Beyond Technology in Smart Cities: A Multivocal Literature Review on Data Governance

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Abstract

Purpose: Smart cities require data governance to articulate data sharing and use among relevant stakeholders. Given the lack of a comprehensive examination of this research topic, this study is aimed at reviewing data governance publications to detect and categorize endeavors backing up data sharing in smart cities.

Design/methodology/approach: A systematic literature review was conducted, and 568 academic and professional sources were identified, but finally, only ten relevant papers were selected.

Findings: Results reveal that data governance must be based on complex mechanisms built upon a multi-actor milieu. Moreover, data governance should be adapted to address power imbalances among all interested parties.

Research limitations/implications: The main limitation is the list of sources considered for the literature review. However, this study provides a holistic overview for researchers and professionals willing to know more about smart city data sharing.

Originality: This review identifies the data governance approaches supporting data sharing in smart cities, analyzes their data dimension, enhances the state-of-the-art literature on this topic, and suggests possible areas for future research.

Keywords: Smart City, Smart society, Data Sharing, Data Governance, Data quality, Literature review

1 Introduction

As part of a vision for a digital society, a city should provide improved and more interactive and responsive public services able to meet the needs of individuals who reside, work or travel in the city

(European Commission, n.d.). The digital transformation of cities to smart cities worldwide is gaining attention because and according to (United Nations, n.d.), around a third of the projected world population will reside in cities by 2050. Moreover, the drivers for technological advancements are ubiquitous: Internet-of-Things, high speed and capacity communications, analytics of big amounts of data, and the application of machine learning and artificial intelligence (Maheswaran and Badidi, 2018).

Information and communication technologies (ICT) are not the only aspects for smart cities, since technology is a necessary but not sufficient component for smart cities (Augusto, 2020; Granath *et al.*, 2021). Various data sources throughout the cities produce data at an increasing scale (Lämmel *et al.*, 2020). For instance, data sources are personal devices (smartphones, wearables, laptops), smart home devices (lighting, security, heating), public services (health, administration, waste management, water supply management, emergency preparedness), and smart grid (smart neighborhood, smart charging). Therefore, the amount of data generated by individuals and private and public organizations is constantly growing (European Commission, 2020). Data has become an essential asset for, among others, the public sector, citizens, businesses, and various interest groups, and provides insights and drives not only the innovation of public services but also new products, digital infrastructures, and ecosystems (Maheswaran and Badidi, 2018). It means that data is at the center of any smart city, given that data availability is dependent on the commands of different stakeholders (Paskaleva *et al.*, 2017). In the European Union (EU), data is envisioned to act as the cornerstone for the new economy going beyond financial and human resources (European Union, 2020). The European strategy for data (European Commission, 2020) has launched an initiative to create a single data market that is open to data from all over the world. However, data control, its management, and availability are aspects to explore in smart city research and practice (Granath *et al.*, 2021).

Over the past decade, multiple usages of data have revealed how data can contribute to smart city digital transformation in large and small municipalities alike (Velsberg *et al.*, 2021) and, more broadly, to societal transformations. In this context, data governance, particularly data sharing, plays a key role in smart cities (Hayes *et al.*, 2020). The future of smart cities lies in the availability of data able to support decision-making but also in the relationships among data sharing stakeholders (Paskaleva *et al.*, 2017). Thus, the focus on data governance is particularly important as its implementation and adoption impact the design and development of smart cities. However, data governance in the scope of smart cities is seen as an emergent research area, and its definition and concepts are continuously expanding. Moreover, there is no comprehensive view of the data governance approaches reported in the literature to the best of our

knowledge (see section 2.3 related works). This paper aims to provide an overview of data governance approaches supporting data sharing in smart cities by conducting a literature review that follows a systematic method called multivocal literature review.

2 Background

2.1 Smart cities

Although cities have been using technology to support their operations for decades, 'smart city' as a term was introduced in the 90s and since then, literature reported a panoply of definitions for the concept (Ismagilova *et al.*, 2019; Koca *et al.*, 2021; Lim *et al.*, 2019; Rodríguez Bolívar and Meijer, 2016). By reviewing 55 selected papers, a recent SLR (Lim *et al.*, 2019) found 38 clear and explicit definitions. Authors stated that smart cities, by means of the use and orchestration of ICT infrastructure as well as institutional, social and human capital could boost citizen participation and democratic governance, but also increase effectiveness and innovation. Moreover, 13 of these identified definitions underlined that smart cities are a way towards sustainable development.

There are also various facets of smart cities. According to another recent SLR on smart cities (Ismagilova *et al.*, 2019), several studies have focused on smart living, governance, economy, environment, or people. Additional works are focused on mobility and transport, security and safety, smart grid, tourism, smart health, or government. From another point of view, the basics and the holistic dimensions are institutions, data, technical infrastructure, energy, and people (Augusto, 2020). However, according to this author, more dimensions can be considered and broken down into subcategories. In this review, authors concentrate on data governance models supporting data sharing in smart cities.

2.2 Data governance

Over the last decade, companies have become aware of data as digital assets in their businesses (Abraham *et al.*, 2019; Garifova, 2015). Thus, the need for data governance models emerged in response to managing data as a strategic resource and ensuring that data has the expected quality (Garifova, 2015). It is also well-known that the value of data held by individuals and organizations can increase exponentially if it is shared and combined with other data sources (Smart Dubai and Nesta, 2020). There is extensive literature on data governance (Abraham *et al.*, 2019; Micheli *et al.*, 2020), but there is a lack of focus on smart cities.

In smart cities, the challenge with using data governance approaches adapted to businesses and organizations is the applicability to an ecosystem with many different actors. The legislative and regulatory

context is vital in establishing the enabling circumstances for diverse data governance methods (Abraham *et al.*, 2019). Such an approach also needs to foster data sharing to drive a smart city's social innovation in this multi-actor environment (Calzada, 2020). The European General Data Protection Regulation (GDPR) is extensively accepted as a de facto standard for smart cities regulation, given the lack of specific data regulation for data protection in most countries (Guha *et al.*, 2020; PricewaterhouseCoopers, 2019). Similar legislations have been introduced from Chile to Japan, from Brazil to South Korea, from Argentina to Kenya (European Commission, 2019). Given the lack of federal data privacy legislation in the USA, numerous states issued their own laws (Guha *et al.*, 2020). However, published data should conform to appropriate open standards (GovEx, 2018).

Another important aspect is that a data governance approach must accommodate increased democratization and transparency throughout processes that involve formulating policies regarding, e.g., urban development, municipal services, and politics. Moreover, the role of the citizen must be protected so that the digital transformation of the city does not become an exercise in the use of state-of-the-art technology without consent, trust, involvement, and co-creation (Artyushina, 2020). Therefore, the citizen perspective must be an integral part of any data governance approach. Citizen participation in the creation of smarter public services is identified as a democratic right according to some previous studies, e.g. (Granath *et al.*, 2021).

2.3 Related work

The first step was identifying and reviewing other existing reviews on this topic. By reviewing the search results from Google Scholar, authors identified several secondary studies, in particular SLRs, but their main focus is not on data governance, e.g., smart city development results (Lim *et al.*, 2019), an information systems perspective (Ismagilova *et al.*, 2019), the application of decision-making methods (Tran Thi Hoang *et al.*, 2019), and big data challenges (Chauhan *et al.*, 2016). There are also two SLRs on smart governance (Rodríguez Bolívar and Meijer, 2016) that aim to define elements, aspired outcomes, and implementation strategies but it was published in 2016 and the keywords were "smart city" and "smart governance". While, (Tan and Taeihagh, 2020) aim to understand, in the context of developing countries, the conceptualizations, motivations, as well as the drivers and barriers to smart city development. Therefore, its main focus is not on data governance.

There are also two closest studies to our multivocal literature review (MLR). (Paskaleva *et al.*, 2017) examines how data governance is enclosed in the sustainable smart city context along with its challenges

and opportunities. This study was published in 2017 and conducted a literature review and a study of practitioners in Norway, the UK, and the Netherlands. The authors proposed a theoretical approach on smart city data governance from the lens of sustainability based on six pillars: 1) Data identification, 2) Data collection, 3) Data generation, 4) Data management and sharing, 4) Data use and legacy, and 5) Project context. (Bozkurt *et al.*, 2022) conducted a text-mining-supported systematic literature review of data governance and its applicability to smart cities. They identified eight urban data governance dimensions 1) stakeholder, 2) organization, 3) data classification, 4) data quality, 5) data access, 6) data management, 7) principles and 8) policy, compliance and legal. In contrast, our MLR differs from previous other previous ones in the methodology used, the number of papers analyzed and the combined analysis of data governance in smart cities that provides a holistic overview of the data governance approaches. Therefore, no other secondary study with the same objectives proposed in our MLR exists in the published literature on this field.

2.4 Research approach

This study used a MLR that is a systematic and structured literature review to describe the state of the art of smart cities data governance but also to synthesize the appropriate previous studies present in the research literature and selected professional publications (grey literature). Grey literature was included because of the large industrial interest in smart cities and to fill the possible gap between industrial and academic publications. Figure 1 depicts an outline of the process that follows the guidelines proposed by (Garousi *et al.*, 2018).

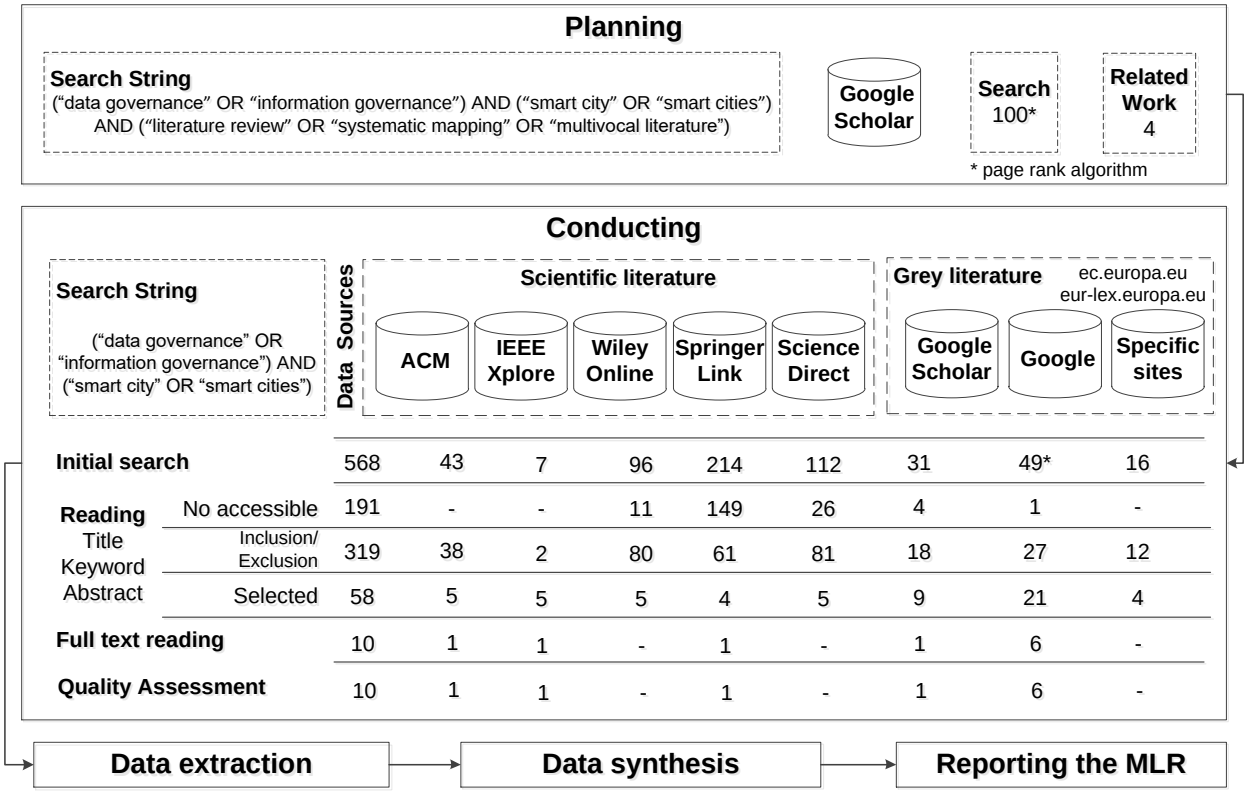

Figure 1. Overview of the multi-stage process

Firstly, authors identify the keywords for the search strings. The initial search terms were "data governance" and "smart city." After conducting a set of preliminary searches to examine and tune the search string, alternative spellings and synonyms were identified. In this case, information governance and data governance are frequently interchangeably used in the literature, although some scholars stress fundamental differences between the two (Eke and Ebohon, 2020). Therefore, the "information governance" was included as part of the search string. Finally, the following boolean expression was formulated ("information governance" OR "data governance") AND ("smart city" OR "smart cities").

The scientific literature was searched in five major scientific databases: ACM Digital Library, IEEE Explorer, Wiley Online, SpringerLink, and ScienceDirect. Alternatively, Google Scholar and Google Search included grey literature on best practices, laws, and regulations, and practical use-cases of data governance in smart cities. However, a stopping condition for grey literature searches was needed due to the large hits in Google Scholar (2530) and the general Google search (43300). The authors applied the search engine rank algorithm (Garousi *et al.*, 2018) to identify only a suitable number of hits. It was found that only the first few pages were relevant for our review. Moreover, given that the EU commission has a strategic focus on data as an asset and the official EU websites provide access to the information published by all EU institutions, agencies, and bodies, a complimentary search was also conducted in two official websites of the EU (ec.europa.eu and eur-lex.europa.eu).

In the initial search, the proportion of literature retrieved seems to get a specific volume in 2016 and then increase year by year with a significant rise in 2020 (see Figure 2a). Given that this MLR was conducted in early 2021, the number of sources is less than the previous year. Out of the retrieved 568 sources, about 191 were unavailable online, while 319 were classified as not relevant, and 58 were found relevant for this review. After the initial screening, 58 sources were selected, and 34 out of them were identified as scientific literature, while the remaining 24 were grey literature (see Figure 2b). We finally got access to the full text of 7 of the 14 papers that were identified as relevant by reading the title, keywords and abstract of those 191. However, they also were excluded after full-text reading. The details are openly available at (Kvalvik *et al.*, 2021).

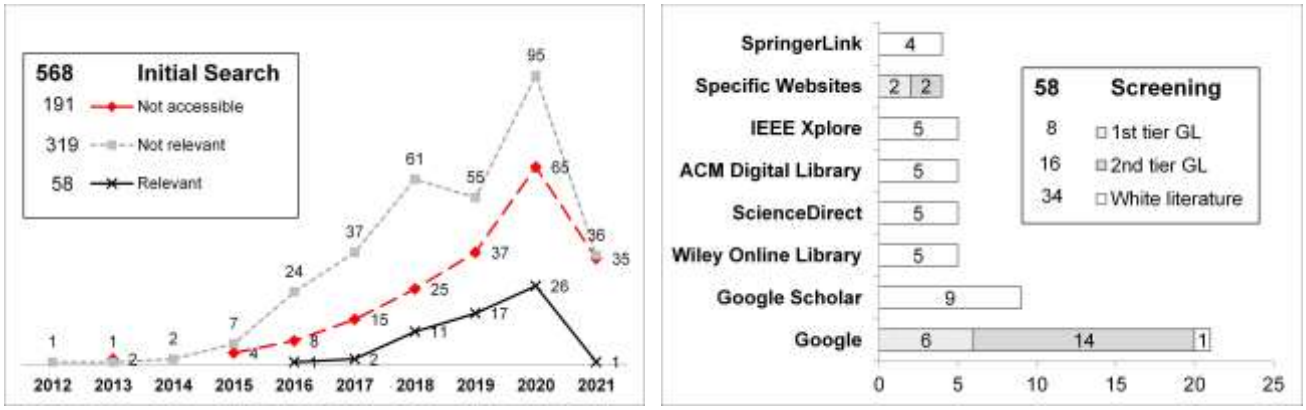

Figure 2. Overview of all search results by year (a) and the selected sources by online data engine (b)

After reviewing the selected sources, only ten sources remained, as shown in Table I. Regarding the years of publication, the authors found no significant studies related to the research topic before 2018. The selected sources were published in 2018, 2019, and 2020 equally distributed between scientific and grey literature. As expected, the recent literature has no citations except by two papers (Beckwith *et al.*, 2019; Koskinen *et al.*, 2019) published in 2019 with 7 and 6 citations, respectively. In grey literature, four selected sources were identified.

Table I. Selected sources by year after full-text reading

Ref.	Year	Database	Citations*
(GovEx, 2018)	2018	Google	N/A
(Lupi, 2019)	2019	Google Scholar	0
(Koskinen *et al.*, 2019)	2019	IEEE Xplore	6
(Beckwith *et al.*, 2019)	2019	Springer Link	7
(PricewaterhouseCoopers, 2019)	2019	Google	N/A
(Guha *et al.*, 2020)	2020	Google	N/A
(Bass and Old, 2020)	2020	Google	N/A
(The Digital Trade & Data Governance Hub, 2020)	2020	Google	N/A
(Draheim, 2020)	2020	ACM Digital Library	0
(Eke and Ebohon, 2020)	2020	Google	0

* Google scholar

3 Smart city data governance components

Smart city data governance involves technology, people, process, and data. Therefore, the findings of this review are presented using these categories.

Technology. AI and Big Data are explicitly mentioned in most selected sources, followed by Machine Learning, Data Science, Cloud computing, and Blockchain. Moreover, data come from several sources in a smart city initiative. For example, social media, open data, internet of things (IoT) (e.g., traffic, weather, noise, and portable devices), non-IoT data sources (e.g., legacy systems, mobile applications, web applications), and other third parties sources. The digital infrastructure has been envisioned as a type of infrastructure and hence a public good as roads, e.g. the platform component of India's DataSmart Cities Strategy (DCS) (Guha *et al.*, 2020). Moreover, a set of data exchange platforms (X-Road, Cybernetica UXP, NLX, and GAIA-X) is described (Draheim, 2020).

People. A smart city initiative also needs to use representative stakeholder data to understand better the people and their needs (Eke and Ebohon, 2020). Thus, establishing a governance body comprised of representatives from various stakeholders with clearly defined roles and responsibilities is a key first step (GovEx, 2018). The right people are needed in developing a data governance structure (Eke and Ebohon, 2020). For example, according to (PricewaterhouseCoopers, 2019), four key stakeholders are required to establish effective data governance and management: Civic authorities, industry advisory board, citizens, academics, and external data governance experts. To ensure fairness, especially citizens should be well-represented, and the board should include members from non-governmental organizations (Koskinen *et al.*, 2019). To create and manage a city data plan, (Lupi, 2019) proposed organizational bodies consist of a

multi-stakeholder advisory board and three teams: 1) a multidisciplinary team of domain and data experts, 2) a coordinating team, and 4) a response team for emergencies.

The focus is also on establishing a structure for data governance. According to the DCS in India (Guha et al., 2020), a designated City Data Officer (CDO) should be accountable for data governance at the city level and establish the formulation of city data policies. The CDO, in turn, should cultivate relationships with, and empower data champions and coordinators from different city areas and governance bodies. Furthermore, a city data office must be established by the CDO to serve as the city's data analytics and management unit. Such a unit must be staffed with the necessary skills in areas as ICT and data science. The DCS suggests setting up city-data alliances (CDA) to develop data-driven partnerships and collaboration on city data, as well as increased engagement of non-state stakeholders such as citizens, scholars, and businesses.

Process. Only nine of the ten selected sources propose a data governance approach in a guideline, a framework, or a model. However, the DataGovHub webinar (The Digital Trade & Data Governance Hub, 2020) was included in this review because the speakers provided insights into the topic and emphasized that any data governance approach should include *privacy*, *transparency,* and *accountability*. In what follows is a brief description of the nine approaches identified in this MLR.

- A guideline on the foundation for smart cities (GovEx, 2018) proposes starting with the people, understanding the local context, and strengthening internal data management based on an *open data* policy. The guidelines also provide insight into the opening and sharing of data and ensure the *security* and *accountability* of public data.
- A fair governance model based on a people-centered approach for data economy ecosystems is presented in (Koskinen *et al.*, 2019). , Such a model comprises a blueprint including technical and non-technical requirement specifications, a set of rules, and ethical guidelines for ecosystem actors. The model highlights the need for having controlling bodies comprised of representatives from all stakeholders.
- A seven-layer model is presented in (PricewaterhouseCoopers, 2019). The model proposes (1) to assess expected current and future *data categories*. Then, it aims to create tools and processes (2) for *informed consent*, (3) for secure and efficient data collection, (4) *anonymization*, (5) data storage, and (6) for secure and tiered access. Finally, the model provides a *monetization* platform (7).

- An approach based on the data flow and the data as commons is proposed in (Beckwith *et al.*, 2019). It highlights the *value* of data and the *privacy* framework (contextual integrity) to think about how different communities might influence the decisions related to data governance. The datashed concept is also used in this approach to thinking about how the value of information changes as it flows.

- A commons-based approach is described in (Bass and Old, 2020). This approach is based on *data commons* and aims to answer how to create city-data commons by addressing digital identity and democratic governance. A good basis for more trusted online interactions and relations is established by using a digital identity system called Attributed-Based Credentials (ABC). Democratic data governance is related to new types of community governance over data, i.e., more democratic forms of data governance.

- A conceptualization of the *City Data Plan* is presented in (Lupi, 2019). It contains a description of the city data governance multi-stakeholder organizational structures, duties assignments, protocols for collaboration and decision-making, plan elements, and implementation mechanisms.

- An inclusive smart city data governance framework is described in (Eke and Ebohon, 2020). It provides a prescriptive approach to understand how data can be used to increase inclusion in smart cities. It proposes a data governance structure based on four pillars: right data, right algorithms, right people, and right policies/standards.

- A technology and data governance framework in the form of a DataSmart Cities Strategy (DSC) is presented in (Guha *et al.*, 2020). The Government of India launched DSC to enable key urban stakeholders to embrace data-driven governance. DSC is based on three elements: process, platform, and people. The last two elements were described above. The process component lays down processes concerning data categorization and standardization aligned to the National Data Sharing and Accessibility Policy. According to the policy, the city authorities must prioritize privacy during data collection, processing, and sharing. The city data policies also guide the data collection, storage, and management.

- A data governance architecture is proposed in (Draheim, 2020). It includes data governance principles such as *data protection* and *data quality*. Moreover, the consent management considers that private and non-government organizations can participate in public-private

partnerships. The data governance architecture involves *interoperability* and *provisioning* and links data assets to legal entities.

In addition, the definitions of five data sharing approaches were identified: *data cooperatives*, *data collaborative, data trust*, *data exchange and marketplace,* and *data commons*. However, only the last two are explicitly mentioned as part of the data governance approaches discussed above.

- *Data cooperatives* are member-owned, and member-controlled organizations that gather and exchange data for the benefit of their members (The Digital Trade & Data Governance Hub, 2020).
- *Data collaborative* adds value to the public good by bringing together individuals from diverse sectors such as public and private organizations, and academic institutions, to exchange data (The Digital Trade & Data Governance Hub, 2020). Given that the DSC (Guha *et al.*, 2020) considers a digital infrastructure as part of public goods, a collaborative data approach seems to be behind that platform.
- *Data trusts* are a legal mechanism that aims to determine more equitable data connections between data beneficiaries and data owners by appointing 'trustees' to handle the data according to agreed-upon conditions (Bass and Old, 2020). In other words (The Digital Trade & Data Governance Hub, 2020), data trust is a mechanism to create more collective power and collective agency by bringing different actors with a relationship due to data use. Although a trusted data strategy is mentioned in (PricewaterhouseCoopers, 2019), it is unclear if the model specifically considers *data trust.*
- *Data exchange and marketplace* refers to digital platforms in which access pricing mechanisms are defined and data is considered as an economic good (Bass and Old, 2020; Guha *et al.*, 2020), and access is regulated through price mechanisms (Bass and Old, 2020). The India Urban Data Exchange (Guha *et al.*, 2020) is a good example although other data exchange platforms are presented in (Draheim, 2020). Moreover, (Lupi, 2019) proposed the concept of the city data plan based on the rules for data rights transfer of public interests data and the recommendations for fair data exchange between all the parties.
- *Data commons* is based on the notion of data as a common good (Bass and Old, 2020; Beckwith *et al.*, 2019; Eke and Ebohon, 2020). Consequently, community members (organizations or individuals) shared data as a common resource and they collectively make

decisions about data access rules. Sustainable data governance policies, according to (Eke and Ebohon, 2020), should promote an open data platform that contributes to the common good. Although two data governance approaches (Bass and Old, 2020; Beckwith *et al.*, 2019) are based on data commons, only the DECODE project provides four pilots (Bass and Old, 2020).

While the data sharing approaches can be useful to think about our capacity to make a different power-sharing arrangement, according to (Bass and Old, 2020), some of these approaches may overlap in practice and there is no clear distinction between them.

Citizen *engagement* has been reported as necessary to institutionalize and strengthen data governance capabilities (Guha *et al.*, 2020; The Digital Trade & Data Governance Hub, 2020). Active *public engagement* is a recurring theme in the pilots of data commons reported in (Bass and Old, 2020). Beyond that, Toronto's smart city initiatives mentioned in (PricewaterhouseCoopers, 2019) establish one principle that includes continuous *engagement* with both public sector stakeholders and the general public while emphasizing the importance of privacy issues and legislation (PricewaterhouseCoopers, 2019). Likewise, according to (Lupi, 2019), a *city data plan* should include the rules of civil society *engagement* that consider rights, benefits, and incentives. However, an active *engagement* of stakeholders is one of the prerequisites for developing a *city data plan*.

4 Data dimension in a data governance approach

In the smart city context, data should be a *strategic asset* (Draheim, 2020; GovEx, 2018; The Digital Trade & Data Governance Hub, 2020) since there are many ways in which data can bring value to different stakeholders. The value of data could assess according to the level of public interest, sensitivity, and relevance (GovEx, 2018). *Data flow* (Beckwith *et al.*, 2019; Koskinen *et al.*, 2019) and *data categories* (Draheim, 2020; Lupi, 2019; PricewaterhouseCoopers, 2019) are also related to *data value*. Except (Draheim, 2020), all the selected sources explicitly highlight the importance of *data value*.

Only the data required for processing should be gathered (Guha *et al.*, 2020; The Digital Trade & Data Governance Hub, 2020). Data should be also only stored and processed for specific purposes and periods of time, *minimality principles* (Draheim, 2020). On the other hand, no duplication of data entry (Guha *et al.*, 2020) is related to the *once-only principle* (Draheim, 2020), which aims to ensure that citizens and companies only provide once the same information to the public organizations. Moreover, the custody and control over data with diverse interests is a subject of contract or agreement discussion (The Digital Trade & Data Governance Hub, 2020). That is related to *data sovereignty* (Bass and Old, 2020), *data stewardship*

(Bass and Old, 2020; Beckwith *et al.*, 2019; Draheim, 2020), and *data ownership* (Bass and Old, 2020; Beckwith *et al.*, 2019; Eke and Ebohon, 2020; GovEx, 2018; Guha *et al.*, 2020; Lupi, 2019; PricewaterhouseCoopers, 2019).

Data quality is another important constituent of a data governance approach (Draheim, 2020; Eke and Ebohon, 2020; GovEx, 2018; Guha *et al.*, 2020; Lupi, 2019; PricewaterhouseCoopers, 2019; The Digital Trade & Data Governance Hub, 2020). Data governance and management are critical as "the more quality data you can integrate, the more value you can create" (PricewaterhouseCoopers, 2019). From an inherent point of view, *data quality* refers to data itself, i.e., characteristics like accuracy, timeliness, completeness (Draheim, 2020; GovEx, 2018), consistency, and credibility (Draheim, 2020). The *data quality* in a city data plan depends on its relevance to inform different levels of decisions (organizational, individual, and collective) may condition (Lupi, 2019). From the technological point of view, *accessibility* is another important characteristic (Beckwith *et al.*, 2019; GovEx, 2018; Guha *et al.*, 2020; Lupi, 2019) that involves these tools (Bass and Old, 2020). *Data quality* assessment requires multiple standards to foster the potential uses of data for several stakeholders. From an *interoperability* perspective, these standards should be suitable to use by local stakeholders (Lupi, 2019). Moreover, the right policies should be adopted for technology standardization and *interoperability* (Eke and Ebohon, 2020). Although the *interoperability* integration can modify the design space of data governance architecture (Draheim, 2020), open standards adoption and promotion can also help to promote *interoperability* (Bass and Old, 2020; Eke and Ebohon, 2020; Guha *et al.*, 2020) and *data portability* (Bass and Old, 2020).

Any data governance approach should ensure the protection of (1) *privacy* and other *rights* of the public (Bass and Old, 2020; Beckwith *et al.*, 2019; Draheim, 2020; Eke and Ebohon, 2020; GovEx, 2018; Guha *et al.*, 2020; Koskinen *et al.*, 2019; Lupi, 2019; PricewaterhouseCoopers, 2019; The Digital Trade & Data Governance Hub, 2020) and (2) the public knows it (PricewaterhouseCoopers, 2019). In this sense, the *data commons* manifesto (Bass and Old, 2020) states that data should respect and support not only human rights but also the natural world. Moreover, individuals must be aware of the types of data collected and utilized as well as the purposes for which they are used. In this context, informed *consent* aims to promote individuals' autonomy and *transparency* regarding the use of personal information, guide *ethical* practice and safeguard individuals' legal rights(Koskinen *et al.*, 2019). Data *resilience* is another basic strategy that aims to protect the data (Draheim, 2020; Guha *et al.*, 2020; PricewaterhouseCoopers, 2019) and helps comply with the legal regulations as GDPR. Data *resilience* is about responding to threats and recovering the lost or compromised data (Guha *et al.*, 2020; PricewaterhouseCoopers, 2019).

Security is another characteristic mentioned in most of the selected sources in this review (Bass and Old, 2020; Draheim, 2020; Eke and Ebohon, 2020; GovEx, 2018; Guha *et al.*, 2020; Koskinen *et al.*, 2019; Lupi, 2019; PricewaterhouseCoopers, 2019). The experience of Indian smart cities and other global smart cities suggests that compliance with standards is a way to institutionalize and strengthen best practices related to *security* and *protection* (Guha *et al.*, 2020). A practical recommendation made by the DECODE project (Bass and Old, 2020) is to establish a data governance policy that imposes not only *privacy* and *security* by design but also *ethics* by design. For instance, one of the DECODE pilots projects included a digital city plan based on an ethical data strategy that includes *privacy*, *security*, *transparency*, and *ethics* in the pursuit of *innovation*. Moreover, *transparency* is another crucial characteristic mentioned in all the selected sources in this review except (PricewaterhouseCoopers, 2019). In the case of the personal/private *data commons* described in (Bass and Old, 2020), a crucial aspect is to ensure the transparency and accountability of data flows and decisions about data access to those who provide data.

A data governance framework to achieve inclusiveness needs to adopt policies and standards that can build *trust*, *transparency*, *accountability,* and *responsibility* (Eke and Ebohon, 2020). Thus, by providing *transparency*, data can support *accountability* (Beckwith *et al.*, 2019) and individuals can *trust* the data governance team to make the right decisions (GovEx, 2018). Similarly, it is reported that o*pen data* enables *accountability* (Beckwith *et al.*, 2019) and therefore a good practice is to ensure *accountability* (Bass and Old, 2020; Draheim, 2020; GovEx, 2018).

A data governance approach should build *trust* to enable active data sharing. It suggests that communities must have *trust* in city administrators to implement good data governance (Beckwith *et al.*, 2019). Moreover, processes, initiatives, and partnerships that can overcome *trust* and mitigate bias associated with data must be included in a data governance framework (Eke and Ebohon, 2020). A *city data plan* should establish negotiation protocols to enhance local stakeholders' *trust* and cooperation in the city data ecosystem (Lupi, 2019). *Trust* is also needed to create positive feedback loops that promote the feeding of additional data while increasing its value to those who access it (Bass and Old, 2020). According to the report published by PWC (PricewaterhouseCoopers, 2019), the foundation of a smart city is trusted data governance and management that can be built based on the seven-layer model aforementioned. Likewise, Koskinen et al. (Koskinen *et al.*, 2019) observe that a governance model for a defined data economy ecosystem that is fair should ensure secure, trustworthy, *transparent* as well as *ethical*, *legal*, *fair* data use and supervision. In the case of data commons, the data governance approach must be based on *trust* (Bass and Old, 2020). The citizens should be aware of the data held by the city and how it is utilized to foster *trust*

in initiatives that aims to increase citizens engagement (Eke and Ebohon, 2020). The different data commons approaches involve groups who benefit from sharing data coming together to decide on rules for managing access while enhancing *trust* and resource *sustainability* (Bass and Old, 2020).

This review identified five data governance mechanisms: *anonymization*, *open data*, *consent*, *city data plan,* and *data monetization*.

Anonymization is the process that aims to minimize the risk of identifying an individual through data. The governance of data created and used could be improved by enforcing data *anonymization* (Lupi, 2019). *Anonymizing* data is a way to protect personal data (PricewaterhouseCoopers, 2019) and ensure data *privacy* (Guha *et al.*, 2020; PricewaterhouseCoopers, 2019). Therefore, *anonymization* by design is a good practice (GovEx, 2018; PricewaterhouseCoopers, 2019). In the context of sharing personal data, greater *anonymity* might give a more secure and trusted foundation for doing so, enabling individuals to have more control over the information they disclose about themselves and determining the conditions under which they reveal information and with whom (Bass and Old, 2020).

Open data is based on a philosophy in which data has no private owner and is available to everyone (Beckwith *et al.*, 2019). The open data movement has led governments worldwide to share their data (Smart Dubai and Nesta, 2020) since *open data* platforms led to enhance public data access (Eke and Ebohon, 2020), as mentioned before. Two good examples are described in (Guha *et al.*, 2020): NYC open data is free public data made available by New York City entities and other partners, while Tel Aviv Open Data is devoted to providing public access to non-confidential information in municipal databases and encouraging application developers to use it. In addition, the government of India has launched an open data platform (Guha *et al.*, 2020; PricewaterhouseCoopers, 2019), and the government of Hong Kong has created a Public Sector Information (PSI) Portal and an open data policy (PricewaterhouseCoopers, 2019).

An open data policy provides the basis for public participation and collaboration (GovEx, 2018), e.g., Lisbon's open data policy is compliant with GDPR (Guha *et al.*, 2020). The DECODE project also promotes *open data* (Bass and Old, 2020) while the *city data plan* proposed in (Lupi, 2019) aims to define shared rules for public, private, restricted, internal data, and not only *open data,* which is usually seen as the only public interest data.

Metadata refers to data that contains information about other data. *Metadata* adds information to the data that makes it easier to manage, find and use, i.e., the details about a dataset are known as metadata (GovEx, 2018). The decision protocols of the city data plan should encompass data uses, nature of the

related *metadata*, data suitability for the intended purposes, access requirements of data, and *data lifecycle* (Lupi, 2019). In this way, an organization can manage its data as an asset.

Consent is a key mechanism for protecting privacy (Bass and Old, 2020; Draheim, 2020; Guha *et al.*, 2020; Koskinen *et al.*, 2019; PricewaterhouseCoopers, 2019; The Digital Trade & Data Governance Hub, 2020). The processing of personal data is based on consent but such consent should only be valid if it is informed and freely given (Guha *et al.*, 2020). *Consent* principles are (Draheim, 2020) 1) individuals have the right to determine whether their data is stored, and 2) individuals are provided with mechanisms to provide or withdraw (opt-in or opt-out) consent. These mechanisms should offer individuals 1) a simple way to understand who will do what with their data, and 2) clear benefits for actively participating in an initiative (PricewaterhouseCoopers, 2019). Therefore, informed consent safeguards the legal rights of individuals (Koskinen *et al.*, 2019). Additionally, individuals should be encouraged to renew their decision to opt-in at regular intervals, with the option of withdrawal of consent at any time (PricewaterhouseCoopers, 2019).

A City-data plan is a policy instrument that outlines a possible way to align a city's development in terms of visions and goals with the collection and use of data generated by smart city initiatives (Lupi, 2019). Although other selected sources did not report a *city data plan*, they recognize its importance as a policy instrument. For instance, the Barcelona City Council released a city plan (Bass and Old, 2020) to implement new municipal data sovereignty policies that enabled data governance adoption. In contrast, Baltimore City released an Inclusive Digital Transformation Strategic Plan, including plans for a Smart City Council and a Data Analytics Hub. Moreover, the Indian government has developed its DataSmart Cities policy framework to help enable city data governance (Guha *et al.*, 2020; PricewaterhouseCoopers, 2019).

Data monetization refers to the process of creating financial value from data (Guha *et al.*, 2020; PricewaterhouseCoopers, 2019) so that it can provide economic sustainability. For instance, two Indian cities are exploring the potential for future data monetization, and Lisbon city has considered it but has not been implemented yet (Guha *et al.*, 2020). Data monetization is a best practice that is included as the last layer of the model proposed in (PricewaterhouseCoopers, 2019). However, *monetization* requires a thoughtful analysis since the focus on a fair data economy is based on the common good over commercial monetization (Bass and Old, 2020).

5 Overview of smart city data governance

Data governance literature does not provide sufficient insights into the smart cities context, and therefore more dedicated research is needed, particularly data sharing. It is an emerging research field that has

received increasing attention in the last five years. Indeed, data governance in smart cities is a topic of interest in a variety of research areas and has been investigated from different viewpoints. In engineering research communities, such as software engineering and information systems, this topic has also been researched. Our review revealed that there are an increasing number of academic studies since 2010. However, the total number of studies directly related to approaches such as guidelines, frameworks, or models has been only nine over the last three years. The selected sources address several dimensions of data governance, but, in general, one-size-fits-all approaches to data governance do not adequately address a particular smart city context. Figure 3 shows an overview of smart city data governance based on our findings.

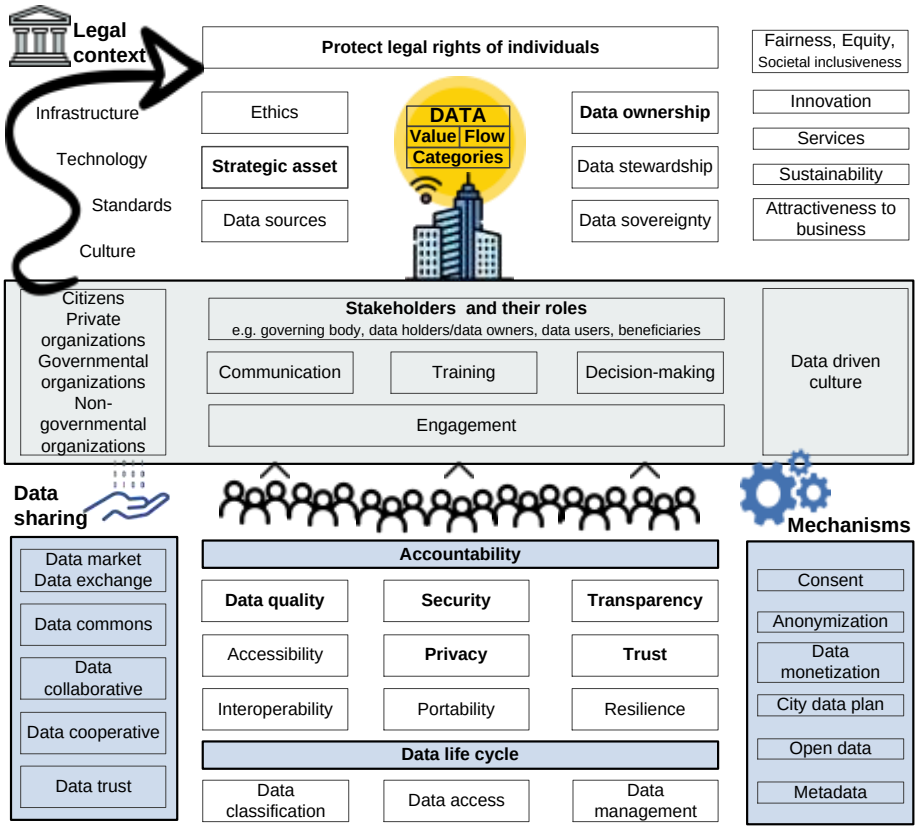

Figure 3. Overview of smart city data governance

In general, there is a legal vacuum that has slowly and gradually fostered the emergence of data governance to properly define data use and data sharing. Although regulatory and legal requirements need to be understood in any smart city initiative, it should be noted that compliance is not governance. Apart from the *legal context*, *infrastructure*, *technology,* and *standards* shape the data governance approach. Such a data governance approach must also mediate the relationships between different actors since data exchanges with outside parties like digital infrastructure providers and other private sector companies are not uncommon in smart cities, i.e., public-private partnerships. In addition to those relationships, the interactions

between the involved stakeholders, their motivations, expectations, levels of expertise, and the laws and rules that govern them determine a particular dynamic and context. Therefore, *stakeholders* and their organizational *culture* also influence the data governance approach. It suggests a need for complex data governance approaches that respond to various interests while *protecting the legal rights of individuals*.

In the smart city environment, a wide variety of data exist. However, the *value of data* needs to be rightly governed to unlock it. Although identifying and classifying the data helps to understand the *importance of data*, different types of data may require different ways of being governed, so the data type needs to be precisely determined —*data categories* and *data sources*. Moreover, when *data flows*, it can generate new values as well as increase or reduce current values. Therefore, the scope of data governance is also defined by *data value*, *data flow,* and *data categories*.

Once data is perceived as a strategic asset for all stakeholders, it is important to clarify rights and responsibilities for the data while ensuring the *value of the data*. The focus is on controlling data collection and data use as well as the impact of that use on individuals. Not surprisingly, *data ownership* is a recurring theme in the selected sources, followed by *data stewardship* and *data sovereignty* which are less discussed. It is particularly important from the legal perspective since data processing must be lawful and the information collected and used fairly. Some governments are introducing privacy regulations to give individuals more rights and control over processing their data. For instance, the GDPR gives individuals rights over their data since they can assert consent, erasure, and portability over their data. However, it goes beyond mere compliance with existing laws and regulations. There are also *ethical reasons* for protecting data and ensuring they are not misused.

Data governance also encompasses a dynamic equilibrium between the interests of all *stakeholders* — including those who provide data. The findings of this review suggest that stakeholders must decide where the balance will be, the types of governance mechanisms to be used to facilitate that equilibrium, and how the mechanisms will be applied. Although it is clear that regulatory authorities and bodies play an important role, *decision-making* bodies are required to ensure that a particular data governance initiative uses data under existing laws and regulations. Moreover, other key *roles* are identified in the selected sources, e.g., governing bodies, data holders/data owners, data users, and beneficiaries.

Citizens and other stakeholders should be involved and engaged in the early stages of the data governance initiative. To do so, explicit communication channels or permanent bodies —e.g., citizen advisory committees— can be created. Moreover, a communication plan can ensure the effective

communication of the data governance initiative itself, its progress, and its result. A *training* program can provide stakeholders with the knowledge and qualifications they need to support a data governance implementation. Moreover, transparent coordination of *decision-making* can support cross-functional alignment. Therefore, effective *communication*, *training*, and *decision-making* coordination facilitate creating a *data-driven culture* that values data assets.

Likewise, multiple stakeholders must be involved in defining *data sharing* policies. Although there are different approaches —*data trust*, *data cooperatives*, *data collaborative*, *data exchange and marketplace,* and *data commons*— all aim to release greater value from data and lead to benefits in the public interest. These data sharing approaches are not all mutually exclusive and can be mixed and matched to accomplish various goals. However, they are still emerging in the context of smart cities, and therefore, a careful analysis is required.

In the light of data governance, the purpose and *value of data,* as well as to whom the data is valuable, should be the focus on each stage of the *data lifecycle*. Another important consideration to facilitate data sharing is *data quality*. Apart from *data quality* related to data itself —accuracy, timeliness, completeness, consistency, and credibility— other characteristics influencing data sharing are *accessibility, interoperability, portability, and resilience*. From a responsible and ethical point of view, other factors that impact data governance are *security, privacy, transparency,* and *trust.* In addition to responsibility and *transparency*, *accountability* is needed because it aims to ensure compliance and assess the impacts of decisions about data throughout its *lifecycle*. Data lifecycle entails *data generation, acquisition, processing, storage* and *archiving* while *data management* deals with the technical issues throughout the data lifecycle. In this sense, *data classification* and *data access* are also important elements due to the heterogeneity of city data (Bozkurt *et al.*, 2022).

Various data governance mechanisms are crucial in setting up a data governance approach, but striking a proper balance may be difficult. For example, easy access to data may conflict with requirements for *security*, *privacy,* and *transparency*. Useful data governance mechanisms reported in the selected sources are 1) *consent* to recognize the individual's right to decide whether to share his/her data and 2) *anonymization* to protect the rights and *privacy*. Moreover, 3) *open data* —open data policy and/or open data platforms— improve public access to data and 4) *metadata* to expand the understanding of data and maximize *interoperability* and traceability. While 5) a *city data plan* is a policy instrument and 6) *data monetization* is to quantify *data value*.

Authors suggest that a holistic view might assist to focus on the social aspects of data sharing and how these softer aspects are intertwined. In this review, some data governance approaches pursue *fairness*, *equity,* and *societal inclusiveness* while others pursue *innovation*, better *services*, *sustainability,* or *attractiveness to business*. As the value in data does not always lie in its sale, it seems that these data governance approaches aim for a positive social impact by focusing on the public interest. The focus on societal challenges and the desire to contribute to a better world is also aligned with previous smart city research (Granath *et al.*, 2021).

6 Limitations

There are some potential limitations and threats to validity in this MLR. Below authors briefly describe them and explain how authors aimed to reduce them.

Selection bias is the main threat in the MLR. A multi-stage process was followed to mitigate this threat. Authors selected sources from five well-known electronic academic databases and two other search engines for grey literature Google scholar and Google search. Moreover, a complimentary search strategy was conducted to identify previous studies that the European Commission published. Collecting relevant grey sources was more difficult than gathering academic literature from databases. Many sources do not propose a data governance approach, their main focus is on conclusions and recommendations without giving evidence that supports them. Despite that few publications made by global consulting firms (e.g., PWC) or European initiatives (e.g., DECODE) were found, one of the major concerns to our study is the representativeness of the selected sources. Besides, all the selected studies are directly associated with data sharing. This choice was taken as our goal was data governance approaches supporting data sharing in smart cities. Although the number of included sources seems to be adequate to get a good overview of the state-of-the-art in this topic, authors found that only nine papers proposed a data governance approach.

Manual data extraction may lead to mistakes in the data that is extracted. This review follows well-established guidelines for MLR (Garousi *et al.*, 2018) to mitigate this threat. A structured review sheet was created to trace the findings. Among the three authors a clear division of responsibilities was established to ensure the validity of this study and reduce bias. Additionally, authors did take extra caution when writing the paper and re-check all sources. To foster verification and replication of this MLR study, a replication package that includes the 568 initial results is available on request from the corresponding author.

This review is focused on data governance in smart cities and includes academic literature and grey literature. However, the search strategy might have missed some sources, and therefore, authors cannot

claim generalizability. Although the inclusion of grey literature addresses a practitioners' point of view, it is restricted to sources that are freely available online.

7 Conclusions

Data governance in smart cities has gradually emerged in response to a legal vacuum, technological advances, business operations changes, and environmental and societal challenges. Data governance provides a means to better frame data use and sharing. However, data sharing deserves a depth analysis since it has an influence on processes inside a city and affects several stakeholders. While understanding the crucial role of data governance and its complexities, practitioners could find it hard to perform proper data sharing. Therefore, empirical research especially from a citizen perspective is needed.

A data governance model for smart cities goes beyond technology, although technology provides important means for implementing a governance model. The findings are in line with previous research (Granath *et al.*, 2021) and raise awareness about the socio-technical aspects of data sharing approaches in smart cities. Authors believe our analysis shed some light on the nascent body of knowledge in this field. The findings also suggest no one-size-fits-all data governance approach that can respond at once to a particular but also a general context. It means radical changes that require the complete integration of technology into processes and services while aligning with societal context and cultural expectations. Thus, further research in this area is also needed.

It is expected that a data governance model for a smart city should react to various interests while *protecting the legal rights of individuals*. So then, it is necessary to combine structures, processes, and mechanisms that, in turn, depend on multiple factors. The stakeholders must decide on the most appropriate combination and its implementation according to their context, needs, capacity, and objectives. However, far from providing benefits alone, data use and sharing also raise important challenges that data governance initiatives inevitably face. Therefore, further empirical research is needed to determine the benefits of a data governance initiative and its stakeholders' challenges. For practical reasons, all stakeholders cannot always participate in the decision-making process, so pilot projects can help to understand better who may be excluded and how to lessen any harmful effects, e.g., social discrimination and exclusion. Moreover, it could be interesting to explore competing interests in particular their outcomes and successful resolutions, and then explore the potential of data sharing and its inherent risks.

Finally, authors hope our review supports the creation of data governance models intended to serve the public interest. Such a focus on the public interest will change the way we think about data and its significance in the digital transformation of society.

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