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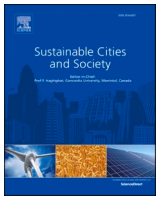

Citizen-centered data governance in the smart city: From ethics to accountability

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ABSTRACT

The concept of a smart city is tightly linked to the promise of using data as a resource to create value for citizens. The present paper systematically examines how such data-based value creation generates challenges for decision-makers in the smart city and how they can deal with these challenges. It formulates a coherent data governance framework that comprehensively covers ethical and legitimacy challenges which can arise over the various stages of data-based value creation. The framework translates abstract ethical requirements into a set of systematically derived governance mechanisms which are at the same time anchored in the concept of democratic accountability. This guiding principle does not demand that citizens necessarily become active themselves to realize citizen-centric data governance for socially sustainable smart city development. Rather, it demands that data governance comprises a suitable set of accountability measures that put the purposes of any data use center-stage.

1. Introduction

In the larger digital transformation of societies and the emergence of a data-driven economy (Cavanillas, 2015; OECD, 2017), cities are positioned as key vehicles of this change. The concept of smart cities embodies the idea that information and communication technologies (ICTs) in urban development can lead to more efficient resource use, sustainable economic development, and a better quality of life (Caragliu, Bo & Nijkamp, 2011). The prospects of realizing these goals are tied to specific uses of ICT, namely those that enable cities to harness the value of data to better monitor and understand processes occurring in the city (Bibri, 2018; Löfgren, William, & Webster, 2020; Meijer, 2018). The present paper systematically examines how such data-based value creation generates challenges for decision-makers in the smart city and how they can deal with them.

The implementation of ICT together with suitable organizational changes to enable data-based value creation alone would amount to a huge task as it requires cities – similar to businesses – to engage in processes of change management. Cities may even have to engage in innovation processes themselves as they aspire to improve or develop new services which generate value for citizens and society based on collected data about city life (Paskaleva & Cooper, 2018). Adding to these functional challenges are further challenges of dealing with possible tensions which result from the larger societal impacts of data-based value creation. Such impacts have been foregrounded in a broader, socio-technical understanding of the smart city formulated as a response to a narrow technology-centered and technocratic smart city vision (Albino, Berardi & Dangelico, 2015; Alderete, 2020; Kitchin, Cardullo & Feliciantonio, 2019; Nam & Pardo, 2011).

First, data-based value creation has various ethically relevant consequences (Ananny, 2016; Mittelstadt & Floridi, 2016; Mittelstadt, Allo, Taddeo, Wachter & Floridi, 2016) that also apply to the smart city context (Calvo, 2020; Edwards, 2016; Kitchin, 2016b). Second, further complexity for decision-makers is introduced in light of a political dimension in smart city data use as data-based solutions for given problems are never neutral (Brauneis & Goodman, 2018; Veale & Brass, 2019) and are embedded in power relations, entrenched interests, and different rationalities of involved stakeholders (D'Ignazio & Klein, 2020; Meijer, 2018; van der Voort, Klievink, Arnaboldi & Meijer, 2019). Looming large in these contributions are also questions of democratic legitimacy. As a response to such legitimacy problems, some scholars have proposed empowerment through direct citizen participation in smart city development and data use (Calvo, 2020; Calzada, 2018; Castelnovo, Misuraca & Savoldelli, 2016; Mann, Mitchell, Foth & Anastasiu, 2020).

All in all, data governance has quickly turned from a peripheral issue to a general concern, and while lots of work on data in the smart city has focused on questions of data extraction and privacy, the consequences of

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data processing, including through the use of algorithmic systems, are becoming more acutely relevant. Also, what may seem like the mere search for technical solutions is often bound up with intricate ethical and political questions. This means that not only are various solutions for building sustainable cities based on harnessing data, but the governance of data in the smart city itself is a question of sustainable city development: Early decisions about establishing socio-technical systems in the smart city are likely to have long-term effects on city life through creating path dependencies and lock-in effects. These may in part be undesirable and hard to correct later, which makes adopting suitable data governance practices key to sustainable city development and to ensuring the production of public value from data. In other words, the smartness of the city itself has to be designed for sustainability. This is, however, less a question of technology but instead of governance and politics (Green, 2020).

As a recent report for the city of Toronto (Coutts & Gagnon-Turcotte, 2020) indicates, existing policies for data governance are often sector-specific, focus on privacy as only one major ethical issue, and hardly spell out concrete accountability mechanisms. Also, smart city strategies and governance frameworks also usually refer to high-level principles concerning their handling of data without specifying their approach to data governance (see Annex A1). Against this backdrop, the present paper aims to fill a gap in the literature by tying together different strands of research, including on data ethics and algorithmic accountability, to develop a coherent account of citizen-centric data governance in the smart city – one that comprehensively covers the potential ethical and legitimacy problems arising from the core activities of data-based value creation. For this purpose, it borrows from a political science perspective to translate ethical requirements into accountability measures. Further, as will be shown below, anchoring data governance in the concept of democratic accountability is especially valuable for lending substance to the idea of citizen-centered governance – which is often advocated but not always substantiated, as Kitchin et al. (2019) note. At the same time, the standard of democratic accountability avoids overly demanding standards of citizen participation in smart city data governance. In a nutshell, the ideas embodied in democratic accountability ensure the continued possibility of contestation, revisability, and learning and in this sense orient smart city data governance toward social resilience and sustainability.

The data governance framework developed below therefore gains particular importance in light of pleas for a human-centric sustainable smarty city development (Yigitcanlar et al., 2019) and the assessment that the main challenges to sustainable smart city development are organizational rather than technological (Mondschein, Clark-Ginsberg & Kuehn, 2021). The novelty and value of the framework below lies in formulating a set of systematically derived governance mechanisms and instruments that lie on a level between high-level, abstract principles of data governance (e.g. Micheli, Ponti, Craglia & Suman, 2020) and very specific technical instructions and checklists such as those found in the so-called Aquabook in the UK (HM Treasury, 2015). The discussion below thus offers an analytical basis for identifying those aspects that are particularly relevant for analyzing impacts of data uses in different smart city settings. It is also particularly relevant for practitioners who must translate abstract ethical values and principles into concrete instruments of data governance. Implementing data-based processes can mean tremendous challenges for decision-makers involved in city development and governance. The complexity of the task may seem overwhelming as there are endless possibilities of refining and using data to create some value, and ethical problems might thus arise in many different ways. Involving citizens in data governance would even add further complexity to smart city development. However, as will be argued below, the possibilities of value creation in the smart city, first, reduce to a manageable set of potential value offers. Second, the resulting ethical and legitimacy challenges depend on the concrete applications as these challenges arise from specific stages and key activities of data-based value creation. Third, realizing citizen-centric data governance addressing those challenges does not mean that citizens necessarily become active in data governance themselves. Rather, it demands a suitable set of accountability measures that start from the purposes of any data use.

2. How to create value from data in the public sector

It is by now commonplace that data has become a key asset from which value can be generated. In the context of the smart city, the value promise of collecting and refining data is tied to a general ability to gain actionable insights from such data used to better fulfill city management tasks (Bibri, 2018; Brauneis & Goodman, 2018; Löfgren, William, & Webster, 2020). Harnessing this potential is a complex task for decision-makers and urban developers. In theory, implementing data-based processes could take a vast number of concrete forms due to manifold kinds of data that could be collected and the kinds of relevant insights one might produce from them. This can make it difficult for decision-makers to navigate the new territory of data-based value creation. However, based on the literature on data-based business models in the private sector (Curry, 2016; Grover, Chiang, Liang & Zhang, 2018; Hartmann, Zakl, Feldmann & Neely, 2014; Mayer-Schoenberger & Ramge, 2019), one can distinguish several recurring models of creating value from data that can also be applied to public sector value creation. These models will be described and illustrated with examples from the smart city context in the following, with further examples listed in the overview in Table 1.

First, value can be created from data even without refining this data (e.g. through analysis). The data can simply be made available as open data, transferred to other actors or it can be sold, either in its raw form or after it has been pre-processed and prepared for further processing. The city of Hong Kong, for example, introduced the Octopus Card, which can be used to pay for services like transportation and parking and as a key for accessing buildings. Through this card, the city has collected personal information about users and their behaviors, information that have not only been used for managing city operations but have also been sold to third parties (Eckhoff & Wagner, 2018: 13–14).

Second, data can serve to optimize internal organization processes and the operations of administrative bodies in various ways. Through more fine-grained information about such processes, one might detect and remedy inefficiencies without substantially changing existing routines. Similarly, processes might be reorganized based on data that indicate how to better integrate different activities. The most far-reaching way of creating value by changing operative processes arguably lies in automating or at least partly automating processes. In the

Table 1
Data-based value offers applied to the smart city context.

Forms of value creation and value offers	Yeung, Howes, & PogrebnaExamples in the smart city context
(1) Data trading and publication	Selling data to third parties (private, public, civil society actors), publish open data
(2) Optimizing administrative processes and operations (including based on predictive analytics)	Process automation, enhanced traffic steering and coordination, emergency management, risk assessments and risk-based and resource allocation (e.g. in predictive policing), energy management, smart waste (e.g. optimized and dynamic routing), environmental monitoring (e.g. air quality)
(3) Data analytics insights for planning/managerial decisions	School zoning decisions, performance analytics and urban dashboards for city planning, forecasting and simulations (e.g. future health and elderly care needs)
(4) Refining data to develop new services/products for citizen use	Citizen recommender systems, citizen reporting apps
(5) Citizen relations	Targeted information offers, customer relationship software, chatbots

regulation of traffic flow, for instance, data may be processed to automatically change the way in which traffic is steered through a city in real-time (Coletta & Kitchin, 2017). This regulation by algorithms can also take advantage of an ability to register patterns in past traffic behavior to better predict and anticipate future traffic for an adaptive and (partly) automated steering by an algorithmic system.

Third, moving to the level of managerial and planning decisions, the production of actionable insights about city processes can inform high-level planning decisions, e.g. for city development. For example, a Berlin city district has drawn on a planning tool that provides information about how school catchment areas can be redrawn for optimal zoning decisions . This optimization is based on criteria such as school capacity, the distances from schools to pupils' homes, and even the overall socioeconomic heterogeneity of the student body. Another example in which data-based insights can inform planning decision would be the anticipation of care needs of the elderly by means of an algorithmic system as developed for use in Copenhagen.

Fourth, gaining more knowledge about city life and citizens' needs can also inform the development of new services and products, which could even themselves be the product of data. In that case, the uses of data would not merely help to improve other services but indeed be the foundation for a new kind of service. Such first-order value creation that uses the data to refine it into truly novel solutions to problems is still rare (Huberty, 2015: 44). It is nonetheless conceivable even in the smart city context as, for instance, the monitoring and analysis of energy use can serve to build models for dynamically optimizing building energy use in ways that have previously not been possible (Huberty, 2015: 44; Bourdeau, qiang Zhai, Nefzaoui, Guo, & Chatellier, 2019). In a similar vein, recommender systems can offer novel ways of managing the overwhelming amount of information about city life in various domains (Quijano-Sánchez, Cantador, Cortés-Cediel & Gil, 2020).

Fifth, large amounts of detailed data on consumers allows businesses to improve their marketing efforts and customer relations, e.g. through more personalized online advertisements. Although cities and public sector agencies do not similarly engage in marketing to foster their competitiveness in a market, they can use data to improve the way they connect with citizens. More than merely being a form of public relations, this can amount to more individualized citizen relations. This potential is exemplified in the project "Active Citizen", a platform developed by the Icelandic NGO Citizen Foundation which employs algorithms to connect citizens and to provide them with targeted notifications and information. The ability to better cater to people's information needs can be particularly helpful in tourism, an area in which city activities may come closer to conventional marketing efforts undertaken by businesses.

These various kinds of possible value offers all reflect ways in which a city can create value for citizens from data about city life. In view of these value offers based on data as the key raw material, the obvious starting point for decision-makers would be the data itself. They might want to determine which data is already collected and which could be collected in the city to ultimately derive value from it. However, while this may be a viable approach for value creation it is problematic for comprehensive and sustainable data governance, which instead requires taking into account the entire chain of value creation – from the raw material to the eventual uses of gained actionable insights and the realized purposes. As the following section shows, ethical and legitimacy challenges emerge at different points of this chain and depend on the concrete implemented processes or applications. Furthermore, the legitimacy challenges that can arise with data-based processes in the smart city concern the purposes and impacts of these processes and therefore lie in conflict with the pragmatic approach that takes data as the starting point.

3. Ethical and legitimacy problems along the data value chain

Translating data into actionable insights and using these insights can have ethically relevant consequences. These fall in realm the of data ethics as "the branch of ethics that studies and evaluates moral problems related to data (including generation, recording, curation, processing, dissemination, sharing and use) […] in order to formulate and support morally good solutions" (Floridi & Taddeo, 2016: 3). This notion of data ethics expressly comprises the processing of data by algorithmic systems, which can inform decision-making, as well as the practices of developing and operating such systems. Such a broad understanding of data ethics is important in the smart city context because data-based value creation potentially involves all those activities referred to above. It should be noted that rather than focusing on discrete moral problems related to data, one could also adopt a broader ethical perspective that is concerned with larger issues of justice and with addressing the systematic causes of injustice (D'Ignazio & Klein, 2020: 62). Also, there are different strands of ethics such as consequentialism or virtue ethics, and different theories of justice that could all inform what counts as the just society or city (Kitchin et al., 2019: 13). For the purpose of formulating a set of data governance measures, the discussion below will focus on the general ethical principles of privacy, justice, and autonomy that embody basic values of common morality and that have been highlighted as particularly relevant in data ethics (Mittelstadt & Floridi, 2016). While an ethical approach that adheres to such deontological principles does not amount to a coherent moral theory, it is based on very general moral action guides that are widely acceptable and defensible from various theoretical moral views. As such, they offer a suitable frame of reference for looking at how concrete data-related activities can become problematic for abstract ethical principles.

Evidently, adhering to data ethics in the smart city does not mean that ethics has to set new norms in this context – the potentially affected ethical values are all well-known. However, ethical questions arise in novel forms where data-based processes are involved. From this follows that adhering to abstract ethical principles and values alone does not suffice for proper data governance in the smart city. First, it is necessary to know where and how exactly ethical problems arise, and thus where decision-makers may have to intervene to prevent ethically problematic forms of data-based value creation. Relatedly, which ethical issues decision-makers need to be mindful of depends on the concrete implemented applications. Consequently, when it comes to regulating data-based processes in the smart city, one size does not fit all. Second, in the context of a smart city, data-based value creation does not merely have ethically relevant consequences for individuals. Rather, this value creation takes place in a public setting, involves question of democratic legitimacy, and therefore also takes on an eminently political dimension. How much this dimension comes to the fore, again, depends on the concrete implemented data-based processes.

These processes can be described in terms of the steps of an entire data value chain (Curry, 2016; European Commission, 2017; Löfgren, William, & Webster, 2020; Zech, 2016), an economic concept that can also be applied to the public sector where realizing value from data follows the same process. Based on this concept, it is possible to assess concrete applications regarding ethical and legitimacy challenges that can arise at three distinct stages of the value chain. *First*, data has to be collected and stored. *Second*, collected data – which may have been pre-processed – can be traded and transferred, or it may be subjected to data processing (e.g. data analysis) to produce insights, which can then, again, be passed on to others. *Third*, the transfer or processing of data for a certain purpose must be distinguished from the final usage of the obtained knowledge or insights and the consequences resulting from this usage. Having produced actionable insights does not by itself create value, they also must be brought to use. Data governance must therefore extend well beyond data extraction and privacy issues. The following discussion is structured along those three elements to highlight where ethical and legitimacy challenges arise along the data value chain in a smart city (for further illustration, see the list of examples in Annex A2).

3.1. Data collection

To the extent that data collection concerns the personal lives of individuals, this first step of the data value chain can create problems for people's information autonomy. As this risk is even exacerbated in the smart city context (Braun, Fung, Iqbal & Shah, 2018; Eckhoff & Wagner, 2018; Edwards, 2016) it will be a major task to safeguard individual control over personal data when establishing processes of data collection. The reason for this is that the very idea of collecting more data for an ever more detailed picture of city life runs against the principle of data minimization, a central maxim that is supposed to safeguard informational autonomy. As people increasingly come in contact with data-collecting entities – in part unobtrusively through sensors that gauge various aspects of city life, such as people's movements and noises – leaving the handling of one's personal data to the individual alone cannot guarantee informational autonomy. The notion of informed consent, it has been noted, basically becomes meaningless under these conditions (Kitchin, 2016b). It will therefore be crucial for smart city development to realize privacy-by-design solutions (Edwards, 2016), which allow for collecting data in a way that safeguards privacy without foregoing the value that can be gained from the data (Eckhoff & Wagner, 2018).

Taking the example of so-called smart meters that allow for obtaining very fine-grained data about energy consumption behavior, privacy by design can be realized without compromising the value that smart meters are mainly supposed to realize in terms of improving energy management. The registered energy patterns are potentially problematic with respect to privacy because smart metering amounts to an ongoing surveillance that produces detailed data from which inferences about people's personal life, habits, and lifestyle, even about the usage of individual household devices, can be made. It is, however, possible to build mechanisms into the very data collection such that data will only be gathered in an aggregated form that does not allow for making inferences about individual households. Some cities, such as Chicago with its Array of things and Amsterdam with tis "Tada" manifesto firmly commit to the use of technical solutions like data minimization to achieve for anonymity or privacy by design. In a similar vein, privacy can be achieved by design through separating data on households stored by the energy network operator und the energy supplier or by performing the data-processing locally, i.e. in the households themselves (Eckhoff & Wagner, 2018: 16–17).

In other cases, data may need to remain as personal data to realize the envisaged value from it and to provide services for citizens. For instance, to improve the public transportation offers and operations, personal or pseudonymized data can have a tremendous value that would be lost if it were aggregated, for instance: Only with detailed individual-level data, i.e. what transportation people use at which times and how they switch between them, is it possible to identify patterns of individual usage. In this way one can change, optimize, or extend existing offers to better accommodate people's needs and habits. However, since data about mobility patterns is sensitive as it allows for identifying people even when data has been anonymized (Gambs, Killijian & Cortez, 2014), the described example presents a major challenge for informational autonomy. In that case, the standards for dealing with people's data in the smart city need to be especially strong. Citizens would have to be guaranteed that only those data are collected that are essential for generating envisaged benefits which are of real value for citizens. And the more detailed the data collected about data subject and the greater the risk resulting for them the stricter the protections of their data would need to be.

All in all, data collection infrastructures in the smart city should be established only if a context-adequate protection of privacy is guaranteed. When dealing with ethical challenges at the stage of data collection, citizen-centered data governance in smart cities needs to be proactive in preventing a loss of individual control over the data collected about them. Data collection should only be as extensive and detailed as necessary. Only if citizens can trust that this is the case, can they be expected to willingly contribute to a common data pool from which they can benefit, without however unduly sacrificing their privacy and control over personal data (see also Braun et al., 2018).

3.2. Data preparation and processing

Even after the stage of data collection, people's informational autonomy is still at risk. First, activities of data preparation (such as preprocessing, aggregation etc.) and processing concern individuals' privacy because data collected anonymously can, as already hinted at above, be processed at a second stage in ways that allow for the reidentification of individuals. This possibility of reidentification through joining and processing data also presents a major obstacle for the goal of publishing open data from which to realize public value and effectively places severe limits on the kinds of data that can be published without privacy risks (Green, 2020: 93–95; Whittington et al., 2015: 1959–1960). Indeed, there are various reported instances in which municipalities have, by making data public, unintentionally revealed sensitive information about individuals (e.g. Green, 2020: 101). By formulating clear guidelines for identifying and dealing with sensitive information, as for the data repositories of Los Angeles and San Francisco, cities can avoid these problems.

The step of data preparation can however also impinge on citizens' informational autonomy to the extent that it serves the repurposing of the data. Specifically, data that has been collected for some purpose can be reshaped into a different form, e.g. by aggregating or anonymizing data that has originally been collected about individuals (Kitchin, 2016b). Once it has been, e.g., aggregated, the data can be used for different purposes than those initially intended. In a similar vein, a city can process and analyze data to generate knowledge from it. This knowledge, e.g. about relationships between personal characteristics and behaviors, forms a new kind of data that is not tied to any person and thus does not fall under personal data. However, such analytics insights, e.g., about relationships between individual characteristics and behaviors, can effectively be used to predict individual behavior. A city could thus sell those insights to third parties that could effectively use them for marketing or other purposes.

This has important implications in the smart city context. In many settings, it will not be possible to directly give away data collected about citizens using services of a smart city. However, after (pre-)processing data, it may well be possible that data is given to third parties that can use it without requiring the original data from which decision-relevant knowledge has been produced. This is not a remote scenario, one should not presume that barriers to passing on repurposed data generally exist. To take the example of Germany, which is known for comparatively strict privacy regulation, a recent assessment concludes that there are virtually no boundaries once data has been reshaped via pre-processing or processing steps (BBSR, 2019). In other words, municipalities are hardly constrained by existing regulation after having transformed the original data format.

This issue of repurposing through (pre-)processing concerns not only and not even primarily the aspect of informational autonomy of the individual. Rather, it also takes on a public dimension. While repurposing and, e.g., selling data may ultimately be of value to the citizens, including as users of services offered by third parties, it also means that data generated in a public context is used for non-public purposes. Extracting data about the inhabitants of the city, their behavioral traces, communication etc., is a form of resource extraction in a public context akin to raising taxes. And while the use of money or "treasure" is one resource for governing, the use of information power ("nodality") is another such resource that can be used for the ordering of social relations (Hood & Margetts, 2007). Importantly, extracting these resources in a public context and exerting public power directly concerns the requirement of democratic legitimacy and accountability. Regarding "treasure", this requirement is embodied in the phrase of "no taxation

without representation". This principle similarly applies to the collection of data about citizens based on democratic idea of "individuals' entitlement to proportional influence over collective decisions that affect them—a norm often called the "all affected (or all affected interests) principle" (Warren, 2014: 40). From this also follows that if a resource is extracted from citizens, they must have a say in how it is used.

In short, any repurposing of data in the smart city context concerns not just individual informational autonomy but also that of *collective autonomy*. As data is extracted from citizens as the members of a community (a city or municipality), they have a legitimate interest that the purpose of data collection will serve the public interest and be of adequate benefit to them. Following Warren (2014: 40–41), democratic accountability realizes the entitlement of citizen influence through mechanisms that enforce answerability and make it possible to sanction those in power by virtue of the fact that citizens are affected by and vulnerable to the exercise of power.

This notion of accountability tied to the all affected principle has important consequences for the idea of data ownership in smart city data governance. The question who owns the data has been underscored as a central issue in smart cities (Desouza & Jacob, 2017: 17; Meijer, 2018: 204), and some conceptions of smart city development strongly promote citizens' ownership of data in terms of being able to access various collected data or at least their own data (Calzada, 2018: 6, 9). However, based on the concept of democratic accountability, ownership would not necessarily mean that citizens actually possess or have direct access to the data. As with taxation, where citizens too are not the ones handling the collected funds, the key question is whether the ends to which they are put by the government are legitimate and serve a public interest. Hence, ownership understood as citizens being in possession of the data collected does not capture what is essential for citizen-centric data governance in the smart city. Rather than the question who has the data, the main issue is that mechanisms for realizing democratic accountability exist. If this is the case, citizens or even the city do not have to possess data in order for public value to be generated from it.

Consequently, to establish rules that direct the handling of data toward the public interest, a smart city must rely on concluding adequate contracts, i.e. binding agreements with other parties that regulate data collection and processing as well as access and transfer, including the possibilities of exerting control and achieving transparency of the practices involved. These requirements do not per se preclude selling data generated in a public context to third parties, but this needs to be legitimized in ways that satisfy democratic accountability.

3.3. The usage of data-generated knowledge and its consequences

After data has been processed to obtain insights from it, the question is still how this knowledge is used and what consequences result from this usage. Even when the collection of data respects citizens' informational autonomy and the processing is oriented towards realizing public value, the eventual use of data-based knowledge may still have unacceptable consequences. These consequences mainly concern the ethical values of decisional autonomy and of justice.

The use of data may ultimately be harmful to justice if, for instance, data about city life offers a distorted image which systematically favors certain perspectives and interests. As Meijer (2018: 199) emphasizes, a major "issue for the governance of smart cities is the governance of urban perception". Perceiving city life through data can already be distorted due to issues located at the level of the data itself. The quality (e.g. regarding the reliability of included measures) and the composition of the data can yield a skewed picture and basis for city management. Individual differences in the use of a citizen relations management app for sending complaints or suggestions, for instance, can lead to a systematically skewed representation of the city and citizens' interests (Green, 2020; Wu, 2020). Even if such biases were absent, decision-makers might still try to leverage the data and knowledge created from it for their own purposes and in line with their views (van der Voort et al., 2019). Importantly, no data and no result of data analysis by itself provides the one correct perception of urban life, they still have to be interpreted and given meaning. This discretion is already present where, e.g., a threshold value has to be chosen, i.e. when deciding what counts as high vs. low score obtained with data analysis or predictions. Neither raw nor processed data can speak for itself, and while this may seem like a minor issue it has an important ethical dimension, as it concerns the creation of knowledge about a shared social space that shapes how people relate to this space and their fellow citizens (D'Ignazio & Klein, 2020: 160–172).

Similar issues arise if data processing occurs through algorithmic systems that are designed to learn decision rules from data to optimize predefined objectives and to deliver decision recommendations or enact decisions themselves. These systems are at work, for instance, where they predict the occurrence of burglaries to coordinate policing activities; where they guide logistics in city waste management based on continuously updated information about container filling levels; or where they are used to optimize bus routes or schooling districts.

While algorithmic systems are likely to play an important role in the processes of creating value from data in a smart city context, they can produce decision outcomes that show an undesirable bias. Forms of algorithmic or algorithm-supported decision-making are never neutral, but incorporate certain assumptions and values regarding what optimization means exactly (Mittelstadt et al., 2016; Yeung, 2017). While optimizing certain objectives, it can remain hidden that algorithmic systems are biased in the sense that they realize goals and values which are not in the interest of those whom they are supposed to serve (Pasquale, 2015). Such a bias can be the result of intentions, carelessness or it can even occur as an unintended result with a carefully designed algorithmic system (Krafft, Zweig, & König, 2020).

This issue of bias concerns, first, the ethical value of *justice* because the outputs of an algorithmic system may lead to a decision-making that is deemed unfair (Lepri, Oliver, Letouzé, Pentland & Vinck, 2018). If, for instance, the data processed by an algorithmic system already contains patterns of unfair discrimination, the system will likely reproduce it when learning a decision model from the data (Barocas & Selbst, 2016). This becomes a sensitive issue where such systems guide the decision-making of municipal agencies or directly give decision recommendations to citizens. Possible undesirable biases in algorithmic decision models also, second, concern the dimension of *collective autonomy* because an algorithmic system may realize objectives and trade one objective against another in ways that are not tied back to citizens' values and preferences. Even seemingly technical tasks such as algorithmic traffic optimization involve value trade-offs that are ultimately of a political sort (Green, 2020: 15–18). Optimizing traffic with regard to certain predefined parameters (e.g. traffic time or CO2 emissions) can easily hide that this may favor car traffic while increasing waiting times for pedestrians and cyclists.

Finally, algorithmic systems may also harm individuals' *personal autonomy*. To the extent that algorithmic systems in the smart city context are employed to shape individuals' information environments and to interfere in their decision situations, their operations can amount to an unsolicited and unethical form of interference with people's choices (Lanzing, 2018; Yeung, 2017). Such a "hypernudging" by means of personalized information offers and recommendations (Yeung, 2017) can steer people in a certain direction in line with the predefined goals of others. While this form of influence is mainly known from commercial applications, such as in online platforms, Ranchordás (2020: 11–12) does note that some cities have made steps in this direction and used apps or personalized emails to steer people's behaviors. It remains to be seen how cities will deal with these challenges. The most far-reaching attempt to establish control over algorithms in a city to date can be seen in a New York City task force established for this purpose. However, due to limited access and powers of this task force, it has hardly been in a position to effectively safeguard accountability.

4. Accountability mechanisms in smart city data governance

Clearly, not all implemented data-based processes in the smart city will entail all the problems described above. Many uses of data will be entirely unproblematic and it will depend on the concrete application and sector, e.g. transportation, waste or health care, which data governance issues arise (see also Annex A2). In any case, however, a given form of data-based value creation can have consequences for one or more of the ethical and legitimacy principles along the data value chain as shown in Fig. 1. The figure provides a comprehensive view on possible issues that need to be addressed for an overall citizen-centric data governance in the smart city.

First, *informational autonomy* is most clearly affected at the first stage, as the mere collection of data can already entail a harm to people's privacy. Their informational autonomy can, however, also be harmed on the second level due to processes that lead to reidentification of individuals. Second, individuals may experience harms not only to their informational autonomy, but also their *decision autonomy* and to *justice*. These risks can be linked to the third stage in Fig. 1¸ i.e. once the knowledge that has been generated from data and is used. This knowledge can, e.g., inform decision-making or serve to structure people's informational and decision environments and thereby to steer them toward certain behaviors. Finally, there is an acute risk of a loss of control over what happens with collected data that concerns not only individual informational autonomy, but also *collective autonomy*. This dimension is affected by activities occurring both at the second and the third stage of Fig. 1: After data has been reshaped at the second stage, this data could be given away and be processed for purposes that were not previously considered. Also, certain goals and values, including specific standards of fairness, can be embodied in the processing of the data with the result of possibly undesirable biases in the resulting outputs. These outputs ultimately inform and guide decision-making and thus lead to an ordering of social relations according to certain predefined objectives. As these issues concern the extraction of a resource in a public context and the exercise of public power, they call for governance mechanisms that establish democratic legitimacy.

The preceding considerations have direct implications for the shape of citizen-centric data governance in the smart city. To conform to democratic accountability, the starting point of this governance must not be the data – the first element in the data value chain – but instead the purposes and impacts of the data use. The *primacy of purposes* forms the center-piece of citizen-centric data governance. Hence, rather than starting from data and exploring what might be done with it, smart city data governance needs to start from the ends and coherently orient data-based processes toward them. Only this approach prevents an unduly extensive collection of data and transparently ties all data-based processes in the smart city to specific goals.

The justifiability of these goals can be ensured through mechanisms designed to establish democratic accountability. Democratic accountability as described above is of central value for fleshing out the idea of citizen-centric data governance. The idea to "place […] policy goals at the forefront" and to focus on people over technology (Green, 2020: 10, 34) directly flows from the principle of democratic accountability. It therefore also safeguards what Kitchin et al. (2019): 15–16) describe as "the right to the smart city" as a collective social space that is shaped according to citizens' needs and demands. At the same time, the concept of democratic accountability avoids overemphasizing the role of direct citizen participation in smart city data governance.

Democratic accountability can realize citizen-centric governance without having to be based on particularly strong direct citizen influence. Recent contributions have pleaded for such direct influence in the form of participatory processes (Cardullo & Kitchin, 2019; Mann et al., 2020; Shelton & Lodato, 2019) or citizen deliberation along the lines of discursive ethics (Calvo, 2020). These are generally desirable ideals of realizing citizen autonomy that provide an important normative point of reference. Yet there is also a risk that with a strong emphasis on citizen participation and deliberation in a smart city, the pendulum might swing too far from the rightly criticized technocratic vision of a smart city. Extensive citizen participation is neither realistic nor is it necessary to realize democratic accountability in a smart city. It is not realistic because citizens tend to shy away from greater participation in political affairs and direct citizen involvement introduces well-known problems of unequal participation and influence (Carpini, Cook & Jacobs, 2004). These issues can be expected to similarly affect citizen participation in data governance and manifest in the overrepresentation of more engaged and data literate citizens (Desouza & Jacob, 2017) – a problem extending even to algorithm design (Robertson & Salehi, 2020). Examples of participatory data governance, such as in Barcelona, may thus serve as ambitious models but are arguably not a blueprint that is suitable for widespread imitation.

This does not constitute a serious problem, however, as strong citizen involvement is not necessary to realize democratic accountability and to align decision-making with the values and views of those affected. This idea is also encapsulated in the governance model of data trusts, intermediary organizations which, if designed accordingly, can act as trustees of the citizens and protect the public interest in the collection

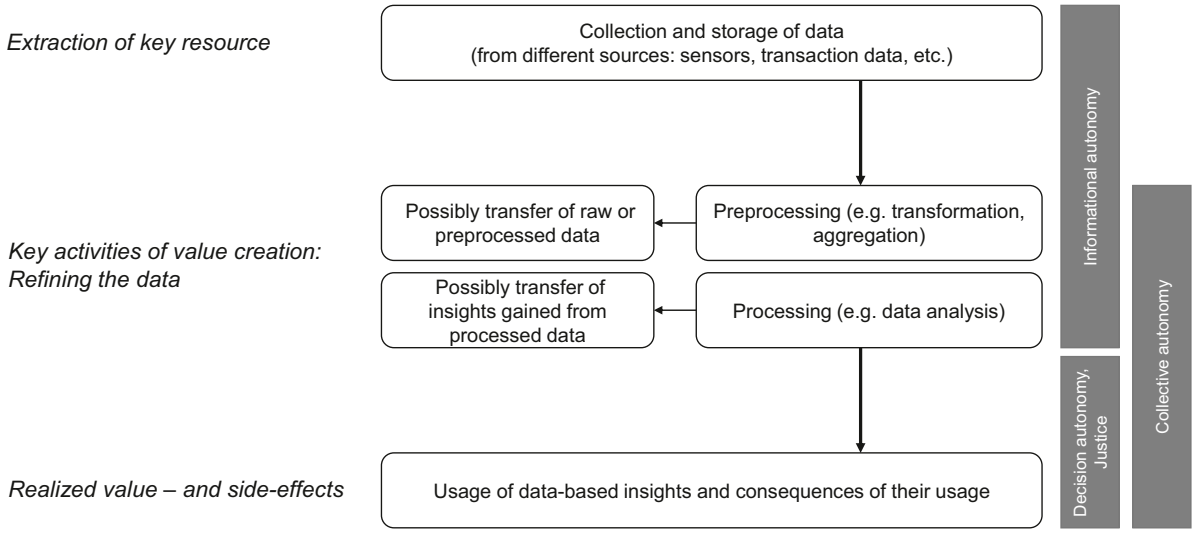

Fig. 1. Ethical and legitimacy problems along the smart city data value chain
Notes: The gray boxes indicate which ethical and legitimacy challenges arise at which stages.

and processing of their data – which may entail auditing by independent experts and citizen consultation to ensure accountability and trustworthiness (Micheli, Ponti, Craglia, & Suman, 2020; Mulgan & Straub, 2019). Hence, direct citizen involvement and decision-making is only one instrument for achieving democratic responsiveness and accountability besides others. Other accountability mechanisms can ensure that data-based processes implemented in the smart city are oriented towards working in the public interest. When anchored in a democratic accountability perspective that places the purposes of data uses first, there is a clear functional and temporal hierarchy in accountability provisions designed so safeguard citizen-centric data governance. These are illustrated in Fig. 2 and will be described in the following.

Ex-ante testing. The most basic element of such data governance consists in orienting processes of data-based value creation toward acceptable goals. In other words, the guiding goals need to be authorized and therefore defensible and justifiable as being in the public interest. To this end, it is important to go beyond merely making transparent these goals data-based processes from the start. It may also be necessary to specify how exactly abstract goals and objectives are incorporated into these processes, including in algorithmic systems. There is no single correct way of performing data processing and using the resulting outputs to deal with a given task, and different ways of, e.g., training an algorithmic decision model from data will be more in line with certain goals and values than others. Consequently, there is considerable discretion in translating general policy goals into the concrete design of data-based processes, which makes technical design aspects a potentially political and value-laden issue (Veale & Brass, 2019). It must therefore be possible to scrutinize this aspect of data-based value creation.

It is at this stage where stakeholders may have to be involved to ensure the acceptability of forms of data processing (Yeung, Howes & Pogrebna, 2019; Veale & Brass, 2019; Lepri et al., 2018; Felzmann, Fosch-Villaronga, Lutz & Tamò-Larrieux, 2020). In this way the objectives that are built into data-based processes can be authorized and validated as being in the interest of those they are supposed to serve. This may entail involving citizens in shaping the forms of data-based value creation, including the design of algorithmic systems (see e.g. Lee et al., 2019). It may, however, already suffice instead to clearly communicate how the development of data-based applications in the smart city has been done and how different values and stakeholder interests have been taken into consideration. The example of an algorithmic system developed to optimize the bus and schooling schedules in Boston shows that even an application that has been carefully developed, tested with stakeholders, and led to improvements over the status quo both in terms of efficiency and fairness, can still face public resistance (Ito, 2018). Clearly communicating the guiding considerations, the value and the purported improvements realized by the system to stakeholders and the public, could make a difference in this regard.

Second, ex-ante testing and auditing of data-based processes is needed to make sure that data-based processes in the smart city indeed serve a specific purpose and do not produce unintended side-effects specifically with regard to informational and decisional autonomy. This requirement is especially important with algorithmic systems that assist or replace decision-making. To avoid undesirable impacts, testing at this first stage can take the form, e.g., of privacy impact assessments (Oetzel & Spiekermann, 2014) and algorithm impact assessments (Kaminski & Malgieri, 2020) that test for biases and possible unfair discrimination. Thoroughly assessing forms of data processing and data use at an early stage may have to involve – depending on the involved risks – a detailed auditing down to the level of inspecting the data, data processing methods and technical quality and fairness measures used (Krafft, Zweig, & König, 2020). Importantly, as the actual impacts and potentially unwanted side-effects only show once data-processing occurs in the real world (Veale & Brass, 2019), properly assessing these processes cannot be done without first establishing them in a given setting. This also makes an experimental phase in which data-based processes are trialed vitally important (Oswald, Grace, Urwin & Barnes, 2018).

Operative transparency. After the implementation of data-based processes, mechanisms and institutions need to be put into place that allow for adequate ongoing transparency of these processes. Such operative transparency involves a general ability for citizens, civil society and other stakeholders to gain a basic understanding of relevant aspects regarding how data are collected, processed and ultimately used in the smart city. This kind of transparency demands that citizens are informed about which processes along the data value chain take place. Any relevant information about the data collection process, the kind of data, the duration of storage, who has access to the data etc. need to be made transparent to the data subjects in plain language understandable to everyone (for an example, see Kitchin, 2016a: 56–57). More detailed information could additionally be prepared for other audiences with expert knowledge required to comprehend technical details of data processing (Cowls, King, Taddeo & Floridi, 2019). Only if there is publicly available information about what data is collected, how it is processed, used and for what purposes this occurs, is it possible to contest existing practices and hold decision-makers to account.

A technical solution for increasing transparency about data-based processes in this context consists in dashboards, i.e. online platforms and interfaces that allow for interactively arranging and monitoring relevant information (Matheus, Janssen & Maheshwari, 2020; see also van Drunen, Helberger & Bastian, 2019). While such dashboards can serve as information sources both on the sides of policy makers and citizens, they also involve forms of preparing and processing data, which require organizational changes to make them work effectively (Matheus et al., 2020: 8). Furthermore, it is important to note that transparency of data-based processes in the smart city is generally desirable, but this does not mean that the responsibility for making use of this transparency lies with citizens alone. Already in the private realm, individuals are incapable of consuming all the information regarding the conditions of data-based services they use. Transparency in itself is therefore insufficient if it means burdening the individual with making use of it (van

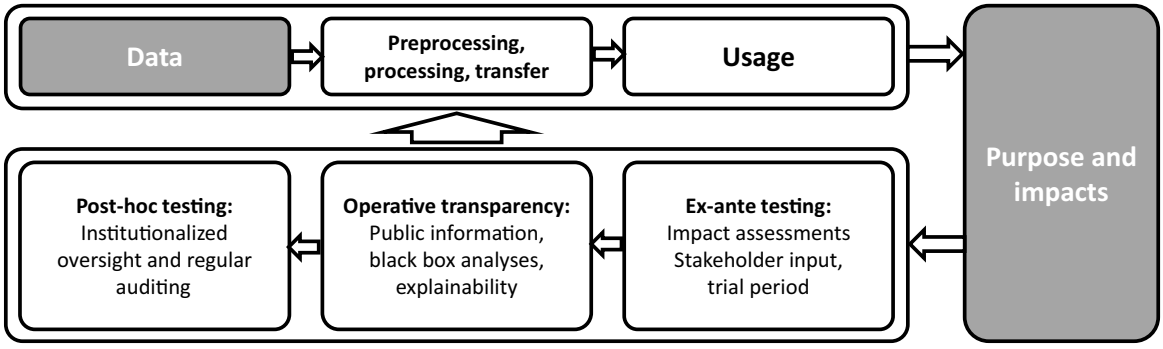

Fig. 2. Accountability for Citizen-Centered Data Governance.

Ooijen & Vrabec, 2019). Nonetheless, transparency is needed so that citizens but also stakeholder organizations and the media (Saurwein, Just & Latzer, 2015) *can* gain information and monitor data-based processes.

Second, operative transparency specifically with regard to algorithmic systems can be achieved via black box analyses (Diakopoulos, 2014). This instrument for achieving some transparency of those systems entails testing which inputs fed into an algorithmic system leads to which outputs. Based on a large number of such observations, it is possible to diagnose undesirable tendencies in the operations of systems. Continuous transparency of data-based processes occurring in the smart city can also be achieved going beyond merely black box analyses through establishing explainability of decision-making as a design feature of algorithmic systems (Holzinger, Kieseberg, Weippl & Min Tjoa, 2018; Samek & Müller, 2019). This feature allows individuals to obtain information about how a concrete decision output has come about. A need for such measures in the smart city may arise with increasing use of learning systems such as chatbots and recommender systems.

Ex-post scrutiny and inspection. The impacts, particularly side-effects, of data-based processes may change or even only manifest over time. It is therefore necessary to establish mechanisms for scrutiny and inspection that are more focused and in-depth but occur selectively and retroactively. With more complex data-based processes and especially with learning algorithmic systems that exhibit a certain degree of autonomy, it can be necessary to regularly check whether they are still performing as desired. Accountability in this regard can be achieved by institutionalizing forms of oversight through regular testing and review (Yeung et al., 2019; Krafft, Zweig, & König, 2020; Felzmann et al., 2020). This also means that competent bodies must be assigned to this task.

Conclusion

Many of the promises tied to the smart city depend on activities which harness data as a key resource to create value for the city and its inhabitants. The new kinds of value offers and the processes that they entail are largely unfamiliar territory for decision-makers and urban developers. A clear understanding of those processes is crucial not only to devise and develop novel solutions that create value for the citizenry, but also to grasp how ethical and legitimacy challenges arise at certain points of an entire data value chain.

Informational autonomy, decisional autonomy, justice, and collective autonomy are impacted at different stages of this chain. Whether and to what degree these issues arise depends on the concrete data-based processes that are implemented in a smart city. Comprehensive data governance in the smart city therefore needs to cover a range of activities involved in value creation and be able to deal with many different possible concrete applications and realized value offers – from improving internal administrative processes, over a better steering of city processes to improved decision-making at the high level of city government and management. Decision-makers in the smart city will need a keen awareness and understanding of these processes to translate abstract ethical principles into data governance practices which are both comprehensive and differentiated enough to accommodate concrete applications. Importantly, data-based value creation in the smart city not only has ethically relevant consequences for affected individuals, but also involves the extraction of a resource in a public setting and exerting public power based on information. This value creation therefore also directly creates challenges for democratic legitimacy and accountability. Yet this does not mean, as has been argued above, that citizen-centric data governance demands strong citizen involvement. They do not need to be the owners of data in the emphatic sense of actually possessing and accessing this data nor do they have to actively participate in data governance to safeguard democratic accountability – an ideal that is hardly realistic and creates other serious problems.

The account developed above instead stresses the importance of a robust suite of accountability measures which can address the ethical and legitimacy challenges arising from data-based value creation and align its implementation with the public interest. To this end, these accountability mechanisms for realizing citizen-centric data governance in the smart city must start from the goals and purposes of data-based value creation. This is important because it runs against a plausible pragmatic perspective that takes data as the starting point – a mentality that promotes amassing data and exploring what can be done with it. Putting purposes first instead naturally follows from anchoring data governance in democratic accountability. This principle is key to sustainable data-based processes as it ensures the continued possibility of learning, contesting, and revising while developing a technological infrastructure that is designed to realize public value from data.

The first building block of citizen-centric data governance rooted in that perspective is (a) a set of measures of *ex-ante testing* that guarantees the acceptability of objectives and the way in which they are built into data-based processes before their implementation. Second, accountability furthermore demands (b) *operative transparency* as the continuing ability to gain information about how data are collected and used after implementation, including possibly the monitoring of algorithmic systems and explainability as a design feature. Third, (c) *ex-post oversight* through regular selective and in-depth scrutiny is particularly important with more complex forms of data processing, such as with implemented algorithmic systems, where long-term effects may change or only show over time. The degree to which such mechanisms are set in place will decide on which path the development a smart city is set.

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Supplementary materials

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