Sociotechnical Perspectives for Data Practices. The Impact of Data-Driven Approaches to Design Theory and Action

Sociotechnical perspectives for data practices. The impact of data-driven approaches to design theory and action.

Abstract.

This paper explores the ways data is transforming design processes, investigating its potential in shaping architectural theory. The study adopts a theoretical framework that views the architectural project as a sociotechnical entity unfolding through a network of actors and documents. By observing two selected case studies, their methodologies and tools for collection, analysis, and synthesis are described, leading to a discussion of data production, its sources, and the actions required for its application. Examining the production network that generates data, making it apt for use, ties it to its evolving significance for architectural theory and practice. The apparent objectivity regarding data applications is then critically examined, letting the socially embedded nature of its practices emerge. Ultimately, data represents a challenge for architects to reflect on their role and competence in a network of actors.

Keywords: Data Practices, Sociotechnical Studies, Architectural Project.

1 Introduction.

In the evolving intersection of architecture and data applications, this paper delves into exploring of how data integration transforms the design process. The research aims to investigate what data can offer to the understanding of architectural processes. As the relevance of data in architectural decision-making becomes increasingly pronounced, the paper scrutinises the multifaceted applications of data in addressing urban challenges. Laboratories and research centres actively contribute to this transformation, crafting advanced tools tailored to facilitate meaningful changes in urban design [1, 2].

While research on data practices, meaning its manifold ways of applications and use, quickly grows in terms of practical endeavours [4–6], and considering the potential impact they may have on architectural competence, theoretical considerations may be drawn in order to further the understanding of architectural practice. By examining the intersections between data practices and architectural practices, the study recognises the reciprocal relationship between data production, its sources, and the actions required for its application. The exploration extends to the development of the intricate relationships among data, its conditions of existence, its devices and the production of related facts and technologies. As the architectural landscape embraces new tools capable of synthesising diverse datasets, this paper navigates the evolving significance of data and its stages of institutionalisation, offering critical insights for architects in shaping the trajectory of design action within data-rich environments.

The contribution will explore first the materials and methods and the empirical foundation, emphasizing the relationship between data-driven approaches and urban concerns. Second, the sociotechnical framework will be introduced as the background within which the architectural project is considered. Third, specific case studies will be examined in terms of methods, goals, and tools for data synthesis. Subsequently, the evolution of data-related facts and technology will be explored, addressing the consequences for architectural practices and design action in terms of critical and theoretical understandings.

2 Materials and methods

The intricacies urban environments face making data a required asset for supporting decision-making processes: ensuring sustainability, improving performance and well-being, and adapting to evolving needs [2, 7]. This spectrum of challenges effectively intersects with the domain of architectural design, and, as such, there is an escalating research interest in this domain to uncover the multifaceted applications of data [8, 9].

The widespread research interest is exemplified by the active efforts of many laboratories and research centres. Examples of such laboratories will follow to illustrate the empirical ground over which considerations are later drawn, while providing a picture of the evolving landscape of research efforts, which scope of investigation lie with data practices, finding ways to use data towards urban applications.

The *Urban Ergonomics Lab* in Beijing is committed to devising innovative spatial strategies that tackle diverse issues in urban space and architectural practices impacting the sustainability of Chinese cities [10–12]. In the Netherlands, a cluster of laboratories working on similar issues are the *Amsterdam Metropolitan Solution*, the *Senseable Amsterdam Lab* and *The New Open* at TU Delft, which use Amsterdam and other Dutch cities as testbeds for data collection and synthesis [4, 13–18].

The research carried out by these laboratories is analysed to determine what concerns both the literature and their ongoing projects to highlight the actors taking part in the development of knowledge in data-driven architecture making.

The laboratories so far showcased represent the main case studies closely observed- However, many other examples exist around the world, encompassing very similar research interests. In Boston, the *MIT Senseable City Lab* in Boston is a well-known research centre committed to examining urban dynamics, and the *Civic Data Design Lab* shares similar interests focusing more on human-generated social data, with projects extending beyond the U.S. and oriented towards policymaking [19–22]. Affiliated with *MIT Senseable Lab*, the *Stockholm Senseable Lab*, and the *Singapore-MIT Alliance for Research and Technology*, provide other perspectives on data practices. In Italy, the Milan-based *Laboratorio di Simulazione Urbana Fausto Curti* engages in research projects to find a middle ground between human-generated and environment-generated data [23–26].

3 The sociotechnical reading of the architectural project

Data practices refer to those research efforts focused on tackling the vastity of data and conceptualising practical applications and theoretical issues. Regarding urban environments, the challenges are manifold, and data is increasingly considered a favourable resource. However, strategies concerning the development of urban environments intersect with architectural practices and the design process. It is necessary to consider design action to delve into the development of data practices and their meaning.

The architectural project can be understood as an inherently processual entity, not merely a result but a collection of practices that unfold over time. While the ultimate output is realising a physical modification of space, architects, in their daily endeavours, do not directly build walls. Instead, their operations and actions materialise in the form of the project itself—a dynamic and performative cloud of documents capable of effecting tangible changes in the world [27].

In breaking down the intricacies of architectural practices, it becomes evident that architects primarily engage in creating and exchanging documents. This perspective stems from the inherent needs of the design process, where any social or bureaucratic interaction must be made explicit and communicated to other actors [27]. For this to happen, the architect relies on specific supports, such as records, inscriptions, and documents whose codes are commonly known and shared among the actors involved [28].

The design process thus unfolds through the continuous exchange of documents among various interlocutors and actors. This cycle, driven by repetitive exchanges that open and close to possibilities, happens through the progressive expansion of this documental cloud, which increases in size and complexity over time. The multiplication of documents and their increasing concatenation play a pivotal role in propelling the project through many stages of institutionalisation [3]; if it works, this rhythm ends with a space modification.

The project's first support for exchange is a variety of documents, from sketches to technical drawings, from emails to reports, and so on. This exchanging activity is a collaborative action involving at least two actors negotiating and producing further registrations. Observing such processes this way reveals a direct correlation between the growth of the documental cloud and the increasing number of actors involved. The reticular-relational model, as developed by Bruno Latour [3], aptly captures the multiplicity of documents exchanged and produced within this network, highlighting the transdisciplinary nature of the exchange essential for project development. When one looks at the practices of making architecture, through which space is modified, action is hybrid and diffused among actors, both human – architects, engineers, stakeholders, citizens – and nonhuman – objects, tools, technologies, norms, constrictions, organisations [29–33].

Within this intricate web, the succession of actions occurs thanks to and because of humans and nonhumans who symmetrically partake in the making [34]. We can imagine architects in the very first stages of a project being engaged in the process of considering instances and problems, exchanging ideas and solutions with other

architects, reach a temporary stop, after which maybe other actors are brought in to allow the project to continue developing. Here, architects are human actors who explicitly express their considerations and exchange them with other human actors through nonhuman carriers: instruments, tools, and codes. Their presence is as much relevant and necessary as it is that of human actors [27, 34].

While understanding the core actions of architects is set on document exchange and production, their role takes place among a reticular network of actors where they develop strategies that are context-specific, never univocal, and dynamically adapted to the nuances of each context [27]. Design action unfolds within identifiable spaces akin to Latour's scientific laboratories, aptly termed "bottega" and "offices" [35]. These spaces are the container from which the documentary multiplicity emanates, encapsulating transdisciplinary competencies and serving as the professional domain of architects. Here, materials, tools, and technologies serve as instruments through which the project materialises into written works. In these environments, space is scrutinised, problems are analysed, information is synthesised, visions and narratives converge, and instruments and architects become intertwined.

4 Results

Architects have always been concerned with the ways of processing information within the design process. Today's great potential with data and its embedded information lies in the vastness of datasets derived from numerous sources, which could be examined comprehensively [36–38] to let new meaningful urban dynamics emerge.

Beyond present issues, the *Urban Ergonomics Lab* anticipates future challenges and aims to enhance the quality of urban spaces, challenging traditional design practices and the referentiality of architects as sole decision-makers. Indeed, the premise for the development of *Urban Ergonomics* is that the subjective perspective of the architect is recognized as problematic because it is neither universal nor reproducible. What is proposed with *Urban Ergonomics* is a design method where the use of data represent the asset to enlarge the scope of considerations the architect would otherwise be unable to reach. [1, 39]. To do so, studying the relationship between human behaviour and spatial design and finding possible bridges is crucial. The objective is to exploit social and behavioural dynamics data to design [1, 6]; this also implies prompting a reassessment of architectural practices by developing methods to support decision-making at the scale of architectural and urban design: this is done by integrating the knowledge developed on datasets reflecting people's interactions with the form of urban environments.

To carry this objective forward, the lab has been implementing a methodology to become integrated into the design processes, which allows the translation of collected data into viable information to support design decisions. To do so, an initial hierarchical taxonomy of experiences is deployed, and a set of tools is adopted to analyse and quantify them. The registering devices are thus essential to allow the collection of data that measure physiological responses to the environment.

The *Amsterdam Metropolitan Solution* aims to foster innovation and address urban challenges by establishing collaborations among government bodies, businesses, research institutions, and citizens. Here, solutions for sustainable urban development are implemented. Many of the research projects currently under progress are focused on harnessing data deriving from phones, social media, and urban sensors. With such assets, the aim is then to predict behaviour of people in indoor and outdoor spaces while also developing tools that allow the integration of different and heterogeneous datasets on the same platform [2, 14, 16, 19, 40, 41].

With a combination of ongoing projects each tackling different topics and issues, this laboratory, in collaboration with many other stakeholders, has been focused on leveraging social media data, open data sources, and environmental data to be supported and analyzed critically on the platform called "Social Glass" [2]. Its objective lies in generating valuable insights to enable a better-informed decision-making process to be used by third parties, from public governmental entities to private firms working with urban environments, such as architects and planners.

While the *Urban Ergonomics Lab* is completely focused on developing a methodology of action while working on specific architectural projects, the *Amsterdam Metropolitan Solution* carries out research projects whose aim is to showcase issues and produce general solutions. Another element of difference is the nature of the data that is collected and analysed: in the first case study, the data considered traces human physiological responses to the environment where the sources are human beings directly, whereas the others consider data deriving from other indirect sources, such as apps, phones, and online activity.

Among these laboratories, many differences may occur in terms of the types of data considered, their sources and how to transform them into knowledge and methodologies apt for use; what remains similar across them is the presence of a great variety of nonhumans that partake in the process of developing such knowledge. Without registering devices such as headset simulators, phones, or cameras, for example, none of these laboratories could collect data on human dynamics, process them and then devise ways to synthetise them in a representative and useful way. These explorations raise broader questions encompassing both the entities involved and the knowledge production process around the use of data. Data practices can be followed in their complex development to understand the intricate relationships among data, its conditions, and the production of facts and technologies concerning it [42].

Contemporary actors in urban processes and future strategies must consider the instances derived from data practices' empirical work and their theoretical implications. Architects' expertise and role may shift because the potential of data lies in the related emergence of new tools capable of synthesising different datasets. To understand this shift, it is essential to reconsider the evolving significance associated with data and its increasing stages of institutionalisation [43].

Data collection methods vary, whether indirectly through third parties or directly through experiments with the help of specific devices in different scenarios. Indeed, once data is collected, the ways it is assembled and meaning is construed can shift significantly across locations, conditions, and projects. This process entangles humans, registering devices, data, synthetical tools, experiments, and projects, one influencing

the other in a continuous back-and-forth dynamics. Effectively managing this complexity and communicating it to the scientific community, as well as establishing methods for data assemblages and tools toward specific objectives is a challenging task undertaken by research centres like those mentioned.

Drawing on the notion of black boxing as conceptually developed by Latour [42], it can be argued that data practices are still in the process of their making, and in this process, the social and technical dimensions are still openly at work to converge on final products. The outcomes of such data practices, whether a platform of data assemblage or visual tool showing hidden patterns concerning human dynamics are not yet opaque; their inner mechanism and the choices behind it can be traced and made visible [34].

In this sense, following Latour's and Yaneva's work, these research centres working to achieve the construction of facts and technologies on data represents a significant ground for observation, providing examples of the multifaceted, social and technical nature of design action [44, 45]. Thus, we can consider how the development of facts is happening and draw some critical considerations as to what insights data practices can offer to urban and architectural ones.

When exploited for its embedded information, data becomes linked with the meaning of the phenomena it depicts. This can encompass various aspects such as urban , human interactions, and physiological responses to precisely configured spaces [2, 46] – all studied to inform decision-making at the architectural and urban scale. With the amount of data that can be collected nowadays, the possibility opens to scrutinising human actions and interactions and synthesising them to a degree that facilitates the derivation of statistical considerations. The underlying implication would be that, via experiments and simulations, ongoing projects can be tested, and the morphological features of already-built spaces can be assessed.

The experimental production of facts and technologies aligns with the main features of technoscience – experiments, simulations, instruments, ontologies, and laboratory environments [42]. In this context, one outcome could be to offer a positivist view of data, one where its meaning is deemed and understood as objective [1]. This would imply treating data not as a simple trace but as a faithful description, objective and natural, of the phenomena it traces, and, in this sense, statistics and laws can be defined upon it [47]. This pursuit of knowledge on data practices has many implications for future practitioners, especially in the technological dimension of the profession, where new tools can represent a challenge to design action [48, 49].

Digital tools able to synthesise large quantities of data are already present in architectural design and, as Carpo noted, have a way of proving effective in changing its practices, both in terms of technical development and conceptualising design problems [50]. However, as architects, when we question the efficacy of architectural action, is the issue genuinely rooted in a need for more objective, verifiable information?

Following the positivist vision that data can provide neutral and objective information, technological instruments, such as *location-based apps*, social media, and immersive realities [20, 51–53], enable the quantitative analysis of phenomena that could previously only be qualitatively studied [54]. The process involves leveraging

statis-tics to legitimise this quantitative analysis. However, the neutrality of this process is apparent.

Consider a scenario where multiple phenomena related to a space could positively support design decisions. In data collection, there is already a form of decision-making a priori that selects which phenomena and, consequently, which data are considered. This decision-making process is closely intertwined with the types of registering devices available to each laboratory in each context; it is thanks to these devices that the phenomena can be registered, and thus, data takes the form of an inscription. [42]. Moreover, the selection, collection, and analysis are likely oriented towards a final, perhaps general, presupposed goal. In this context, data represents a phenomenon and enables it to be registered and interpreted. However, the entire process, from collection to analysis to synthesis, is not neutral; instead, it carries a complex social and technical network of interactions.

The approach of critical theory can help recognise the lack of neutrality in this intricate process, acknowledging phenomena on human dynamics and behaviour as socially produced rather than exclusively governed by natural laws [47]. The entire process, from collection to analysis and synthesis, is socially embedded, with each step influencing the others. Actors, including humans and nonhumans, continuously interact, shaping the data-rich environment. Devices used for data collection also play a role in influencing both data and human actors. This web of interactions forms significant chains, linking people, things, expertise, organisations, tools, devices, and instruments. In data-rich environments, these actors participate in a continuous process of bonding and re-bonding, producing facts and technologies.

Data itself takes on an instrumental presence and a capacity for action, thus becoming a powerful nonhuman actor in shaping architectural processes. Additionally, for data to manifest the phenomena it represents, various technical inscription devices are necessary to create these records [19]. Consequently, data functions as a nonhuman participant and can be interpreted as symbols, inscriptions, and documentation of the design procedure. Recognising the socially produced nature of these practices, architects must adapt to emerging tools and actively participate in shaping the trajectory of design action within data-rich environments.

Within this framework, the potential is for data to offer a unique opportunity to open the discourse to diverse and plural architectural perspectives. The vast datasets, derived from various sources that reflect urban dynamics, human interactions, and responses to spaces, present a rich tapestry of insights. As active participants in decision-making processes, architects could leverage these diverse perspectives to inform their designs and enrich the dialogue surrounding urban development.

In embracing plural perspectives, architects can harness the power of data not only as a tool for technical advancement but as a catalyst for inclusive decision-making. The very nature of data, with its multitude of sources and narratives, encourages architects to consider a broader spectrum of influences in their design processes. This inclusivity fosters a more holistic and responsive approach to architectural practices, aligning with the evolving needs of diverse communities.

5 Discussion and conclusions

This study's findings lie with the possibility of observing and drawing critical considerations from the innovations brought about by research laboratories working with data applications to architectural and urban environments. As the creation of novel approaches and instruments for maximizing the potential uses of data in urban settings is increasing, collected data can be translated into insightful knowledge to support design choices.

However, in navigating the evolving landscape of data practices within architectural research, we find ourselves at a crucial intersection of technological innovation, design processes, and societal implications. Data integration to the project challenges traditional notions and reshapes the profession's technological dimension. Along with practical applications, this potential for translation and the impact on architectural competency should be addressed theoretically as well. Within the theory of the architectural project and the relational reticular model of distributed action, as developed by Latour, it is possible to recognise the lack of objectivity and neutrality that data seem to represent and thus comprehend it as yet another actor coming to play a part in the design process.

In this sense, the potential impact of this study lies in observing and detailing the development of facts and technologies within these data-driven research which can lead to an analysis of this innovation, thus allowing architects to actively reflect on their role and competence in a network of actors. Within this perspective, decision support tools derived from data hold the potential to go beyond conventional boundaries and catalyse a shift towards more inclusive, equitable, and sustainable architectural practices. However, providing contextual descriptions of very specific research efforts in data practices limits the study to situated descriptions and theoretical considerations.

Future prospects may be represented by undertaking detailed examinations to understand how such methodologies and platforms used in data-driven architectural practices might evolve into standard procedures. This may involve tracing the trajectory of their adoption, identifying key factors that contributed to their acceptance, and assessing the visible impact on architectural expertise.

References

1. Zhang, L., Deng, H., Mei, X., Pang, L., Xie, Q., Ye, Y.: Urban Ergonomics: A design science on spatial experience quality. Chin. Sci. Bull. 67, 1744–1756 (2022). https://doi.org/10.1360/TB-2021-1241.

2. Bocconi, S., Bozzon, A., Psyllidis, A., Titos Bolivar, C., Houben, G.-J.: Social Glass: A Platform for Urban Analytics and Decision-making Through Heterogeneous Social Data. In: Proceedings of the 24th International Conference on World Wide Web. pp. 175–178. ACM, Florence Italy (2015). https://doi.org/10.1145/2740908.2742826.

3. Latour, B.: Reassembling the social: an introduction to Actor-Network-Theory. Oxford Univ. Press, Oxford (2007).

4. Psyllidis, A., Bozzon, A., Bocconi, S., Titos Bolivar, C.: A Platform for Urban Analytics and Semantic Data Integration in City Planning. In: Celani, G., Sperling, D.M., and Franco, J.M.S. (eds.) Computer-Aided Architectural Design Futures. The Next City - New Technologies and the Future of the Built Environment. pp. 21–36. Springer Berlin Heidelberg, Berlin, Heidelberg (2015). https://doi.org/10.1007/978-3-662-47386-3_2.

5. Feng, Y., Duives, D., Daamen, W., Hoogendoorn, S.: Data collection methods for studying pedestrian behaviour: A systematic review. Building and Environment. 187, 107329 (2021). https://doi.org/10.1016/j.buildenv.2020.107329.

6. Zhang, L.: Urban Ergonomics: A Promising Domain of Cross-Disciplinary Investigations. World Architecture. 1–4 (2021).

7. Ciuccarelli, P., Lupi, G., Simeone, L.: Visualizing the Data City: Social Media as a Source of Knowledge for Urban Planning and Management. Springer, London (2014).

8. Lange, M.D., Waal, M.D.: Chapter 4 Owning the City: New Media and Citizen Engagement in Urban Design. In: Etingoff, K. (ed.) Urban Land Use. pp. 87–110. Apple Academic Press, 3333 Mistwell Crescent, Oakville, ON L6L 0A2, Canada (2017). https://doi.org/10.1201/9781315365794-5.

9. Dwivedi, Y.K., Hughes, L., Ismagilova, E., Aarts, G., Coombs, C., Crick, T., Duan, Y., Dwivedi, R., Edwards, J., Eirug, A., Galanos, V., Ilavarasan, P.V., Janssen, M., Jones, P., Kar, A.K., Kizgin, H., Kronemann, B., Lal, B., Lucini, B., Medaglia, R., Le Meunier-FitzHugh, K., Le Meunier-FitzHugh, L.C., Misra, S., Mogaji, E., Sharma, S.K., Singh, J.B., Raghavan, V., Raman, R., Rana, N.P., Samothrakis, S., Spencer, J., Tamilmani, K., Tubadji, A., Walton, P., Williams, M.D.: Artificial Intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. International Journal of Information Management. 57, 101994 (2021). https://doi.org/10.1016/j.ijinfomgt.2019.08.002.

10. Hao, J., Zhi, J., Zhong, R.: The Rise of Big Data on Urban Studies and Planning Practices in China: Review and Open Research Issues. Journal of Urban Management. 4, 92–124 (2015). https://doi.org/10.1016/j.jum.2015.11.002.

11. Santi, E.: Uncertainty and design practice in China. The Apparatus of Shanghai experimental architecture. Journal of Architecture and Urbanism. 41, 120–128 (2017). https://doi.org/10.3846/20297955.2017.1317298.

12. Rizzardi, P.A., Zhang, H.: The Condition of Chinese Architecture. Singapore TCA Think Tank (2018).

13. Qiu, S., Psyllidis, A., Bozzon, A., Houben, G.-J.: Crowd-Mapping Urban Objects from Street-Level Imagery. In: The World Wide Web Conference. pp. 1521–1531. ACM, San Francisco CA USA (2019). https://doi.org/10.1145/3308558.3313651.

14. Ratti, C., Frenchman, D., Pulselli, R.M., Williams, S.: Mobile Landscapes: Using Location Data from Cell Phones for Urban Analysis. Environ Plann B Plann Des. 33, 727–748 (2006). https://doi.org/10.1068/b32047.

15. Speelman, E.N., Ligtenberg, A.: Simulating urban dynamics from the bottom up: the City Simulation Lab. International Journal of Geographical Information Science. 33, 1–25 (2019).

16. Hoogendoorn, S.P., Bovy, P.H.L.: Pedestrian route-choice and activity scheduling theory and models. Transportation Research Part B: Methodological. 38,

169–190 (2004). https://doi.org/10.1016/S0191-2615(03)00007-9.

17. Hölscher, C., Meilinger, T., Vrachliotis, G., Brösamle, M., Knauff, M.: Up the down staircase: Wayfinding strategies in multi-level buildings. Journal of Environmental Psychology. 26, 284–299 (2006). https://doi.org/10.1016/j.jenvp.2006.09.002.

18. Venverloo, T., Duarte, F., Benson, T., Bitran, Q., Beldad, A.D., Alvarez, R., Ratti, C.: Evaluating the Human Experience of Autonomous Boats with Immersive Virtual Reality. Journal of Urban Technology. 28, 141–154 (2021). https://doi.org/10.1080/10630732.2020.1802214.

19. Klopp, J., Williams, S., Waiganjo, P., Orwa, D., White, A.: Leveraging Cellphones for Wayfinding and Journey Planning in Semi-formal Bus Systems: Lessons from Digital Matatus in Nairobi. In: Geertman, S., Ferreira, J., Goodspeed, R., and Stillwell, J. (eds.) Planning Support Systems and Smart Cities. pp. 227–241. Springer International Publishing, Cham (2015). https://doi.org/10.1007/978-3-319-18368-8_12.

20. Milusheva, S., Marty, R., Bedoya, G., Williams, S., Resor, E., Legovini, A.: Applying machine learning and geolocation techniques to social media data (Twitter) to develop a resource for urban planning. PLoS ONE. 16, e0244317 (2021). https://doi.org/10.1371/journal.pone.0244317.

21. Williams, S.: More Than Data: Working with Big Data for Civics. Journal of Law and Policy for the Information Society. 11, (2015).

22. Williams, S.: Data Action: Using Data for Public Good. The MIT Press, Cambridge, Massachusetts (2022).

23. Morello, E., Piga, B.E.A.: Experiential simulation in architecture and urban space: Introduction to the special issue edited by Eugenio Morello and Barbara E. A. Piga. ambiances. (2015). https://doi.org/10.4000/ambiances.671.

24. Piga, B.E.A., Salerno, R.: Non-conventional Representation for Urban Design: Depicting the Intangible. In: Cocchiarella, L. (ed.) ICGG 2018 - Proceedings of the 18th International Conference on Geometry and Graphics. pp. 1694–1705. Springer International Publishing, Cham (2019). https://doi.org/10.1007/978-3-319-95588-9_152.

25. Piga, B., Tangredi, C., Signorelli, V.: Investigating the traveler experience: the use of eye-tracking for urban design purposes. Presented at the 10th Conference of the European Architectural Envisioning Association. , Delft, the Netherlands (2011).

26. Piga, B., Morello, E.: Environmental design studies on perception and simulation: an urban design approach. ambiances. (2015). https://doi.org/10.4000/ambiances.647.

27. Armando, A., Durbiano, G.: Teoria del Porgetto Architettonico. Dai Disegni agli Effetti. Carocci, Roma (2017).

28. Ferraris, M.: Documanità: filosofia del mondo nuovo. GLF editori Laterza, Bari (2021).

29. Latour, B.: Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts. In: Shaping Technology-Building Society. Studies in Sociotechnical Change. pp. 259–264. MIT Press, Cambridge, MA, USA.

30. Yaneva, A.: Made by the Office for Metropolitan Architecture: an Ethnography of Design. 010 Publishers, Rotterdam (2009).

31. Loukissas, Y.A.: Co-designers: cultures of computer simulation in

architecture. Routledge, London (2012).
32. Callon, M.: Le Travail de Conception En Architecture. Les Cahiers de La Recherche Architecturale. 37, 25–35 (1996).
33. Todella, E.: The architectural design practice in the folds of decision-making processes: La pratica della progettazione architettonica nelle pieghe dei processi decisionali. Valori e Valutazioni. 33, 3–16 (2023). https://doi.org/10.48264/VVSIEV-20233302.
34. Yaneva, A.: Latour for Architects: Thinkers for Architects. Routledge, Abingdon (2022). https://doi.org/10.4324/9780429328510.
35. Latour, B.: Cogitamus: sei lettere sull'umanesimo scientifico. Il Mulino, Bologna (2013).
36. Beaulieu, A., Leonelli, S.: Data and society: a critical introduction. Sage, London (2022).
37. Kitchin, R., McArdle, G.: What makes Big Data, Big Data? Exploring the ontological characteristics of 26 datasets. Big Data & Society. 3, 205395171663113 (2016). https://doi.org/10.1177/2053951716631130.
38. Dijck, J.V., Poell, T., Waal, M.D., Artieri, G.B., Marinelli, A.: The Platform Society. Public Values in a Connective World. Guerini Scientifica (2019).
39. Wu, C., Zhou, S., Ye, Y.: The Application of Human Behaviour Modelling in Urban Ergonomics Design. World Architecture. 369, 46–49 (2021).
40. Feng, Y., Duives, D.C., Hoogendoorn, S.P.: Wayfinding behaviour in a multi-level building: A comparative study of HMD VR and Desktop VR. Advanced Engineering Informatics. 51, 101475 (2022). https://doi.org/10.1016/j.aei.2021.101475.
41. Hölscher, C., Brösamle, M., Vrachliotis, G.: Challenges in Multilevel Wayfinding: A Case Study with the Space Syntax Technique. Environ Plann B Plann Des. 39, 63–82 (2012). https://doi.org/10.1068/b34050t.
42. Latour, B.: Science in Action: How to Follow Scientists and Engineers through Society. Harvard University Press, Cambridge, Mass. (1987).
43. Latour, B., Woolgar, S.: Laboratory Life. The Construction of Scientific Facts. Princeton University Press, Princeton, New Jersey (1986).
44. Latour, B., Yaneva, A.: Give Me a Gun and I Will Make All Buildings Move: An ANT's View of Architecture. In: Architectural Theories of the Environment. pp. 117–124. Routledge (2013). https://doi.org/10.4324/9780203084274-13.
45. Yaneva, A.: Mapping Controversies in Architecture. Ashgate Pub. Co, Farnham (2012).
46. Rau, P.-L., Guo, Z.: Human Factors and Ergonomics of High-Quality Urban Space Design: Human Centred Design. World Architecture. 369, 16–18 (2021).
47. Bronner, S.E.: Critical Theory: a Very Short Introduction. Oxford University Press, New York, N.Y (2011).
48. Leach, N.: Architecture in the Age of Artificial Intelligence: an Introduction to AI for Architects. Bloomsbury visual arts, London (2022).
49. Crawford, K.: Atlas of AI: power, politics, and the Planetary Costs of Artificial Intelligence. Yale University Press, New Haven (2021).
50. Carpo, M.: The Second Digital Turn. The MIT Press (2017).
51. Yang, D., Qu, B., Yang, J., Cudre-Mauroux, P.: Revisiting User Mobility and Social Relationships in LBSNs: A Hypergraph Embedding Approach. In: The World

Wide Web Conference. pp. 2147–2157. ACM, San Francisco CA USA (2019). https://doi.org/10.1145/3308558.3313635.

52. Sim, R.H.L., Xu, X., Low, B.K.H.: Data Valuation in Machine Learning: “Ingredients”, Strategies, and Open Challenges. In: Proceedings of the Thirty-First International Joint Conference on Artificial Intelligence. pp. 5607–5614. International Joint Conferences on Artificial Intelligence Organization, Vienna, Austria (2022). https://doi.org/10.24963/ijcai.2022/782.

53. Zhang, L., Deng, H., Mei, X., Xie, Q.: Urban Ergonomics and Subterranean Space Design: A Preliminary Study on Empirical Methodologies and Design Making Patterns. World Architecture. 369, 19–23 (2021).

54. Iliadis, A., Russo, F.: Critical Data Studies: an Introduction. Big Data & Society. 3, (2016). https://doi.org/10.1177/2053951716674238.