Monitoring the *Sustainable Development Goals* in cities: Potentials and pitfalls of using smart city data

Smart city strategies highlight the potential to generate new type of data through new technology, for example crowdsourced data. Based on an empirical study, we show the potentials and limits of using new data for monitoring urban sustainability and especially the Sustainable Development Goals.

Florian Koch, *Sarah Beyer*, *Chih-Yu Chen*

Monitoring the *Sustainable Development Goals* in cities: Potentials and pitfalls of using smart city data
GAIA 32/S1 (2023): 47–53

Abstract
The latest debate on smart cities and sustainability is underpinned by the United Nations' *2030 Agenda* and their accompanying *Sustainable Development Goals (SDGs)*, which place urban data and monitoring systems at the forefront. Therefore, there is a strong need to assess the data-driven capabilities that will help achieve the *SDGs*. To fill the capability gaps between existing tools and *SDG* indicators, new smart city data sources are now available. However, scant indicators and assessment criteria have been empirically validated. This paper identifies some of the challenges alongside the potential of using new local data in urban monitoring systems. A case study of an *SDG* monitoring platform implementation in a district of Berlin is examined, and the results show that the use of locale-specific, and unofficial data not only improves data availability, but it also encourages local public participation. Based on our empirical findings, we determine that the incorporation of new data for urban sustainability monitoring should be treated as a complex social process.

Keywords
indicators, smart cities, Sustainable Development Goals, urban data, urban development

Prof. Dr. Florian Koch | University of Applied Sciences HTW Berlin | Berlin | DE | florian.koch@htw-berlin.de

Sarah Beyer, MSc | University of Applied Sciences HTW Berlin | Berlin | DE | sarah.beyer@htw-berlin.de

Chih-Yu Chen, MSc | University of Applied Sciences HTW Berlin | Berlin | DE | chih-yu.chen@htw-berlin.de

https://doi.org/10.14512/gaia.32.S1.8
Received May 22, 2022; revised version accepted January 25, 2023 (double-blind peer review).

Since the early 2000s, cities worldwide have been developing so-called "smart city" strategies that have attracted considerable attention from urban researchers (Jong et al. 2015). Despite the abundant literature on the many facets of smart city constructs, a concise definition is lacking, and the specific characteristics remain ambiguous (Miller et al. 2021). Early smart city models were developed and/or supported by large technology companies that provided glossy images of hyper-modern cityscapes but neglected realistic social and environmental considerations. Notable urban studies have criticized negative aspects of these corporate-driven smart cities as lacking democratic legitimacy (Engelbert et al. 2022) or being built upon neoliberal urban agendas (Glasmeier and Christopherson 2015). In recent years, smart city strategies have diversified with the increasing complexity of digitalization in terms of its actors, technologies, and objectives. These approaches range from private projects built from scratch, such as Songdo in South Korea, to commons-based, civil society-driven approaches, such as Barcelona en Comú (Charnock et al. 2021). There is now a plethora of smart city constructs, making realistic ideation extremely difficult. Chang et al. (2021) postulated the need to provincialize smart cities: smart cities now incorporate diverse landscapes of smart and "ordinary" locations that are loosely connected through the use of information technologies, such as big data, location-independent digital data flows, and networked technologies, as well as experimental approaches to applying these technologies (Caprotti et al. 2022). An important crosscutting issue for all approaches is the role of the data. Often, smart cities are envisioned to be constructed upon the emergence, flow, visualization, and commercialization of data (i. e., data-driven urbanism; Kitchin et al. 2018).

Questions of "smartness" and sustainability have also emerged in terms of a juxtaposed desire for smart cities and the vital need for global sustainability (Fromhold-Eisebith et al. 2019). Thus, a close examination of specific smart city policies and their potential impacts on the various dimensions of sustainability is needed. Notably, recent research has highlighted the impact of digital smart grids and smart meters on the promotion of renewable

>

energy and the potential of shared mobility in order to foster modes of transport, which depend less on individual car-ownership (Lange and Santarius 2018). However, other authors have identified the development of smart cities as the cause of increased energy consumption and the overuse of raw materials (David and Koch 2019). There is also a risk of stakeholder disengagement with top-down implementation of smart cities (Sontiwanich et al. 2022).

Meanwhile, the United Nations' *2030 Agenda* and the accompanying *Sustainable Development Goals (SDGs)* have generated new debates on smart cities and their sustainability, and urban data collection and monitoring capabilities are central to the issues, and increased government accountability is expected to become a result (Bowen et al. 2017). From this debate, a new brand of sustainability science has begun identifying and evaluating new urban data sources, such as those used in smart city approaches, that can be used to monitor urban sustainability. Kharrazi et al. (2016) argued that urban big data (e.g., sensor data emerging from Internet of Things [IoT] devices), individual- and household-level survey data, geospatial analytics, citizen science, and social media sources can be used to fill the gaps in existing *SDG* data collection and analysis tools. Similarly, MacFeely (2019) discussed the potential of big data cultivated from web-scraping, satellite imagery, and smart meters, and Creutzig et al. (2019) identified the potential to facilitate urban climate solutions through the harmonization of data collection, machine learning, big data approaches and the application of machine learning-based textual analysis of qualitative data. Focusing on social-media data, Ilieva and McPhearson (2018) discussed the specific attributes of social-media data (e.g., geo-tagged Twitter posts) and highlighted their utility for urban sustainability. Fritz et al. (2019) and Fraisl et al. (2020) took issue with the fact that citizen-generated data have so far been largely ignored in *SDG* data collection solutions, despite their obvious advantages, such as being inexpensive and timely.

Although the promise of these data, which we hereafter refer to as "new data", has been clearly recognized, difficulties remain, as there is little empirical evidence on how cities are using the new data to monitor urban sustainability, particularly for *SDGs*. Presently, traditionally collected data such as official data from statistical offices and other authorities, including international organizations, are used to evaluate *SDG* approaches (Fritz et al. 2019). This is likely caused by the extant guidelines, which mostly leverage official data for political, regulatory and availability reasons (Bertelsmann Stiftung et al. 2020, Siragusa et al. 2022). Moreover, voluntary local reviews, which are published by cities for local *SDG* assessment, mainly use official data.

This paper brings together smart city approaches and sustainability data research and adds case study evidence to the debate. By combining work from critical data studies with the urban sustainability literature, we aim to identify the potentials and pitfalls of using new local data in urban monitoring systems. In addition to conceptual and literature-based reflections, the paper takes an empirical approach. Our research questions include "What opportunities do new data offer for urban *SDG* monitoring systems?," and "What are the challenges of using new or complementary unofficial data sources (such as those collected in smart city approaches) in *SDG*-related urban monitoring systems?" To answer these questions, this paper is divided into four parts. The upcoming section provides an overview of the relationships between data and urban development, followed by an examination of the challenges of data-driven urban monitoring systems. Then, the case of Treptow-Köpenick is provided. Our overarching purpose is to contribute to the emerging debate on smart city development and sustainability by describing how policymakers and researchers should (re)examine the use, treatment, distribution, accessibility, and visualization of available official and unofficial data for sustainable urban development.

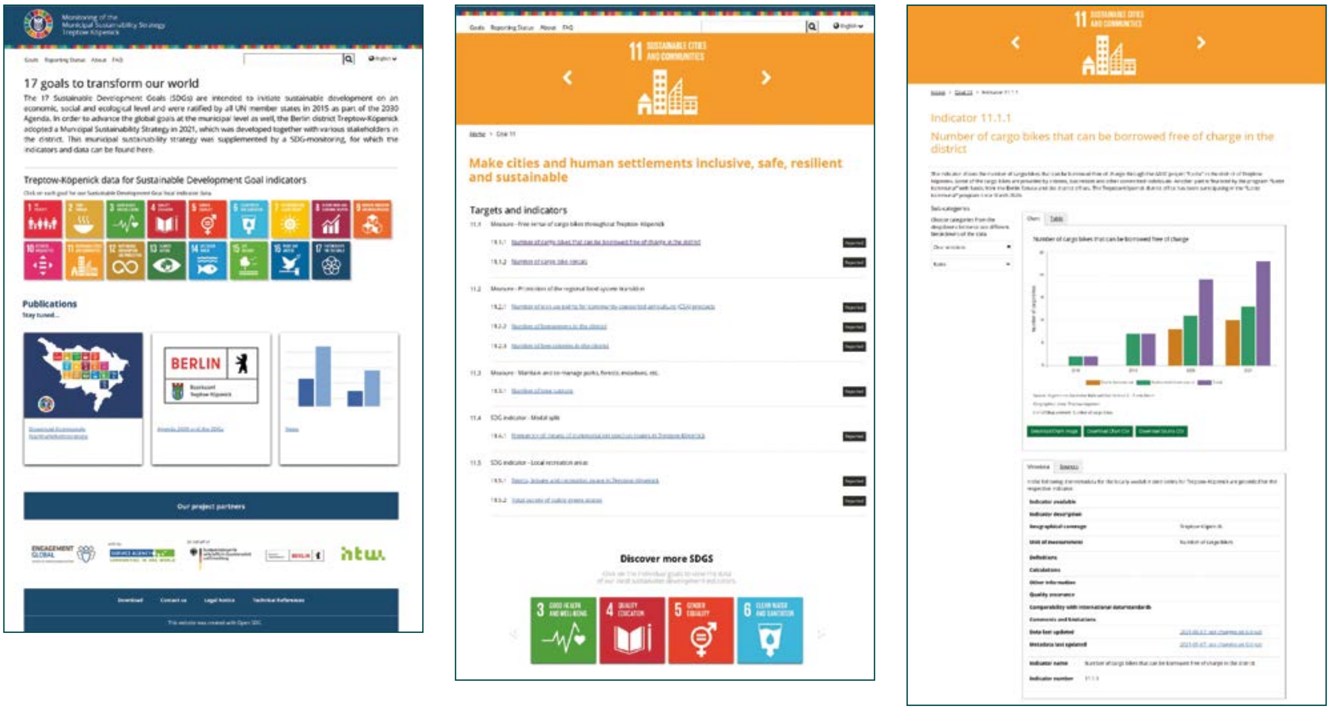
Better data, better cities?

Urban data include all digitally available information of general relevance to urban social settings, which can have different origins, ownerships, and management styles (Schieferdecker 2021). Cities have long collected and processed similar data, but new technologies have driven changes in their use. New sources and subsequent analysis and visualization methods have emerged, and their uses currently include built environment monitoring, real-time energy demand visualization, and air quality reporting. Compared with traditional data curation methods, new data sources and types offer advantages of cost, collection frequency, timeliness, and geographic scope (Fritz et al. 2019, Fraisl et al. 2020).

The ubiquitous presence of new data sources (e.g., sensors that use the Internet of Things) and modern aggregation and visualization methods is expected to lead to data-rich and -driven forms of urban management, but it comes with challenges and risks (Kitchin 2016) in terms of security, privacy, and ownership (Pagliarin 2021). Moreover, there are many unknown risks about the non-objectivity of data in general (Frith 2017) and the exclusive focus on particular types of knowledge (e.g., instrumental vs. scientific; Kitchin 2016).

Accordingly, authors from data science studies argue that the composition and use of data must be critically analyzed. D'Ignazio and Klein (2020) showed that ignoring gender-related datasets leads to biased conclusions in data analytics. Törnberg and Uitermark (2021) argued for a new heterodox computational social science that highlights the risks of molding data analytics into a new digital capitalism. Relatedly, Zuboff (2019) linked the role of surveillance data in capitalist societies to high exploitation risks. Safransky (2020) describes how algorithms in data-driven assessment tools for urban investment decisions lead to the racialization of space and spatialization of poverty. MacFeely (2019) and Ilieva and McPhearson (2018) identified new legal, ethical, technical, and reputational pitfalls to many of these technologies.

Hence, it is an obvious fallacy that "better data" will automatically lead to "better cities." Conventional wisdom states that



landing page | *list of local targets and indicators* | *data visualization*

FIGURE 1: Treptow-Köpenick's *Sustainable Development Goal* monitoring system: the platform consists of a landing page with a general introduction and a list of all *Sustainable Development Goals (SDGs)* (left), and subpages listing the targets and indicators for each *SDG* (center) and showing the specific results for each indicator (right).

more precise and accurate data and simpler, more powerful interfaces will be inherently beneficial to society because better policy decisions and emergency measures can be made (Holden 2013), for example in terms of urban energy consumption and traffic flow assessments. The assumption that "better leads to better" is an instrumentalist and positivist paradigm that is reflected in the United Nations' *2030 Agenda*. A notable example is the postulated assumption of "Better data for a better planet and better lives" (Daguitan et al. 2019, p. 71). Great care is needed going forward to ensure that the new data are not used exclusively for instrumentalist (Kitchin 2016) or positivist (Pfeffer and Georgiadou 2019) outcomes. Moreover, in an ever-changing global policy environment, the use of data analytics in sustainability fields is increasingly assigned a discursive-interpretative role, whether in education, politics, or society at large (Pupphachai and Zuidema 2017).

Data and monitoring systems

The role of monitoring systems in sustainable urban development is to make decision-level information more accessible and transparent by collecting and analyzing the appropriate data and selecting the best indicators for measuring change. This is functionally fine, but it is less clear how well the existing data platforms can support these objectives (Kitchin 2016). The collection and curation of urban sustainability data are complex and confusing, especially when deciding the best way to apply them to measuring the achievement of *SDGs* (Siragusa et al. 2022). Hence, systems must not be designed in isolation as the relevancy of the data and the tenets of society are highly dispersed and interconnected.

Notably, the desired indicators must be accessible from the collected data. As such, the indicators should be socially derived. Therefore, the mere existence of unused or unresolved urban data features in a dataset is insufficient for creating new indicators. Moreover, it is dangerous owing to the several fallacies and biases discussed above. Michalina et al. (2021) argued that a city's specific conditions and goals must be considered when defining sustainability indicators. Accessibility is also crucial for socially beneficial data monitoring. For example, if users are provided raw data, they can assess the development of certain indicators without depending on the interpretations of others. In this context, Schieferdecker (2021) highlighted the importance of open data, as defined for example in the eight open data principles.[1] That is, data must be complete, disaggregated, timely, freely accessible, published and machine-processable, non-discrimina- >

1 *https://opengovdata.org*

tory, non-proprietary, and license-free and reusable (Lwin et al. 2019). Furthermore, the existence of metadata and their accessibility are equally important for understanding the information retrieved. For example, reducing urban CO_2 emissions is important for achieving *SDG 13,* but emissions are currently measured in different ways based on the necessary theoretical assumptions and aggregation requirements. Therefore, appropriate disambiguation information should be provided in the metadata.

The origin of the data must also be considered. Recently, new data sources have emerged that have the potential to support smart cities, such as citizen science data and sensor data (Cutter 2021). This provides a potential major shift in the traditional role of the public sector from exclusive data consumers to producers (e. g., crowdsourcing), in which private actors (e. g., individuals, companies, and civil organizations) provide the data. Because cities engaged with *SDG* monitoring tend to rely only on official data, the potential benefits of other types and sources of data (so-called unofficial data) require examination.

We must acknowledge the social complexities that influence the data, their metadata, and their interpretations so that production and use of new data for Sustainable Development Goals *monitoring can be fully understood as a social process rather than a purely technological one.*

Importantly, data are not to be considered neutral or “raw,” as they originate from and affect the context of the given societies. They are shaped by beliefs and biases (Luque-Ayala and Marvin 2020), they reflect power inequalities, unequal access, and institutionalized justice systems (D’Ignazio and Klein 2020). This is even more applicable to private data sources, wherein issues of propriety, exploitation, profit, and confidentiality are paramount. In summary, urban monitoring systems must not be viewed as neutral technical assemblage but the result of complex interactions (Kitchin et al. 2015). Hence, even with suitable indicators, the context of the collected data and the purposes of their desired use must become part of the analytical framework (D’Ignazio and Klein 2020).

The case of Treptow-Köpenick

Treptow-Köpenick is one of twelve districts in the Federal State of Berlin. The district is located in the southeastern part of the state and has a population exceeding 276.165. Districts have the status of municipalities, and their mayors and administrations enjoy certain degrees of autonomy. Treptow-Köpenick began developing a sustainability strategy in 2017 using *SDGs* to construct its framework. The effort entailed a lengthy participatory process that involved the public. The resultant strategy included 68 specific measures, such as the free rental of cargo-bikes *(SDG 11),* reduction of food waste in public schools *(SDG 3),* and a new climate protection vision *(SDG 13)*. Our research team was onboarded in 2019 and has documented the progress and lessons learned thus far. A formal strategy was adopted in 2021, and from this, the district has planned standardized but locale-specific data-driven monitoring systems that include extant sources and tools. The system was launched in February 2022[2] and contains 1. a landing page with a general introduction and a list of all *SDGs,* 2. the targets and indicators for each *SDG,* and 3. the specific results for the respective indicators (figure 1). Next, we describe our experiences with indicator selection, data collection, and data handling.

Methodology

The selection of indicators was closely linked to the district’s *SDG*-based sustainability strategy. The district government and affiliated planners decided to focus on measure- and impact-related indicators. The former reflects the efficacy of related policy measures, and the latter reflects *SDG* attainment. For example, for *SDG 11,* the district established the “free rental of cargo bicycles throughout Treptow-Köpenick” measure, which is represented by the specific indicator, “number of cargo bicycles that can be rented free of charge in the district”. Complementarily, the “modal split” indicator is used to measure *SDG* impact. The district’s “municipal climate protection concept and climate protection manager” measure includes the measure-related “job shares for climate protection management in the administration” indicator and an index indicator on the topic of municipal climate protection. “CO_2 emissions” is an *SDG* impact indicator.

The indicator selection criteria were built around data availability and quality, in addition to the strength of their traceability to the district’s sustainable urban development strategy. In addition, we analyzed whether or not actions taken by the municipal government can influence the development of a particular indicator. Some indicators often used in *SDG* monitoring, such as “funding for international development cooperation”, depend on the national or federal state level, and the municipal level therefore has no authority to take action in this policy area. In this context, various existing *SDG* indicator reports from other cities were consulted.

2 *www.sdg-treptow-koepenick.de*

Official data (such as from the micro census) were solicited first, as they were readily accessible. Then, available "new data" sources were incorporated, which happened to reflect air quality, water quality, and traffic sensor data, to name a few. Part of the traffic data reflects cyclists per street per weekday, whose sensors were funded by the Berlin Senate, which collects this data and publishes annual reports. The figures from these reports are then fed into the monitoring system. As there is no interface between the Senate's data and the monitoring system, the system does not display real-time data, but uses data from the annual reports.

As the work progressed, it became clear that the official data were not as available as initially believed. Hence, the integration of unofficial data was greatly expanded. The district government and planners understood that this step would require the involvement and active support of both private citizens and local officials who had participated in building the sustainability strategy. Hence, the bulk of unofficial data was acquired from civil organizations, including schools and churches. For example, the *Mundraub Association*[3] provided crowdsourced data on edible plants in the district and their locations, and the *Foodsharing Organization* provided data on the amount of food saved (i.e., not wasted) in kilograms. Web-scraping techniques were also used to track the number of solidarity farming collection points across the district.

Owing to the heterogeneity of official and unofficial sources, metadata were added to all indicators to convey origins, collection methods, and data providers. Eventually, all indicators were publicly discussed using the *Adhocracy* platform, where individuals can provide comments vetted with researchers and policymakers. An attempt was made to take the suggestions into account in the final version of the monitoring.

After approval, the selected indicators and their data origins were published online using the *Open SDG* platform,[4] which was created through a collaboration between the UK Office for National Statistics, the US government, and the nonprofit Center for Open Data Enterprise. The results can be accessed worldwide for *SDG* reporting. Barcelona, Los Angeles, and Bristol, for example, use the platform too. The chosen technical solution was based on open data principles, meaning that all raw data and metadata in the system must remain accessible and processable by all users.

Results

A total of 87 indicators were selected from the above processes using anonymized and highly aggregated data. In total, 47 datasets came from official data sources, and 24 were unofficial. Crowdsourced, sensor, and web-scraped data were used to support eight indicators. Out of 87 indicators, 16 could not be suitably supported by the data (table 1).

Discussion

The theoretical debates on the use of smart city data to monitor the *SDGs* mentioned above emphasize that new data sources allow for more accurate monitoring, however, the case of Treptow-Köpenick district of Berlin clearly illustrates the many difficulties involved in balancing official and unofficial data sources. Notably, the selection and availability of indicators, the need to contextualise data collection and the inclusion of different data providers proved challenging.

TABLE 1: Results of indicator selection.

INDICATOR/ DATA	MEASURES	IMPACT ON SDGS	TOTAL
official data	26	21	47
data from civil society organizations	15	9	24
no data			16
TOTAL			**87**
NEW DATA SOURCES			
sensor			4
crowdsourcing			3
webscraping			1
TOTAL			**8**

The selection of appropriate indicators and the search for suitable data was demanding, as there were large gaps in official data. The integration of unofficial data and the involvement of civil society actors was a logical consequence for all stakeholders in the project.

During the development of the monitoring system, shortcomings in the types and sources of data (traditional and "new" types of collection, official and unofficial data sources) became apparent. For example, CO_2 emission data were not aggregated at the district level. Hence, Berlin-level total emissions were divided proportionally, which relied on assumptions of scope and source. This means that the data for Treptow-Köpenick is heavily influenced by the other eleven districts of Berlin.

It was difficult to track and measure the quality of the data provided by civil organizations, and the collection methods varied among providers. For example, one indicator is the number of bicycle trips in the Stadtradeln bicycle competition. Such crowdsourced data often lack measures of reliability and accuracy. More difficult was the translation of qualitative report data into basic indicator parameters. For example, the indicator that uses data on the number of racist, antisemitic, homophobic and right-wing extremist incidents per year in Treptow-Köpenick. People can report such incidents digitally or in person to a civil society organization that forwards the data to the monitoring system. Importantly, it is nearly impossible to know the true number of unreported incidents, but we know that it is "high." The role of metadata in these cases allows platform users to be aware of the origin and shortcomings.

>

3 *www.mundraub.org*
4 *www.open-sdg.org*

The purpose of the case study was to inform the development of a monitoring system that could provide the district's population with the opportunity to follow the progress meeting the *SDG* measures. Through participatory events, attempts were made to initiate a joint *SDG* monitoring system. However, engaging and retaining the interests of local actors proved to be very difficult. Although many private citizens and agencies were willing and active in providing data, the labor needed to adequately process the data was unforthcoming. As a result, D'Ignazio and Klein's (2020) call to reduce the inequity of data-related social monitoring and decision-making methods fell short, and the need to illuminate the extant power imbalances was only partially met. The process of contextualizing data was not as transparent as we had desired. Nevertheless, data-searching and collaboration efforts have led to the establishment of new contacts and partnership opportunities. In summary, the case presented provided the beginning of a joint dialogue with the district.

The overarching guidance to the district was the *2030 Agenda* and the desire to pursue *SDGs*. Accordingly, the continued development and maturation of the monitoring system will reflect this agenda as it changes and grows. Over time, more clearly quantifiable targets and thresholds will be set for the indicators as they mature. The lack of precise target values was not unexpected, and it provided demand signals for roadmap development, which must be facilitated politically by district- and state-level sustainability strategies.

Concluding remarks

The use of smart city data (i.e., unofficial data from diverse sources and providers, often collected more frequently) provides exciting new opportunities for municipalities as they engage with local stakeholders to promote public participation in *SDG* monitoring. Notably, this process is not straightforward, and one must account for the different perceptions and values of sustainability of the many stakeholders as well as various practical constraints. Many authors have emphasized the theoretical potential of harnessing emerging data for smart city approaches and sustainability measurement. Our empirical example demonstrated the pitfalls of this complexity and some of the associated technical barriers (e.g., lack of data interfaces). It remains difficult to assess data quality at the city level, and the time and resources needed from public and private sources are daunting. Illuminating the barriers is a prerequisite for overcoming them, and our results frame the problem for future research and actions. Notably, our findings highlight the critical role of metadata in determining the utility and feasibility of indicator identification and definition. As noted, data are not neutral items; they are socially and politically constructed and reflect issues of power and existing biases in society.

Metadata are therefore an integral part of Treptow-Köpenick's monitoring system, as it allows potential shortcomings, underestimations and other forms of data inaccuracy to be made visible and explained. This transparency is particularly necessary for the new, unofficial data sources.

The Treptow-Köpenick district case clearly shows that in order to use new and unofficial data in *SDG* monitoring, compromises are required. Rather than viewing new data as a purely neutral technological set of figures, we must acknowledge the social complexities that influence the data, their metadata, and their interpretations so that production and use of new data for *SDG* monitoring can be fully understood as a social process rather than a purely technological one.

Acknowledgement: We would like to thank *Dennis Lumme* from the Bezirksamt Treptow-Köpenick and *Sebastian Ohlmeyer* from the Service Agency Communities in One World (SKEW) for their cooperation throughout the project. We would also like to thank three anonymous reviewers and the editors of the special issue for their helpful comments.
Funding: The work represents the results of the *INDIKON (Indikatorenset für die kommunale Nachhaltigkeitsstrategie Treptow-Köpenick)* and *DATAKON (Datenmanagement und -vermittlung für die kommunale Nachhaltigkeitsstrategie Treptow-Köpenick)* projects supported by Engagement Global and its Service Agency Communities in One World (SKEW) funded by the German Federal Ministry for Economic Cooperation and Development BMZ 2020–2021.
Competing interests: The authors declare no competing interests.
Author contribution: All authors have contributed equally to this work and share the first authorship.

References

Bertelsmann Stiftung et al. 2020. *SDG-Indikatoren für Kommunen – Indikatoren zur Abbildung der Sustainable Development Goals der Vereinten Nationen in deutschen Kommunen.* Gütersloh: Bertelsmann Stiftung. www.bertelsmann-stiftung.de/de/publikationen/publikation/did/sdg-indikatoren-fuer-kommunen-all (accessed January 30, 2023).
Bowen, K. J. et al. 2017. Implementing the "Sustainable Development Goals:" Towards addressing three key governance challenges – collective action, trade-offs, and accountability. *Current Opinion in Environmental Sustainability* 26: 90–96. https://doi.org/10.1016/j.cosust.2017.05.002.
Caprotti, F., I. C. C. Chang, S. Joss. 2022. Beyond the smart city: A typology of platform urbanism. *Urban Transformations* 4/1: 4. https://doi.org/10.1186/s42854-022-00033-9.
Chang, I. C. C., S. C. Jou, M. K. Chung. 2021. Provincializing smart urbanism in Taipei: The smart city as a strategy for urban regime transition. *Urban Studies* 58/3: 559–580. https://doi.org/10.1177/0042098020947908.
Charnock, G., H. March, R. Ribera-Fumaz. 2021. From smart to rebel city? Worlding, provincializing, and the Barcelona model. *Urban Studies* 58/3: 581–600. https://doi.org/10.1177/0042098019872119.
Creutzig, F. et al. 2019. Upscaling urban data science for global climate solutions. *Global Sustainability* 2: e2. https://doi.org/10.1017/sus.2018.16.
Cutter, S. L. 2021. Urban risks and resilience. In: *Urban informatics.* Edited by W. Shi, M. F. Goodchild, M. Batty, M. P. Kwan, A. Zhang. Singapore: Springer. 197–211. https://doi.org/10.1007/978-981-15-8983-6.
Daguitan, F., P. Lehohla, C. Mwangi. 2019. The current state of our data and knowledge. In: *Global environment outlook – GEO-6: Healthy planet, healthy people.* Edited by U.N. Environment. Cambridge, UK: Cambridge University Press. 56–73. https://doi.org/10.1017/9781108627146.009.
David, M., F. Koch. 2019. Smart is not smart enough! Anticipating critical raw material use in smart city concepts: The example of smart grids. *Sustainability* 11/16: 4422. https://doi.org/10.3390/su11164422.
de Jong, M., S. Joss, D. Schraven, C. Zhan, M. Weijnen. 2015. Sustainable–smart–resilient–low carbon–eco–knowledge cities: Making sense of a multitude of concepts promoting sustainable urbanization. *Journal of Cleaner Production* 109: 25–38. https://doi.org/10.1016/j.jclepro.2015.02.004.

D'Ignazio, C., L. F. Klein. 2020. *Data feminism. Ideas series.* Cambridge, MA: MIT Press.

Engelbert, J., A. Ersoy, E. van Bueren, L. van Zoonen. 2022. Capitalizing on the "public turn:" New possibilities for citizens and civil servants in smart city-making. *Journal of Urban Technology* 29/3: 3–17. https://doi.org/10.1080/10630732.2021.1963647.

Fraisl, D. et al. 2020. Mapping citizen science contributions to the UN *Sustainable Development Goals. Sustainability Science* 15/6: 1735–1751. https://doi.org/10.1007/s11625-020-00833-7.

Frith, J. 2017. Big data, technical communication, and the smart city. *Journal of Business and Technical Communication* 31/2: 168–187. https://doi.org/10.1177/1050651916682285.

Fritz, S. et al. 2019. Citizen science and the United Nations *Sustainable Development Goals. Nature Sustainability* 2/10: 922–930. https://doi.org/10.1038/s41893-019-0390-3.

Fromhold-Eisebith, M. et al. 2019. *Towards our common digital future. Summary*. Berlin: German Advisory Council on Global Change (WBGU). www.wbgu.de/fileadmin/user_upload/wbgu/publikationen/hauptgutachten/hg2019/pdf/WBGU_HGD2019_S.pdf (accessed January 30, 2023).

Glasmeier, A., S. Christopherson. 2015. Thinking about smart cities. *Cambridge Journal of Regions, Economy and Society* 8/1: 3–12. https://doi.org/10.1093/cjres/rsu034.

Holden, M. 2013. Sustainability indicator systems within urban governance: Usability analysis of sustainability indicator systems as boundary objects. *Ecological Indicators* 32: 89–96. https://doi.org/10.1016/j.ecolind.2013.03.007.

Ilieva, R. T., T. McPhearson. 2018. Social-media data for urban sustainability. *Nature Sustainability* 1/10: 553–565. https://doi.org/10.1038/s41893-018-0153-6.

Kharrazi, A., H. Qin, Y. Zhang. 2016. Urban big data and *Sustainable Development Goals:* Challenges and opportunities. *Sustainability* 8: 1293. https://doi.org/10.3390/su8121293.

Kitchin, R. 2016. The ethics of smart cities and urban science. *Philosophical Transactions. Series A, Mathematical, Physical, and Engineering Sciences* 374: 2083. https://doi.org/10.1098/rsta.2016.0115.

Kitchin, R., T. P. Lauriault, G. McArdle. 2015. Knowing and governing cities through urban indicators, city benchmarking, and real-time dashboards. *Regional Studies, Regional Science* 2/1: 6–28. https://doi.org/10.1080/21681376.2014.983149.

Kitchin, R., T. P. Lauriault, G. McArdle (Eds.). 2018. *Data and the city. Regions and cities.* London: Routledge. https://doi.org/10.4324/9781315407388.

Lange, S., T. Santarius. 2018. *Smarte grüne Welt? Digitalisierung zwischen Überwachung, Konsum und Nachhaltigkeit.* Munich: oekom.

Luque-Ayala, A., S. Marvin. 2020. *Urban operating systems: Producing the computational city.* Cambridge, MA: MIT Press. https://doi.org/10.7551/mitpress/10869.001.0001.

Lwin, K. K., Y. Sekimoto, W. Takeuchi, K. Zettsu. 2019. City geospatial dashboard: IoT and big data analytics for geospatial solutions provider in disaster management. Paper presented at the *2019 IEEE International Conference on Information and Communication Technologies for Disaster Management (ICT-DM)*. Paris: December 18–20. https://doi.org/10.1109/ICT-DM47966.2019.9032921.

MacFeely, S. 2019. The big (data) bang: Opportunities and challenges for compiling *SDG* indicators. *Glob Policy* 10/S1: 121–133. https://doi.org/10.1111/1758-5899.12595.

Michalina, D., P. Mederly, H. Diefenbacher, B. Held. 2021. Sustainable urban development: A review of urban sustainability indicator frameworks. *Sustainability* 13/16: 9348. https://doi.org/10.3390/su13169348.

Miller, B., K. Ward, R. Burns, V. Fast, A. Levenda. 2021. Worlding and provincializing smart cities: From individual case studies to a global comparative research agenda. *Urban Studies* 58/3: 655–673. https://doi.org/10.1177/0042098020976086.

Pagliarin, S. 2021. *Data Policies in Europäischen Smart Cities: Erfahrungen, Chance und Herausforderungen*. Bamberg: Otto-Friedrich-Universität. https://doi.org/10.20378/irb-52940.

Pfeffer, K., Y. Georgiadou. 2019. Global ambitions, local contexts: Alternative ways of knowing the world. *ISPRS International Journal of Geo-Information* 8/11: 516. https://doi.org/10.3390/ijgi8110516.

Pupphachai, U., C. Zuidema. 2017. Sustainability indicators: A tool to generate learning and adaptation in sustainable urban development. *Ecological Indicators* 72: 784–793. https://doi.org/10.1016/j.ecolind.2016.09.016.

Safransky, S. 2020. Geographies of algorithmic violence: Redlining the smart city. *International Journal of Urban and Regional Research* 44/2: 200–218. https://doi.org/10.1111/1468-2427.12833.

Schieferdecker, I. 2021. Urbane Datenräume und digitale Gemeingüter – Instrumente für Open Government und mehr. In: *Praxishandbuch Forschungsdatenmanagement.* Edited by M. Putnings, H. Neuroth, J. Neumann. Munich: De Gruyter Saur. 175–196. https://doi.org/10.1515/9783110657807-010.

Siragusa, A., I. Stamos, C. Bertozzi, P. Proietti. 2022. *European handbook for SDG voluntary local reviews – 2022 edition.* Luxembourg: Publications Office of the European Union. https://publications.jrc.ec.europa.eu/repository/handle/JRC129381 (accessed January 30, 2023).

Sontiwanich, P., C. Boonchai, R. J. S. Beeton. 2022. An unsustainable smart city: Lessons from uneven citizen education and engagement in Thailand. *Sustainability* 14/20: 13315. https://doi.org/10.3390/su142013315.

Törnberg, P., J. Uitermark. 2021. For a heterodox computational social science. *Big Data & Society* 8/2: 205395172110477. https://doi.org/10.1177/20539517211047725.

Zuboff, S. 2019. Surveillance capitalism and the challenge of collective action. *New Labor Forum* 28/1: 10–29. https://doi.org/10.1177/1095796018819461.

Florian Koch

Studies in spatial planning and urban sociology. 2002 Dipl.-Ing. Raumplanung, 2009 Dr. phil. Since 2018 professor for Real Estate Management, Smart Cities and Urban Development at the University of Applied Sciences HTW Berlin, DE. Research interests: digitalization and urban sustainable development, housing and urban climate governance.

Sarah Beyer

Studies in integrated natural resource management. 2020 MSc at Humboldt-Universität zu Berlin, DE. Since 2020 research associate at the University of Applied Sciences HTW Berlin, DE. Research interests: sustainable urban transformation, sustainable development in the global North, digitalization.

Chih-Yu Chen

Studies in urban planning. 2019 MSc at National Cheng Kung University, Tainan, TW. Since 2022 research associate at the University of Applied Sciences HTW Berlin, DE. Research interests: digitalization, urban sustainable development, and urban informatics.