan.2020.103903.

URECH, P. R. W., MUGHAL, M. O. & BARTESAGHI-KOC, C. (2022), A simulation-based design framework to iteratively analyze and shape urban landscapes using point cloud modeling. Computers, Environment and Urban Systems 91, 101731. doi:10.1016/j.compenvurbsys.2021.101731.

VOLLMER, D., COSTA, D., LIN, E. S., NINSALAM, Y., SHAAD, K., PRESCOTT, M. F., GURUSAMY, S., REMONDI, F., PADAWANGI, R., BURLANDO, P., GIROT, C., GRÊT-REGAMEY, A. & REKITTKE, J. (2015), Changing the course of rivers in Asian cities: Linking riparian landscapes to human benefits through iterative modeling and design. Journal of the American Water Resources Association, 5 (3), 672-688. doi:10.1111/1752-1688.12316.

WALLIS, J. & RAHMANN, H. (2016), Landscape Architecture and Digital Technologies. Routledg, New York.

WILLIAMS, S. & PROQUEST (2020), Data Action: Using Data for Public Good. The MIT Press, Cambridge, Massachusetts.

WILSON, J. P. (2014), Towards Geodesign: Building New Education Programs and Audiences. In: LEE, D. J., DIAS, E. & SCHOLTEN, H. J. (Eds.), Geodesign by Integrating Design and Geospatial Sciences, GeoJournal Library, 1, 3-11. doi:10.1007/978-3-319-08299-8_23.

WISSEN HAYEK, U. & GRÊT-REGAMEY, A. (2021), Conceptualizing a Web-based 3D Decision Support System Including Urban Underground Space to Increase Urban Resiliency. Journal of Digital Landscape Architecture, 6-2021, 85-93. doi:10.14627/537705005.

WOOD, H. (2017), The Architecture of Artificial Intelligence. Archinet (blog). March 8, 2017. https://archinect.com/features/article/149995618/the-architecture-of-artificial-intelligence (15.03.2023).