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Development and evaluation of an urban data governance reference model based on design science research

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ABSTRACT

In the urban context, data governance has only recently gained attention, though the increased importance of data with the emergence of smart cities is unprecedented. Data governance helps ensure the efficient management, utilization, and protection of data, all essential for enhancing service delivery, refining decision-making processes, and fostering trust in data integrity. This study presents a data governance reference model adapted to urban requirements – the urban data governance reference model – developed following the design science research paradigm. We describe the steps of the reference model development, from establishing a scientific theory base to analysis of the problem environment in 27 EU cities to the development process of the artifact and evaluation through expert interviews in 10 EU cities. The findings reveal that no reference model for urban data governance exists in the scientific literature. In practice, cities face challenges such as data silos, lack of interoperability, and redundancies, as well as a lack of data culture. Support for creating data governance programs is also lacking. The urban data governance reference model harmonizes technology, organization, and culture through four foundation layers and four pillars. Experts' evaluation of the reference model provides essential insights into its completeness, comprehensibility, applicability, and possible improvement measures for future research. It is highly adaptable and can serve as an orientation aid for cities implementing data governance.

1. Introduction

Cities generate a considerable amount of data from various sources and application areas, ranging from demographic, building, mobility, environmental, and economic data to education and health data. These data from many sources vary significantly in type, granularity, timeliness, frequency, and scope. In addition, a variety of actors are involved in the urban data landscape, including citizens, firms, research institutions, and non-governmental organizations (Ahlers, Wienhofen, Petersen, & Anvaari, 2019; Batty et al., 2012; Chourabi et al., 2012; Silva, Khan, & Han, 2018; Stone, Knapper, Evans, & Aravopoulou, 2018; Zanella, Bui, Castellani, Vangelista, & Zorzi, 2014). Data provide essential information about a city and assist city administrations in making informed decisions, such as the efficient use of resources, urban planning, traffic management, economic and innovation promotion, and crisis management, and also increasing the attractiveness for business and tourism and improving the quality of life for citizens (Ahlers et al., 2019; Broccardo, Culasso, & Mauro, 2019; Jayasena, Mallawaarachchi, & Waidyasekara, 2019; Stone et al., 2018).

Consequently, data are an essential asset for cities. Especially nowadays, when digitalization has become ubiquitous, correct data handling is vital. However, what is the right way to handle data? Data governance can help to address this question (Abraham, Schneider, & vom Brocke, 2019; Khatri & Brown, 2010; Seiner, 2014; Weber & Klingenberg, 2021; Weber, Otto, & Österle, 2009). Data governance is essential in today's data-driven world, where increasingly more data are being collected and used. Data governance can increase trust in data, improve the quality of decision-making, and ensure compliance by defining and monitoring processes, responsibilities, and accountabilities within the data life cycle (Abraham et al., 2019; Janssen, Brous, Estevez, Barbosa, & Janowski, 2020; Koltay, 2016; Mahanti, 2021b; Otto, 2011; Thompson, Ravindran, & Nicosia, 2015; Weber et al., 2009). Bozkurt

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et al. (2022, p. 2687) define urban data governance as follows: "Urban data governance assesses all data-related issues of a city from a holistic perspective. The main goal is to ensure sustainable urban development by managing data in the interest of citizens and promoting business and services." However, there is only a weak knowledge base with regard to the scientific investigation of data governance in an urban context. After all, a literature review by Kvalvik, Sánchez-Gordón, and Colomo-Palacios (2023) shows that research on data governance has increased in the last five years. Still, the literature on data governance hardly takes an urban perspective (Bozkurt et al., 2022).

Similarly, only a few cities have holistically addressed urban data governance. For example, high-level concept and strategy documents on city digitalization projects discuss the basics of data processing rather than data governance as a foundational concept (Department of IT and Digitalization, H, 2020; Digital Glasgow Board, 2018; Digitales und IT (DIGIT) Stadt Freiburg im Breisgau, 2019; Senatsverwaltung für Wirtschaft, E. und B, 2018; Stadt Böblingen, 2021; Stadtrat Stadt Zürich, 2018). Only a few smart city pioneers have introduced data governance sophisticatedly, such as Data Excellence Vienna (Lutz & der Stadt Wien, 2019), Data for London (Romualdo-Suzuki & Greater London Authority, 2016), and City Data Commons Barcelona (Barcelona City Council, 2022). However, the relevance of data governance has arrived in cities, as specific data strategies are published alongside digitization strategies considered groundwork for urban data governance (Bozkurt, Flaisch, Hertweck, & Rossmann, 2023).

Furthermore, scientific studies show that cities lack fundamental guidelines and design principles for data governance (Bozkurt et al., 2022; Choenni, Bargh, Busker, & Netten, 2022; Cuno, Bruns, Tcholtchev, Lämmel, & Schieferdecker, 2019; Franke & Gailhofer, 2021; König, 2021; Lupi, 2019; Paskaleva et al., 2017; Thompson et al., 2015). A reference model for urban data governance can help cities develop governance programs tailored to their needs (Bozkurt et al., 2022). In this paper, we address this knowledge gap in research and practice by posing the following research question (RQ):

RQ: How can a scientifically grounded reference model improve data governance in cities?

To address this RQ, we defined three specific research objectives:

(1) Firstly, the conceptual development of the urban data governance reference model (UDGRM) builds on the design science research (DSR) paradigm. This study systematically constructs a model that integrates established theoretical foundations with practical insights, ensuring both academic rigor and real-world applicability.
(2) Secondly, the characterization of the reference model's requirements, dimensions, and elements draws from scientific literature and the experiences of 27 EU cities. The UDGRM is designed to enhance urban data governance by addressing key barriers such as interoperability, siloed data management, and stakeholder complexity.
(3) Thirdly, practical relevance of the reference model is evaluated through feedback from ten data governance experts across EU cities. Their assessment ensures the model's completeness, comprehensibility, and applicability, allowing for refinement and broader adoption.

The UDGRM was developed to directly improve urban data governance by addressing the structural, organizational, and cultural limitations of existing governance models (Bozkurt et al., 2022; Bozkurt, Rossmann, Konanahalli, & Pervez, 2023; Thompson et al., 2015). Unlike frameworks that focus on corporate environments, the UDGRM incorporates mechanisms that enable cross-departmental coordination, stakeholder engagement, and the structured integration of diverse data sources. It establishes standardized governance protocols to reduce data silos, improve collaboration between city agencies, and ensure that governance structures remain adaptable to evolving regulatory and technological landscapes (Bozkurt, Rossmann, et al., 2023; Kvalvik et al., 2023). By combining theoretical depth with practical relevance, the UDGRM bridges the gap between theoretical governance models and the dynamic, interdisciplinary demands of smart cities.

To address these challenges, the UDGRM enhances interoperability and decision-making capacity in urban administrations. Its modular design allows cities to implement governance mechanisms that evolve alongside technological and regulatory advancements. By providing standardized data management protocols, the UDGRM minimizes inefficiencies linked to fragmented data landscapes. Additionally, it enables self-assessment and benchmarking, helping cities evaluate their governance maturity and refine data management strategies. The model fosters data-driven decision-making by ensuring that governance improvements are based on structured methodologies rather than reactive policy adjustments. Moreover, it supports flexible governance structures that respond effectively to both immediate needs and long-term strategic objectives.

By adopting reference models, cities can further enhance efficiency and reduce unnecessary expenditures by avoiding redundant solutions, minimizing trial-and-error costs, and optimizing resource allocation (Fettke & Loos, 2003; Rosemann & Reinhard, 1997; Rosemann & Schütte, 1999; Vom Brocke, 2015). The UDGRM offers clear, adaptable guidelines that expedite the deployment of data governance strategies, enabling cities to respond to emerging data needs quickly. Furthermore, its technology-independent and non-monetarily motivated design promotes inclusivity and is suitable for cities of all sizes, offering a holistic view that enhances its broad applicability and straightforward implementation.

Thus, the artifact represents a significant advancement by not only addressing theoretical gaps in urban data governance but also demonstrating tangible improvements in governance efficiency, coordination, and adaptability. Its reference-based approach enables cities to streamline governance workflows, integrate diverse stakeholder needs, and enhance compliance mechanisms without the need for costly ad hoc solutions. The UDGRM provides a practical, scientifically validated tool that helps cities implement structured, scalable, and sustainable data governance frameworks. Ultimately, this research advances the scientific understanding of urban data governance by demonstrating how a theoretically grounded model can lead to practical improvements in governance structures and decision-making processes.

This paper proceeds as follows: Section 2 provides an overview of the DSR paradigm and the research process of this project. Section 3 provides an understanding of data governance and an overview of related work. Sections 4, 5, and 6 present the main tasks of the DSR process and provide an understanding of the problem space (Section 4), the design and development of the artifact (Section 5), and the demonstration and evaluation of the artifact (Section 6). The study concludes with a comprehensive discussion in Section 7.

2. Research design

This study utilizes the DSR Framework. DSR originated in engineering research and was first taken up by Simon (1969) to investigate how science can influence design (Hevner, March, Park, & Ram, 2004; Johannesson & Perjons, 2021). More recently, however, information systems (IS) researchers have adopted DSR as a research paradigm, mainly through the influential work of Hevner et al. (2004) and Hevner (2007).

DSR is fundamentally a problem-solving paradigm (Hevner et al., 2004) that aims to solve complex problems with innovative solutions (artifacts) by incorporating scientific rigor into the design of these solutions using scientific methods and existing knowledge of the problem domain (Goldkuhl, 2016; Hevner et al., 2004; Johannesson & Perjons, 2021; Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007). The artifact is created through several iterations (Goldkuhl, 2016) and contributes to the problem environment by addressing the problem.

However, other contributions to the design process should be made available to practitioners and researchers, such as framing and identifying the problem, understanding the stakeholders, and any other insights that emerge during the DSR project (Goldkuhl, 2016; Hevner et al., 2004; Johannesson & Perjons, 2021; Peffers et al., 2007). Hevner (2007) presents DSR in terms of relevance, design, and rigor cycles, encompassing activities from problem identification to the final artifact's application or presentation. The relevance cycle links the problem area to the design cycle by, for example, identifying stakeholders; the design cycle comprises the activities for creating the artifact and its evaluation; and the rigor cycle incorporates scientific methods and knowledge bases into the design activity (Hevner, 2007). In addition to the DSR framework and its cycles, Hevner et al. (2004) outline seven fundamental DSR guidelines (Gx) to help researchers conduct DSR and readers evaluate and better understand DSR work: A purposeful artifact (G1) addresses a relevant problem (G2), is rigorously evaluated (G3), contributes to research (G4), is based on scientific principles (G5), is developed iteratively (G6), and is communicated effectively (G7).

The study by Fedorowicz and Dias (2010) highlights gaps in applying the DSR guidelines in digital government, suggesting that while the guidelines are well-established theoretically, their practical implementation often falls short. Similarly, Goldkuhl (2016) recognizes a gap in applying DSR to research areas involving the digitalization and modernization of public administration, noting that digital government is a field of growing interest with considerable potential for DSR. More recent research by Carter, Yoon, and Liu (2022) confirms this shortfall and underscores the urgency of more fully integrating DSR methods. Despite a decline in publication numbers since 2014, innovative designs in digital government continue to emerge in leading IS and digital government journals, showcasing the field's dynamism and the practical application of DSR methodologies. Therefore, this research explicitly contributes methodologically to the application of DSR in digital government research by adhering to the DSR paradigm outlined by Hevner et al. (2004) and Hevner (2007).

Although Hevner et al. (2004) provide the principles of the DSR paradigm, they do not specify a precise process for DSR projects. Therefore, we developed a research process based on the principles of Hevner et al. (2004) and Hevner (2007), as presented in Fig. 1. The middle column (design cycle) shows the design tasks fulfilled by the activities in the relevance and rigor cycles. The process begins with the task "understanding of the problem space," which we demonstrate in Sections 3.2 and 4. This task aims to understand the problem space and defines the scope of the problem to be solved. In addition, the requirements for the artifact are determined. Within the environment (relevance cycle), activities are carried out to identify cities' data governance challenges and derive requirements for the artifact. In addition, the current status of data governance in cities is recorded. These activities are carried out through expert interviews with municipal experts. As part of the rigor cycle, the knowledge base is established, the research context is defined, and the research structure is determined. For this purpose, a systematic literature review is conducted. In addition, scientific methods are applied to qualitatively analyze the expert interviews, with cognitive mapping playing a central role in understanding the environment.

The next task refers to the "design and development of artifact," which we demonstrate in Section 5. The aim is to deliver a solid artifact based on knowledge from practice and science by synthesizing the results and using appropriate modeling techniques. This task is linked to

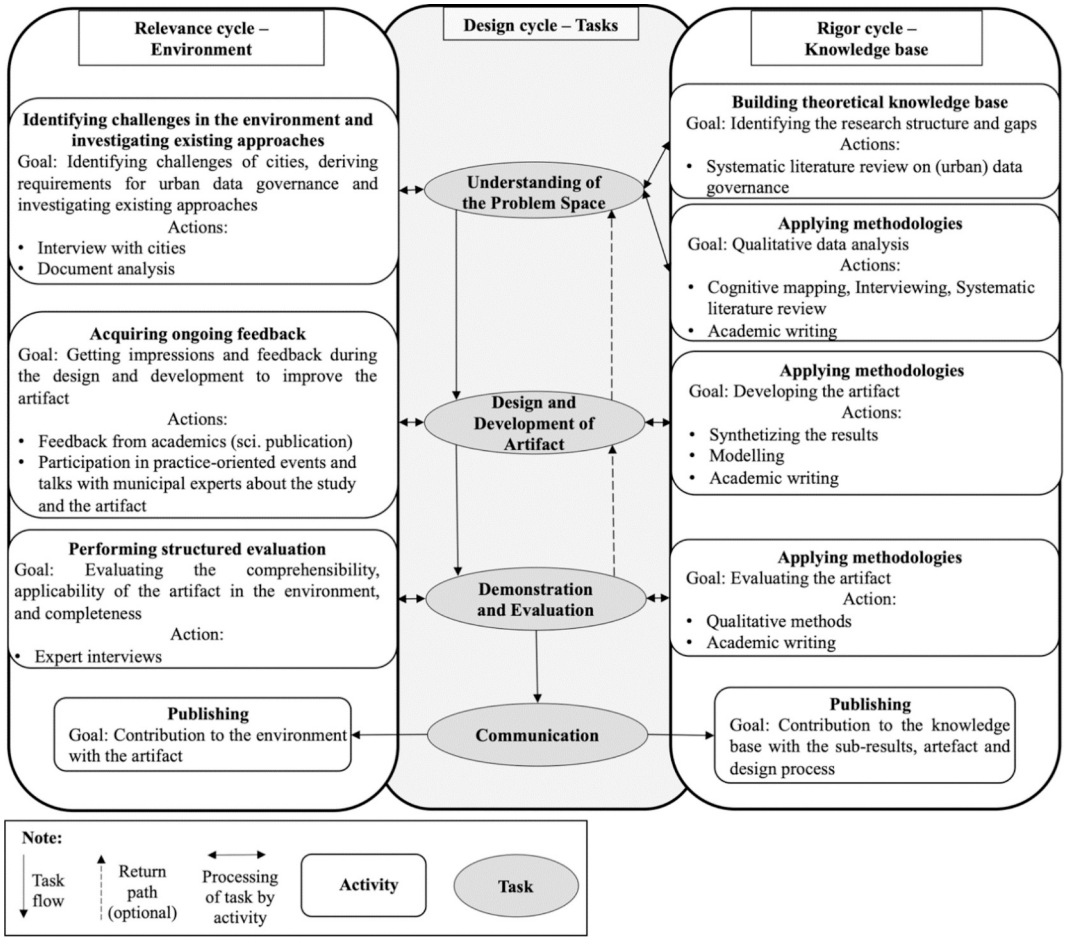

Fig. 1. Application of DSR.

the relevance and rigor cycles. The relevance cycle continuously reviews and evaluates the development of the artifact and provides feedback to improve it through various actions. For example, regular participation in practice-oriented events allows discussion of the development of the artifact with experts, collection of feedback from users, and establishment of a community of interest. The results achieved, and drafts produced are then published. The direct input from the problem domain and the scientific community ensures that the artifact addresses the problem domain correctly. If the problem area is not addressed correctly, problem identification and requirement derivation can be revised via a backward path. The rigor cycle then provides methods for developing the reference model for urban data governance and publishing scientific work that includes modeling and qualitative analysis.

Subsequently, a group of practice experts evaluates the artifact for comprehensibility, applicability, and completeness in the context of the "demonstration and evaluation" task, as demonstrated in Section 6. If necessary, changes are made via the return path.

Finally, the process ends with "communication." The results, which are written and published, contribute to the knowledge base and the problem environment. However, publishing the results of other DSR tasks makes a continuous contribution to the knowledge base and the problem environment.

3. Theoretical background and research landscape of urban data

The following section aims to establish a common understanding of data governance, urban data governance, and related research. An in-depth analysis of the existing literature clarifies this paper's positioning within the research landscape and highlights its contribution to closing existing knowledge gaps.

3.1. Data governance

In general, governance refers to the act of administration in the public or private sector (Emerson, Nabatchi, & Balogh, 2012). It forms the framework within a system for processes, power distribution, conflict resolution, and resource management (Weber & Klingenberg, 2021). Various scholars have contributed to the understanding of the concept of governance (Bevir, 2013). For example, Chhotray and Stoker (2009) emphasize the complex decision-making that occurs through the "practice of collective decision-making" among diverse and multiple actors. Kooiman (2003) describes governance as a series of "interactions" between public and private actors to solve societal problems or create societal opportunities, with institutions providing the context for these interactions and creating a normative basis for all such activities.

From an urban perspective, governance is more than the elected government of a city; it also entails the management and collaboration across a complex network of city authorities, firms, researchers, and citizens (Bingham, Nabatchi, & O'Leary, 2005). Achieving management and cooperation among the various actors requires optimized processes to effectively use information and communication technology and data for high transparency and citizen participation. Today, cities are characterized as data factories that generate vast amounts of data quickly and continuously from various sources (Barns, 2018; Taleb, Dutta, Ksentini, Iqbal, & Flinck, 2017). The handling of these data poses a multi-layered problem with technical, organizational, and collaborative aspects, as a multitude of different data sources, types, and actors are involved (Ahlers et al., 2019; Batty et al., 2012; Broccardo et al., 2019; Chourabi et al., 2012; Silva et al., 2018; Zanella et al., 2014). This situation leads to two interrelated topics: data governance and data management in cities.

While data management deals with technologies, systems, and their implementation, data governance creates the framework for data management by addressing aspects of the data life cycle, such as required actions and responsibilities (Dama International, D. M. A, 2017; Khatri & Brown, 2010). Data governance ensures that data policies and standards are aligned with an overall strategy and culture so that all stakeholders have shared use of data. It aims to define and ensure the correct handling of data assets (Weber et al., 2009; Weber & Klingenberg, 2021). To ensure the proper handling of data, the action fields of data governance include guidelines, rules, standards, processes, structures, roles, responsibilities, and decision-making rights in all data matters (Khatri & Brown, 2010; Mahanti, 2021b; Seiner, 2014; Weber & Klingenberg, 2021). Wherever data are handled, some form of data governance exists, but the absence of formalization leads to a lack of guidelines and authority in handling data, which in turn results in interoperability, quality, and security problems, a lack of transparency, and loss of trust in the data and the organization (Mahanti, 2021a).

3.2. Related research

Our analysis of existing literature in urban data governance is structured into two phases. We specifically targeted literature reviews in the initial phase to understand the research landscape. Literature reviews provide insight into the research landscape and serve as an essential basis for further research (Okoli, 2015; Paré, Trudel, Jaana, & Kitsiou, 2015; Webster & Watson, 2002). To this end, we searched on Google Scholar using the keywords "literature review," "literature analysis," "data governance," "city," and "urban data governance." This search led to two relatively recent and relevant research papers, Bozkurt et al. (2022) and Kvalvik et al. (2023), which provide comprehensive insights into the research landscape for urban data governance.

Bozkurt et al. (2022) aim to stimulate research in urban data governance by providing a foundational perspective for future studies. They offer a comprehensive overview of data governance and identify relevant aspects of this branch of research that could serve as a basis for developing an urban data governance framework. In their study, they analyzed 612 publications using a text-mining approach and identified ten research clusters, one of which includes explicitly urban-focused work. Their search covered five scientific databases (ACM, EBSCOhost, Emerald, IEEE, WoS) with the search term "data governance," with the results including publications up to the year 2022. They conducted a qualitative full-text analysis within the city cluster and identified 15 relevant papers.

Kvalvik et al. (2023) expanded the scope of the research by integrating gray literature via Google searches in addition to the scientific databases (ACM, IEEE, Wiley Online, Springer Link, and ScienceDirect). They formulated the search query ("information governance" OR "data governance") AND ("smart city" OR "smart cities"), which led to 568 sources up to the year 2022, ten of which were classified as relevant.

In this initial review phase, we identified from the mentioned literature reviews a corpus of 25 papers considered potentially relevant for our study on urban data governance. However, to ensure the quality and relevance of our selection, we conducted a rigorous screening process. We removed four duplicates. Furthermore, we excluded seven papers due to either lack of availability or restricted access, which precluded a thorough examination. Additionally, four papers were eliminated because their focus on technical implementation did not align with our research's broader strategic and governance scope. This systematic exclusion of papers that did not meet specific criteria allowed us to narrow down the corpus to 10 highly pertinent papers, enabling a more focused and compelling analysis of the landscape of urban data governance.

In the second phase of our analysis of related work, we focused on discovering new publications added since the reviews of Bozkurt et al. (2022) and Kvalvik et al. (2023). We combined the databases of the works mentioned above. We searched for the period from 2022 to 2024 in the ACM Digital Library, EBSCOhost, Emerald Insight, IEEE Xplore, Wiley Online Library, SpringerLink, and ScienceDirect.

For the search, we used a combination of the search terms used in the previous reviews by Bozkurt et al. (2022) and Kvalvik et al. (2023):

"data governance," "information governance," "smart city," and "smart cities." Additionally, we integrated the term "urban data governance" into our search queries. The results of this comprehensive search led to the identification of six (Bokolo, 2023; Bozkurt, Flaisch, et al., 2023; Bozkurt, Rossmann, et al., 2023; Gilman et al., 2024; Guo, Zhu, Ding, Liu, & Zhao, 2022; Kaginalkar, Kumar, Gargava, & Niyogi, 2023) further publications (one from Emerald, one from IEEE, two from EBSCOhost, one from ScienceDirect, and one from SpringerLink). Table 1 offers a synthesized overview of the urban data governance research, including studies from Bozkurt et al. (2022) and Kvalvik et al. (2023), along with the six new studies added since 2022.

The analysis of existing research in the field of urban data governance reveals significant knowledge gaps characterized by the data source's limitations and the lack of systematic development processes. Many studies, including work by Beckwith et al. (2019), Bokolo (2023), Cuno et al. (2019), Kaginalkar et al. (2023), Paskaleva et al. (2017), and Thompson et al. (2015) rely on relatively small or specific data sets that do not cover the full range of urban data governance challenges. In contrast, this paper uses data from interviews with representatives from 27 cities. This extensive database reflects various urban data governance issues and allows for more robust and generalizable findings. This approach significantly improves the generalizability and applicability of the research findings and provides a more informed basis for developing governance strategies tailored to the diverse needs of urban environments (Gilman et al., 2024).

Unlike many ad hoc models without clear methodological guidelines, such as those mentioned in studies by Choenni et al. (2022), Guo et al. (2022), König (2021), Liu et al. (2017), this research proposes a structured approach that starts with initial data analysis and leads through various stages of development to expert validation. Through this structured DSR approach, we can ensure that the artifact of this research is both scientifically sound and practical in real-world application scenarios.

While studies such as Beckwith et al. (2019), Cuno et al. (2019), and Liu et al. (2017) have provided valuable technical frameworks, there remains a critical need for a holistic perspective that integrates cultural and organizational dimensions, which are often overlooked. This paper introduces an urban data governance model that addresses this need by incorporating a comprehensive approach to managing the complex interactions within urban data ecosystems, as described by Gilman et al. (2024).

Moreover, the importance of including diverse social groups and adhering to legal standards, as pointed out by studies such as those by Bokolo (2023), Eke and Eboho (2020), and Franke and Gailhofer (2021), is tackled in this research. The proposed model includes mechanisms that enhance compliance and cultural inclusivity, reflecting community values and promoting broader stakeholder engagement.

Additionally, this paper includes the citizen participation, a crucial element underscored by Choenni et al. (2022), König (2021) by proposing transparent governance structures and effective stakeholder management, the aim is to involve citizens in the decision-making process, thereby increasing the acceptance and impact of urban governance initiatives.

Finally, this study addresses the discrepancy between technology practice and theory identified by Gilman et al. (2024) and Guo et al. (2022). This paper lays the foundation for scientifically robust and practically applicable urban data governance by merging field-tested knowledge with theoretical insights.

The reference model formulated in this paper builds on the theoretical groundwork of Bozkurt et al. (2022), who identified key dimensions of urban data governance. However, their work remained conceptual and lacked empirical validation. To address this gap, we present an extended version of the reference model, enriched with empirical insights from 27 expert interviews across EU cities. This empirical foundation strengthens the model's relevance by capturing the practical governance challenges cities face, ensuring that the

Table 1
Related work.

Reference	Data source	Contribution to urban data governance
Thompson et al. (2015)	Two case studies with Western Australian public agencies	Provides an initial understanding of the challenges and issues in data governance in the public sector.
Paskaleva et al. (2017)	Interviews with: Manchester, Eindhoven, Stavanger	Provides an understanding of how data governance measures are applied in smart city projects. Presents a preliminary framework that provides data dimensions relevant to city data governance.
Liu, Heller, and Nielsen (2017)	Not specified	Highlights challenges of urban data from heterogeneous sources with quality issues and sensitive content, complicating processing and publication. Proposes a technical framework for collecting, cleansing, anonymizing, and publishing data by sensitivity level to ensure secure, privacy-compliant use.
Beckwith, Sherry, and Prendergast (2019)	Case study in a US suburban neighborhood	Examines how smart cities manage data as a commons to create economic benefits while safeguarding citizens' interests, emphasizing data governance as a community-focused approach that regulates data flow to prevent harm and ensure transparency, protection, and sustainable use.
Lupi (2019)	Enterprise data governance plans versus city plans	Presents a concept for linking data governance to the city's development agenda. The focus is on data privacy and data manipulation in smart cities.
Cuno et al. (2019)	Structured interviews with three German cities	Clarifies the concept of the urban data space, allowing an ecosystem for data exchange and value creation using all types of data within the city. Provides a classification of urban data, including legal and monetary aspects and ideas for technical implementation.
Eke and Eboho (2020)	Literature on urban inclusion, smart cities, and data governance	Provides an approach to understanding how data can be used to improve inclusion in smart cities by describing dimensions: right data, right algorithms, right people, and right policies and standards.
Franke and Gailhofer (2021)	Regulatory debates and policy proposals	Structures the debate on data governance from a regulatory perspective.
König (2021)	Not specified	Describes a citizen-centric data governance framework that addresses the ethical and legitimate challenges of using citizen data.
Choenni et al. (2022)	Not specified	Describes approaches to building data quality and trust in the urban data ecosystem, focusing on collaboration among stakeholders.
Guo et al. (2022)	Not specified	Highlights gaps between technology and theory in urban data governance, noting challenges like data silos and inadequate verification methods. It classifies urban data by legal, monetary, and

(*continued on next page*)

Table 1 (*continued*)

Reference	Data source	Contribution to urban data governance
		technical aspects and proposes a multi-layered framework to foster effective data sharing and value creation within the city.
Kaginalkar et al. (2023)	Interviews with experts in urban air quality	Identifies key challenges in urban data governance, such as fragmented data systems, lack of integration standards, and limited stakeholder engagement. Creating an integrated data infrastructure and promoting collaborative governance will enhance data sharing and analysis for effective, data-driven air quality solutions.
Bokolo (2023)	Interviews with partners within the "+CityxChange" project	Examines data-driven methods to enhance urban planning and service design in smart cities, highlighting issues like inadequate data security, poor interoperability, and risk assessment challenges. The paper underscores the role of data governance in ensuring secure, effective data use through clear regulations, supporting data-driven strategies.
Bozkurt, Flaisch, et al. (2023)	Eight EU cities' data strategies	Explorers' data governance's role in effectively applying urban data strategies, focusing on standardization, training, and clear role definitions to ensure these strategies are practically implemented and sustained.
Bozkurt, Rossmann, et al. (2023)	Expert interviews with 27 EU cities	Captures the current state of data governance in cities, identifying challenges in data handling and success factors for data governance.
Gilman et al. (2024)	Literature on smart city data	Addresses challenges of data in smart cities, such as availability, heterogeneity, management, analytics, privacy, and security. It offers an overview of these issues and emphasizes the need for further research to develop effective data architectures and strategies for smart cities.

UDGRM is not just theoretically sound but also directly applicable to urban administrations. Moreover, to further refine the model and enhance its practical utility, we conducted a systematic evaluation with ten municipal governance experts from the EU. This evaluation assessed the model's comprehensibility, applicability, and completeness, leading to refinements that increase its adaptability across different urban contexts. By integrating both empirical validation and theoretical grounding, the UDGRM bridges the gap between academic research and the operational realities of urban data governance. Additionally, the UDGRM does not solely build on urban governance literature but incorporates established data governance theories (e.g., Khatri and Brown (2010)), which inform the structured design principles of the UDGRM. This ensures that the model aligns with proven data governance concepts while remaining adaptable to the complex and evolving needs of cities. Ultimately, the UDGRM offers a universally applicable, dynamic solution that fosters sustainable and responsive urban data governance by translating scientific insights into actionable governance mechanisms.

4. Understanding of the problem space

This section covers the first task in the DSR process: "understanding of the problem space." It combines the scientific knowledge base and methods of the rigor cycle with the practical findings from the relevance cycle's problem environment. This combination provides an optimal basis for developing a purposeful artifact.

4.1. Building the theoretical knowledge base

A solid theoretical foundation is essential for any DSR project (Johannesson & Perjons, 2021; Peffers et al., 2007). In alignment with this principle, this study integrates both urban-specific governance needs and topics and existing governance theories to develop a governance model that is scientifically rigorous and practically applicable. The UDGRM integrates urban governance research and data governance theories, ensuring the model captures the complexities of urban environments and effective governance mechanisms.

While Section 3.2 outlines the broader research landscape and highlights knowledge gaps, not all studies discussed therein directly shaped the development of governance models. Instead, a core theoretical foundation was derived from the synthesized findings of Bozkurt et al. (2022), who conducted a systematic literature review and content analysis of over 600 academic papers to identify key governance dimensions in urban settings. They specifically analyzed 15 studies with a strong urban focus, using an inductive coding process to distill urban data governance into eight interdependent dimensions: policy, compliance and legal; stakeholder; organization; data classification; data quality; data access; data management; and governance principles. This framework informs the design of urban governance mechanisms and anchors the theoretical basis of our study.

In addition to urban-specific insights, established data governance theories introduce principles that shape structures across various domains. These theories are crucial for structuring accountability, decision-making, and regulatory alignment in complex environments, translating into actionable mechanisms that ensure the UDGRM's effectiveness and practicality. Seiner (2014) introduces the concept of non-invasive data governance, which emphasizes integrating governance mechanisms into existing workflows and organizational structures rather than imposing disruptive, top-down approaches. His approach focuses on formalizing existing accountabilities for data management rather than assigning entirely new responsibilities. Non-invasive governance leverages established policies, procedures, and practices to align with organizational culture and minimize disruptions effectively. This perspective is particularly relevant for urban data governance, where governance must be embedded in pre-existing municipal processes rather than introduced as an additional bureaucratic layer.

The DAMA-DMBOK framework (Dama International, 2017) provides a structured approach to data governance, emphasizing key principles such as standardization, decision rights, and accountability. These principles establish mechanisms to systematically manage data across organizations and ensure compliance with governance policies. Furthermore, Dama International (2017) highlights the integration of governance with other data management domains, including data architecture, security, and data integration, demonstrating the interdependencies within governance structures. This structured approach aligns with the need for standardized data models, metadata management, and interoperability in urban data architectures.

While Dama International, D. M. A (2017) establishes a broad governance framework, Weber et al. (2009) offer a detailed model that specifies roles and responsibilities. Their approach, based on IT governance and organizational theory, introduces a responsibility assignment matrix to streamline decision-making and enhance accountability in data quality management. In the urban governance context, these structured role definitions are essential for ensuring that responsibilities

are clearly distributed between municipal departments, data governance units, and external stakeholders.

Khatri and Brown (2010) differentiate between data governance and data management, emphasizing the distinction between decision rights and implementation. Their five decision domains, data principles, data quality, metadata, data access, and data lifecycle, offer a structured foundation. Additionally, they introduce a governance matrix to clarify decision accountability within organizations, providing a mechanism to allocate governance responsibilities effectively. The differentiation between governance and management is also relevant in urban data governance, where dedicated governance units provide strategic oversight, while data management units focus on the technical execution of governance policies.

Gluchowski (2020) and Mahanti (2021a, 2021b) discuss compliance, risk management, and regulatory governance. Gluchowski (2020) focuses on how governance aids in compliance and risk mitigation through structured frameworks, addressing regulatory challenges, data ethics, and accountability. Mahanti (2021a, 2021b) explores the economic and legal impacts of data governance, demonstrating the influence of governance structures on regulatory compliance. Both perspectives contribute to a broader understanding of governance as a means of ensuring sustainability, legal alignment, and long-term strategic coherence in data-driven organizations. In urban settings, compliance and risk mitigation play a crucial role, particularly in defining data protection classes, privacy mechanisms, and the legal design of data-sharing agreements between municipalities and service providers.

Integrating urban-specific insights with established governance theories, this study bases the UDGRM on a scientifically sound foundation. Bozkurt et al. (2022) identified governance dimensions that help decode urban challenges, and general data governance theories facilitate turning these challenges into actionable governance structures. This approach not only validates the theoretical basis of the UDGRM but also strengthens its methodological integrity. Furthermore, this approach resolves the identified gap in previous urban data governance research, which lacked an integrated governance model that connects theoretical principles with practical governance mechanisms. The design principles of the UDGRM, which incorporate these tested governance theories and mechanisms, will be detailed in subsequent sections. By refining this theoretical foundation through empirical validation with 27 expert interviews, this study ensures that the governance approach is both academically rigorous and applicable to real-world urban governance challenges.

4.2. Identifying challenges in the environment and investigating existing approaches

After detailing the rigor cycle activities of the first DSR task, this section elaborates on the relevance cycle activities within the same task. DSR is a problem-solving paradigm (Hevner et al., 2004); identifying problems and opportunities occurs early in DSR (Hevner, 2007). The application domain specifies the problems and the acceptance criteria for evaluating the artifact by defining how the artifact improves the environment and how this can be measured. In this context, an extensive interview study with experts from 27 EU cities was conducted by Bozkurt, Rossmann, et al. (2023). In DSR, interviews can help determine solutions in the problem space, as the interviewees are in this space and constitute its stakeholders. Thus, the problem space can be adequately considered before the artifact's design (Siemon, 2022). This methodological approach made it possible to gain in-depth insights into the problem area directly from the cities concerned. The expert interviews helped gain a sound understanding of the specific challenges and needs of the cities and precisely define the requirements for the artifact to be developed. These insights are crucial to ensure that the resulting artifact responds effectively to the real problems and needs of the cities and provides measurable added value.

The interviews were conducted with EU cities, using the EU Digital Economy and Society Index (DESI) (European Commission, 2022) as a guide for the selection of cities and focusing on four leading countries (Finland, Denmark, the Netherlands, and Sweden) and the median countries of the DESI (Germany and Austria). In total, 27 cities were interviewed. All interviewees worked directly in city administration and were strategically or operationally involved in data governance and data management. Detailed information on the sample is provided in Appendix B, Table B.1.

In data analysis, the interviews were coded and divided into three themes: "current status," "challenges," and "success factors." These themes underpinned cognitive maps that visualized the data, aiding in understanding data governance's current state, challenges, and success factors in the cities. Cognitive maps were created for all 27 interviews, culminating in an aggregated map capturing the essence (Bozkurt, Rossmann, et al., 2023).

Fig. 2 illustrates the current state of data infrastructure, data sharing, and data governance in the city. No city-wide data governance program defines principles and guidelines and sets the framework for handling data. Departments have their data governance mechanisms that regulate the day-to-day handling of data. The data infrastructure is described as distributed and decentralized, which indicates many redundant data sets. Often, outdated and closed specialist applications characterize the system landscape. Overall, the current state is entirely of data silos, which prevent data exchange, meaning that data are typically shared only to fulfill the legal administrative mandate and in an individual, project-dependent manner. The departments for geographic information systems are just one of the few departments driving data affinity and the breaking down of data silos (Bozkurt, Rossmann, et al., 2023).

Fig. 3 shows the cognitive map section describing the challenges facing cities. The multi-layered challenges in dealing with data are of an organizational nature, such as a lack of personnel; of a cultural nature, such as old-fashioned ways of thinking; and of a technological nature, such as the lack of interoperability. A complete overview of data assets is absent, leading to redundancy and inconsistency. That makes data integration projects complicated and resource-intensive. An old-fashioned mindset shapes the cultural aspects of the organization, which is reflected in the rejection of change and innovation and the reluctance to share data. Even simple data governance activities are considered an additional workload in day-to-day business and are not well accepted. Cultural change is occurring slowly, as cities also face the problem of being unattractive to young employees and suffering from a "chronic" lack of skilled workers, which manifests in low IT expertise, poor technology decisions, and a strong attachment to service providers. However, such significant changes can only be realized with money and political support, which are not always available. Finally, there is a lack of best practices and guidance frameworks required to develop a data governance program (Bozkurt, Rossmann, et al., 2023).

Fig. 4 outlines the success factors. A cross-departmental central unit for data governance needs to be established. This unit needs strong backing from top management to implement the data governance measures. The data governance unit does not implement technical aspects but sets the framework for doing so. This includes activities to define roles and responsibilities. Considering the cautious, old-fashioned way of thinking, a lean-role concept is recommended. One core role is the so-called multiplier, who has specific specialist knowledge and acts as an intermediary between the department and the data governance unit. A city alliance is an essential factor that enables standardization across city boundaries and accelerates implementation projects by exchanging best practices and experiences. In addition, motivation and culture are considered as critical success factors. Therefore, reducing complexity is vital to make the benefits of data governance tangible for everyone and to promote acceptance. A roadmap and iterative implementation are crucial to reducing complexity, as data governance is not a process with start and end points but a continuous cycle (Bozkurt, Rossmann, et al., 2023).

The cognitive map analysis revealed multiple structural and

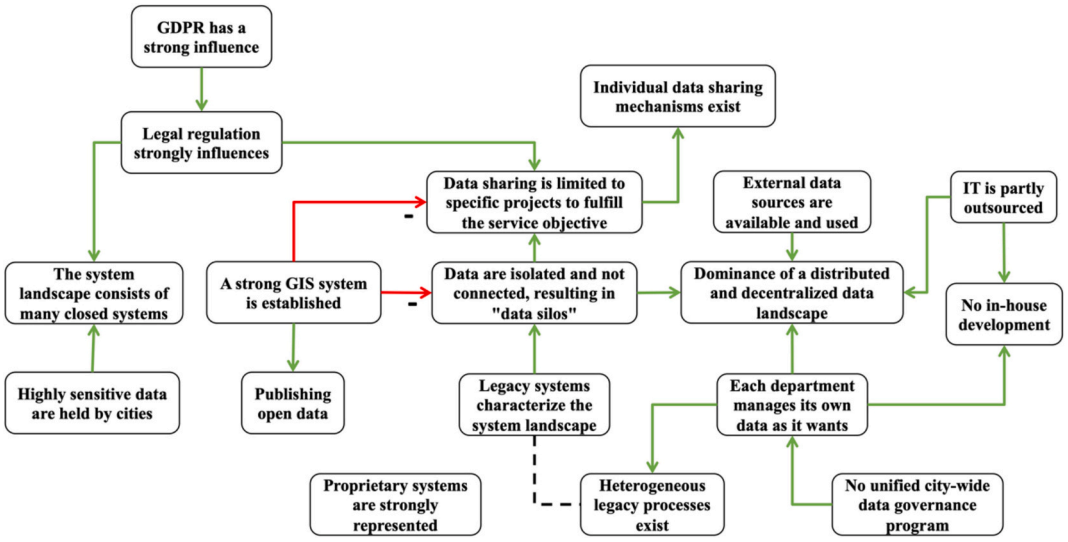

Fig. 2. Part of the cognitive map focused on the "current state." Red arrows = negative impact; green arrows = positive impact. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

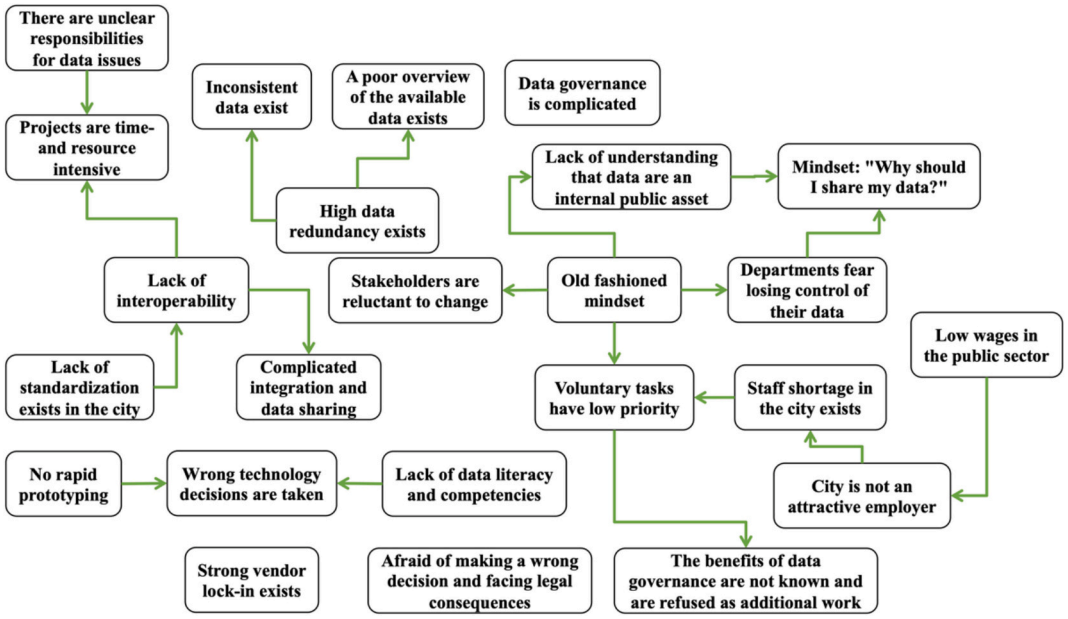

Fig. 3. Part of the cognitive map focused on the "challenges."

organizational barriers in urban data governance that significantly limit data's efficient use and integration. The map enables a detailed definition of the problem and reveals critical challenges in three areas: cultural, structural, and technological barriers. For example, cultural barriers such as the resistance to data-based innovation and structural deficits such as outdated IT infrastructures were identified, as well as a lack of data governance strategies that lead to data silos and redundant data sets. An in-depth analysis also revealed that these problems are caused by organizational structures and technological and cultural factors, highlighting the need for a comprehensive, integrated solution.

A practical and adaptable governance model was developed to address these challenges and equip cities with comprehensive data governance. Its requirements were derived directly from the cognitive maps' analysis, which identified key problem areas and success factors. This analysis underscored the need for fundamental action fields to establish structured, standardized data management practices. To meet these needs, the UDGRM defines essential governance principles while maintaining flexibility and technology independence, ensuring applicability across diverse municipal settings. Additionally, the model integrates requirements based on cultural barriers identified in the interviews to foster acceptance within city administrations. A key finding was the necessity of a data governance model that is easy to understand and implement incrementally, avoiding disruptive transformations. The analysis further revealed that urban governance challenges are interconnected and multidimensional, requiring a holistic approach that equally considers technological, organizational, and cultural aspects. A central issue identified was the persistence of data silos, which the UDGRM mitigates by promoting data exchange and creating interoperable structures. Likewise, the findings emphasized the need for a stronger data-driven culture. To address this, the model includes measures that enhance collaboration among internal and external stakeholders while fostering a data-oriented mindset. Finally, recurring issues such as redundancies and inconsistent data structures are tackled through clearly defined responsibilities and an organized approach to

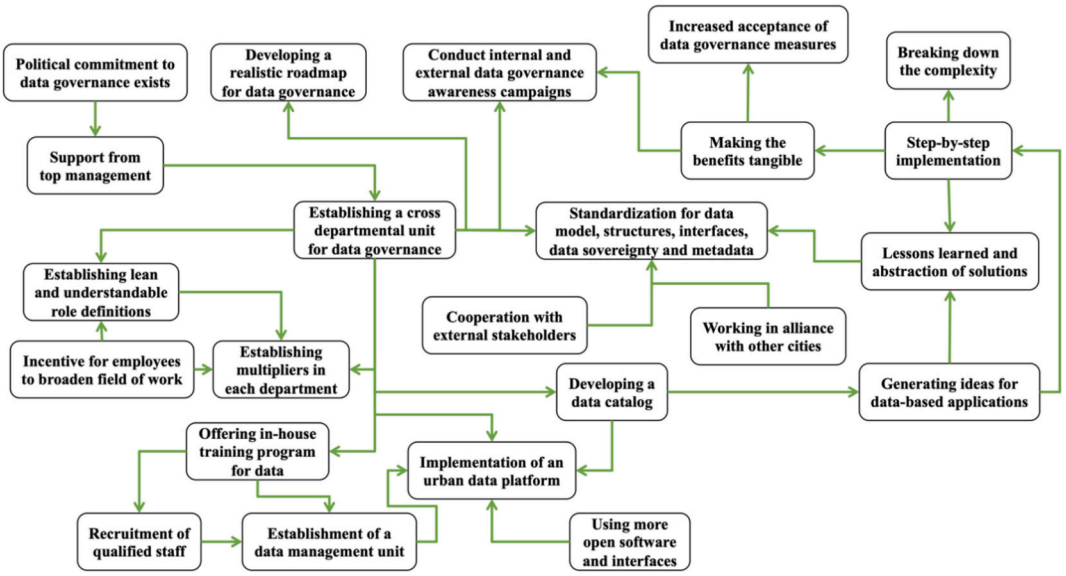

Fig. 4. Part of the cognitive map focused on "success factors."

managing city data assets. These features ensure that cities can leverage the UDGRM to develop robust governance strategies tailored to their specific challenges, ultimately fostering the sustainable use of urban data.

5. Design and development of artifact: The UDGRM

In this section, we describe the design and development of the artifact as the second DSR task (Fig. 1). Our approach follows the principles of reference modeling, a well-established methodological approach in information systems research, extensively explored by scholars such as Fettke and Loos (2003), Rosemann and Reinhard (1997), Rosemann and Schütte (1999), Schermann, Böhmann, and Krcmar (2009). Reference models serve as generalized frameworks that capture best practices and standardized processes within a specific domain, facilitating reuse and adaptation across different organizations. According to Fettke and Loos (2003), they act as conceptual blueprints, representing domain classes and providing context-independent solutions for organizational challenges. Rosemann and Reinhard (1997) and Rosemann and Schütte (1999) highlight their normative function, offering design recommendations for recurring governance problems and enabling knowledge transfer. Vom Brocke (2015) positions reference modeling as an integral part of design science research, helping develop generalizable artifacts that describe solution principles rather than rigid implementations. Similarly, Schermann et al. (2009) emphasize that reference models serve as standardized frameworks to accelerate problem-solving in information systems and organizational structures.

While reference modeling provides the structuring approach for generalizing UDGRM's governance principles and meta-requirements, its substantive content is derived from urban data governance research, general data governance theories, and empirical insights from expert practitioners. To ensure conceptual rigor, the development of UDGRM is based on two key theoretical streams. First, urban-specific governance insights were synthesized by Bozkurt et al. (2022), who systematically identified key governance content for urban data governance through a systematic literature review and inductive coding of 15 directly relevant studies. These insights shaped the key content of the initial UDGRM version, as detailed in Table 2, referencing the original sources from urban data governance literature. Second, UDGRM incorporates established data governance theories, ensuring alignment with widely accepted governance principles. These theories provide structured mechanisms for decision rights, accountability, compliance, metadata management, and interoperability, directly influencing the formulation of UDGRM's design principles.

For instance, Dama International, D. M. A (2017) provides a structured foundation for governance standardization, metadata management, and interoperability, which directly informed UDGRM's approach to standardizing data models and metadata governance. Weber et al. (2009) introduce structured governance roles and accountability models, which influenced UDGRM's governance board and role definitions. Similarly, Khatri and Brown (2010) emphasize the differentiation between governance and management, particularly in decision rights allocation and governance matrices, shaping UDGRM's strategic oversight mechanisms. The model also incorporates Seiner's (2014) non-invasive governance approach, embedding governance mechanisms into existing structures rather than imposing rigid bureaucratic layers, aligning with UDGRM's cultural integration strategies. Furthermore, Mahanti (2021a, 2021b) highlights regulatory compliance and governance risk mitigation, reinforcing UDGRM's legal and compliance frameworks.

Beyond its theoretical underpinnings, the UDGRM was refined through extensive empirical validation, ensuring its applicability to real-world urban governance challenges. The first step in extending the model beyond theory involved 27 expert interviews (Bozkurt, Rossmann, et al., 2023), as shown in Table 2. These interviews yielded expert opinions, detailed information on practical challenges, and access to internal documents and insights from municipal projects. By integrating these elements, we enhanced the initial UDGRM to include practical governance mechanisms observed in real-world applications. This approach reflects the iterative and adaptive nature of reference model development, as described by Vom Brocke (2015), where theoretical frameworks are refined through continuous feedback and empirical validation.

Following this, we attended three practice-oriented conferences and engaged in discussions with practitioners to further develop the artifact. These discussions provided direct insights into existing urban data governance projects, such as digital twin development, data portal architectures, data steward workshops, data catalog initiatives, and role definitions within municipal departments. Practitioners offered detailed insights on their governance processes, challenges, and best practices. This further grounded UDGRM in real-world urban governance dynamics and ensured that the model addressed practical needs.

Finally, we attended two scientific conferences to obtain feedback from scholars through discussions. These exchanges helped refine the

Table 2
UDGRM dimensions synthesized from initial versions and insights from expert interviews.

	Combination logic of scientific literature synthesis (Bozkurt et al., 2022) and expert interviews (Bozkurt, Rossmann, et al., 2023)			
UDGRM dimensions	Key contents of initial UDGRM version (sources)	Concepts derived from expert interviews Challenges and success factors drawn from the interviews	TY	Topic
IT architecture landscape	Standards, interoperability, integrability, IoT, architecture, open API (An, Sun, Bai, & Deng, 2016; Austin & Lie, 2019; Calzada & Almirall, 2020; Cuno et al., 2019; Doneda & Belli, 2020; Kazmi, Serrano, & Lenis, 2019; Lupi, 2019; Thompson et al., 2015)	Legacy systems, proprietary systems, closed systems	CH	Systems
		Urban data platform, open software, and interfaces	SF	
Data architecture landscape	Open-, private-, internal-, and public-restricted data; big, enterprise, research, and government data; data model; data source; data monitoring; data linkage; data infrastructure; data life cycle; data generation; data collection; data storage; data quality; data reusability; standards; interoperability; misshape; asymmetry; inconsistency; misinterpretation (An et al., 2016; Artyushina, 2020; Austin & Lie, 2019; Calzada & Almirall, 2020; Cuno et al., 2019; Doneda & Belli, 2020; Kazmi et al., 2019; Lupi, 2019; Paskaleva et al., 2017; Popham, Lavoie, & Coomber, 2020; Zulkarnain, Kosala, Ranti, & Supangkat, 2019)	Sensitive data, inconsistent data, high diversity, low standardization, missing interoperability, redundancy	CH	Data
		Individual data-sharing mechanisms, data sharing limited to specific projects, complicated integration, and data sharing	CH	Data sharing
		Distributed and decentralized data landscape, data silos	CH	Architecture
		Data classification, data models and structures, data sovereignty, metadata, open data	SF	Data
Organizational structure	Collaborative, comprehensive, alignment, multi-disciplinary, transformation, needs and interests, technology steward, governance officer, responsibilities, ownership, data stewards, data committee, data provider, data consumer, data subject, data collector (An et al., 2016; Cuno et al., 2019; Doneda & Belli, 2020; Lupi, 2019; Paskaleva et al., 2017; Rayi, Bothra, Wallace, & Venkatesh, 2019; Thompson et al., 2015; Yulfitri, 2016)	Non-unified city-wide data governance, unclear responsibilities, each department manages its data in its own way, heterogeneous legacy processes, data silos	CH	Structure
		Cross-sectional unit for data governance, data management unit, lean and understandable role definitions, multipliers in each department, support from top management	SF	
Human resources	Collaboration, data stewards, technology stewards, governance officers (Cuno et al., 2019; Lupi, 2019; Rayi et al., 2019; Thompson et al., 2015; Yulfitri, 2016)	Low wages in the public sector, city not an attractive employer, staff shortage, poor technology decisions, fear of making a wrong decision and facing legal consequences, lack of data literacy	CH	Personal
		In-house training program, incentives for employees to broaden the field of work, recruitment of qualified staff, official instructions	SF	
Culture management	Sharing, standards (An et al., 2016; Artyushina, 2020; Austin & Lie, 2019; Calzada & Almirall, 2020; Cuno et al., 2019; Doneda & Belli, 2020; Kazmi et al., 2019; Lupi, 2019; Paskaleva et al., 2017; Popham et al., 2020; Rayi et al., 2019; Thompson et al., 2015)	Lack of acceptance of data governance, fear of losing control of data, reluctance to publish/share data, unknown benefits of data governance, burden of data governance as additional work, reluctance to change, lack of understanding that data are internal public assets, old-fashioned mindset, voluntary tasks with low priority	CH	Culture
		Organizing awareness campaigns, making benefits tangible	SF	
Stakeholder management	Public service providers, citizens, authorities, research institutions, companies, standards (An et al., 2016; Austin	A high degree of outsourcing	CH	External partner
		Cooperation with external stakeholders, alliance of cities, political commitment	SF	

(continued on next page)

Table 2 (*continued*)

	Combination logic of scientific literature synthesis (Bozkurt et al., 2022) and expert interviews (Bozkurt, Rossmann, et al., 2023)			
	& Lie, 2019; Calzada & Almirall, 2020; Cuno et al., 2019; Doneda & Belli, 2020; Kazmi et al., 2019; Lupi, 2019; Paskaleva et al., 2017; Rayi et al., 2019; Thompson et al., 2015; Zulkarnain et al., 2019)			
Legal and compliance management	Privacy; protection; GDPR; transparency; security; ethics; trust; justice; regulations; legal; rights; sharing; ownership; open-, private-, internal-, and public-restricted data (An et al., 2016; Artyushina, 2020; Austin & Lie, 2019; Calzada & Almirall, 2020; Cuno et al., 2019; Doneda & Belli, 2020; Kazmi et al., 2019; Lupi, 2019; Paskaleva et al., 2017; Popham et al., 2020; Rayi et al., 2019; Sarker, Khatun, Alam, & Islam, 2020; Thompson et al., 2015; Zulkarnain et al., 2019)	Unclear legislation, vendor lock-in	CH	Legal
Methods and tools		Lack of frameworks and best practices, complexity of data governance, no overview of data	CH	Method/ approach
		Consideration of lessons learned and abstraction of solutions, step-by-step implementation, breakdown of the complexity, realistic roadmap, data catalog	SF	

Notes: TY = type, CH = challenge, SF = success factor.

model from an academic perspective, ensuring alignment with existing design science research in digital governance. By integrating practitioner knowledge from expert interviews and practice-oriented conferences with academic perspectives, UDGRM was iteratively refined to bridge the gap between theory and real-world governance needs.

A tabular representation of the UDGRM is insufficient to describe it comprehensively and convey its design principles. Therefore, in Fig. 5, we depict the reference model as a house comprising four foundation layers, four pillars, and a roof bound by dashed lines. This means that activities in individual areas cannot be separated; instead, they mutually influence each other and must be considered and harmonized.

The foundation layers and pillars represent the model's dimensions, while the roof conveys the most fundamental design principle, that is, a city's data governance must constantly evolve and adapt to the changing environmental conditions that affect all foundation layers and pillars. Urban data governance should not be a one-time project (Seiner, 2014; Weber & Klingenberg, 2021) but requires continuous review and evolution to keep the city's data governance program current in a dynamic environment (Bibri, 2021; Del Esposte et al., 2019; Kourtit, Nijkamp, & Steenbruggen, 2017). Data strategy is essential to ensure commitment from all stakeholders (Adelman, Moss, & Abai, 2005; Bozkurt, Flaisch, et al., 2023). Therefore, a realistic roadmap for implementing individual measures must be developed. Successfully implemented measures lead to a change in the organization and the working standards of the affected processes. Therefore, the lessons learned from the changes must always be incorporated into the strategy to avoid an inflexible data governance program; instead, the program must respond appropriately to change.

5.1. IT architecture landscape

The IT architecture landscape represents the fundamental underlying technological requirement for all data life cycle phases, from data capture to deletion (Khatri & Brown, 2010). This essential component forms the backbone that supports and enables all processes in the data life cycle. The design principles are as follows:

- *ITA1 – The complete mapping of the IT infrastructure*: This principle maps which processes exist, who is involved in these processes, which services exist, and which hardware and software are used. This overview helps eliminate redundancies and shadows the IT landscapes (Hermawan & Sumitra, 2019; TOGAF, 2024).
- *ITA2 – Strong internal IT expertise*: This principle establishes and ensures strong internal IT expertise to prevent the transfer of control of the IT infrastructure to external service providers.
- *ITA3 – Open standards and independence of the IT*: In this principle, collaboration with external partners may result in a lock-in with one provider. Such lock-in threatens sovereignty, which has a lasting negative impact on all data-related matters. To avoid being locked to a specific provider, open standards are recommended to ensure the independence of the IT architecture.
- *ITA4 – Data protection levels*: Software should not be closed by default, as the same privacy levels do not apply to all software. Objectively considering whether specific software must be closed by default is appropriate. In this way, the compartmentalization of an entire architecture due to possible data protection concerns can be prevented.
- *ITA5 – Data exchange and interfaces*: Data exchange and system interfaces must already be considered in the IT landscape. A data platform is a central element in the IT landscape for data exchange, in addition to a data warehouse, operational systems, and IoT systems that complete the IT architecture landscape (Dama International, D. M. A, 2017; Gluchowski, 2020).

5.2. Data architecture landscape

The data architecture landscape focuses on the conceptual and logical consideration of data structures, their design, and organization. The design principles are as follows:

- *DA1 – Standardization of data models and extract, transform, and load (ETL) processes*: Standardized data models and ETL processes increase data semantic and syntactic interoperability, allowing existing data to be reused and redundancies to be minimized (Dama International, D. M. A, 2017; Gluchowski, 2020). This makes integration projects significantly faster and more economical.

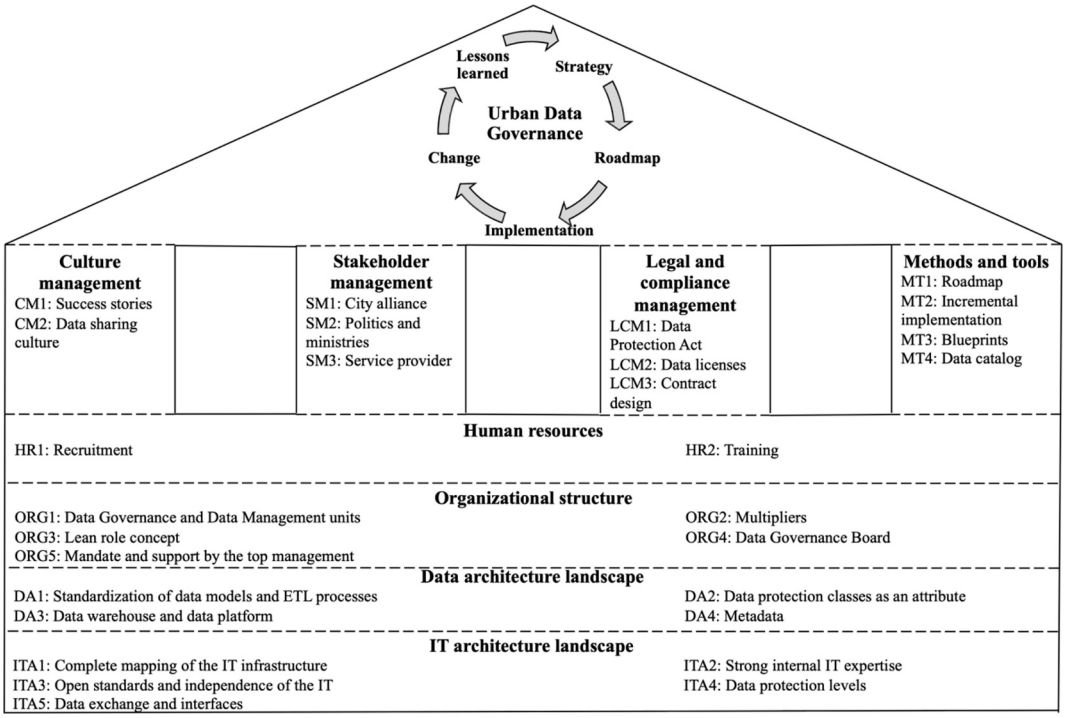

Fig. 5. The urban data governance reference model (UDGRM).

- *DA2 – Data protection classes as an attribute*: The data model should contain the protection classes (open, internal, and closed) at an attribute level, which also facilitates the publishing of open data. Data protection and sharing are essential elements of urban data. Shared data can create high value, but not all data are equally sensitive, which requires additional resources in projects when individual decisions must be made about which data can be shared.
- *DA3 – Data warehouse and data platform*: Infrastructural elements constitute the data warehouse, aggregating internal data from structured sources (Bauer & Günzel, 2013; Vaisman & Zimányi, 2022). The city data platform maps internal and external sources and target systems, focusing on unstructured and time-series data (Barns, 2018; Buchinger, Kuhn, Kalogeropoulos, & Balta, 2021; Jeong, Kim, & Kim, 2020).
- *DA4 – Metadata*: Metadata contributes significantly to better organizing data and improving interoperability and integration (Dama International, D. M. A, 2017; Khatri & Brown, 2010; Weber & Klingenberg, 2021). Particular attention should, therefore, be paid to metadata quality.

5.3. Organizational structure

The organizational structure defines the design principles for roles, units, and authorities. It creates efficient workflows by defining and organizing responsibilities into clearly defined roles and hierarchies. The structure serves as a basis for the targeted alignment of resources and competencies:

- *ORG1 – Data governance and data management units*: The data governance unit is the steering and advisory unit (Dama International, D. M. A, 2017; Mahanti, 2021b; Weber et al., 2009) that works in close cooperation with the individual departments of a city. This unit leads concrete measures, from a city's strategy to implementation, and is involved in designing and implementing data governance measures. By contrast, the data management unit contributes to the technical view of the implementation activities. Both units must be organized centrally and independently of the specialist departments and require authority to issue directives so that the measures of these units are not considered optional. Bundling the two teams into one data unit as a superordinate organization is possible.
- *ORG2 – Multipliers*: Multipliers must be set up in individual departments to break down organizational silos within the city. Multipliers act as intermediaries between the department and the data units. They must be recruited within their departments to ensure the best possible expertise.
- *ORG3 – Lean-role concept*: Role definitions must be clear, and an overload of roles must be avoided (Bozkurt, Rossmann, et al., 2023).
- *ORG4 – Data governance board*: A governance board is required at the highest management level (Dama International, D. M. A, 2017; Gluchowski, 2020; Weber & Klingenberg, 2021), consisting of the department heads of the functional departments, the head of the data unit, and privacy and ethics officers.
- *ORG5 – Mandate and support by top management*: A comprehensive organizational restructure is not possible without the formal approval and mandate of the city's top management.

5.4. Human resources

Employees are essential for digitalizing a city and ensuring successful data governance. Recruitment and training are the two fundamental design principles:

- *HR1 – Recruitment*: When recruiting, the attractiveness of a city as an employer must be reinforced in close cooperation with the human resources department, especially for IT and data-intensive staff. A city is considered a less attractive employer than the private sector (Bozkurt, Rossmann, et al., 2023).
- *HR2 – Training*: A qualification program can help increase employees' data literacy. To ensure a basic understanding, every employee must know the most critical factors in dealing with data. Such an understanding can increase acceptance of data governance measures in the long run and help improve data quality and maintain a data-driven mindset. The focus is on raising awareness of data quality, ensuring basic knowledge of data management and

governance, and defining the measures required to implement them. As part of the qualification program, an extended training path is needed for specific roles, such as multipliers, data managers, and data governance experts. Collaboration with professional training organizations can help in these cases.

5.5. Culture management

Ensuring acceptance of data governance and data-driven thinking requires implementing targeted awareness-raising measures (Bozkurt, Rossmann, et al., 2023; Seiner, 2014). The following design principles should be considered to implement these measures successfully:

- *CM1 – Success stories*: Tangible, successful examples of data governance measures should be presented to all involved to clarify the benefits of data governance for their daily work. This helps ensure that data governance is not perceived as additional work. Awareness-raising campaigns are an effective way to demonstrate the relevance and success of the measures regularly.
- *CM2 – Data-sharing culture*: Particular attention should be paid to promoting data sharing. A culture of data sharing is essential to break down data silos in the long run. Concerns and uncertainties about data sharing must be dispelled through awareness-raising campaigns that clarify that data sovereignty is not lost when data are made available internally or externally.

5.6. Stakeholder management

Cities are complex networks with many stakeholders (Marrone & Hammerle, 2018). Therefore, urban data governance is not limited to city administration but also considers municipal utilities, education, research, technology providers, civic communities, and other cities through three design principles:

- *SM1 – City alliance*: A city alliance offers the opportunity to learn from others' experiences and save resources by achieving goals effectively and efficiently. It promotes cooperation and standardization in a complex network of cities.
- *SM2 – Politics and ministries*: Close cooperation with politicians and ministries is necessary for long-term support, as funding is often impossible without political backing (Bozkurt, Rossmann, et al., 2023). Such collaboration gives policymakers practical insights, thus preventing the enforcement of impractical policies that hinder city initiatives.
- *SM3 – Service provider*: Service providers are essential for cities, so special attention should be paid to their involvement in the city's data strategy.

5.7. Legal and compliance management

Cities own sensitive data that require special attention to be protected appropriately (Barns, Williams, Comninos, & Bartlett, 2017; Bibri & Krogstie, 2020; Liu et al., 2017; Puiu et al., 2016). Legal and compliance management plays a crucial role here by defining design principles that ensure that the process of data-driven work and data projects complies with legal requirements. These principles serve as a guide for implementing measures that guarantee the integrity and confidentiality of data and ensure that all data-based activities are carried out in line with legal provisions and compliance standards.

- *LCM1 – Data Protection Act*: This principle establishes basic legal knowledge among critical people involved in data operations (e.g., data owners and multipliers). It plays a vital role in ensuring that projects are not blocked and that a lack of basic knowledge does not prevent the publication of open data.
- *LCM2 – Data licenses*: Data and protection categories must be drawn up and implemented.
- *LCM3 – Contract design*: Contracts with service providers and software providers must be designed regarding data sovereignty so that the city can always access raw data and APIs.

5.8. Methods and tools

The final pillar addresses the design principles in the context of methods and tools governing urban data. Urban data governance is a comprehensive commitment that requires establishing a secondary organizational structure and must be treated as an integral part of daily operations (Dama International, D. M. A, 2017; Mahanti, 2021a; Weber & Klingenberg, 2021). The data governance department must apply essential methods and tools to operate effectively.

- *MT1 – Roadmap*: A realistic roadmap includes the measures in an urban data governance program. It should be designed to be implemented in stages and to allow reaction to short-term changes.
- *M2 – Incremental implementation*: A step-by-step implementation that starts with easily achievable measures ensures that motivation is maintained and provides cultural management with input that showcases the benefits of implementation.
- *MT3 – Blueprints*: Transferring experience and proven practical solutions to other areas increases internal standardization and implementation efficiency. Workshops and seminars can give participants firsthand information on the most important use cases.
- *MT4 – Data catalog*: A data catalog is a central tool for all areas of urban data governance that is constantly updated and maintained. It makes it possible to break down data silos. It also serves as a source of information and a data quality and development aid for applications.

6. Demonstration and evaluation of artifact

The following section describes the "demonstration and evaluation" task of the DSR process in Fig. 1. Evaluation plays a central role in DSR (Hevner et al., 2004; Johannesson & Perjons, 2021; Peffers et al., 2007; Venable, Pries-Heje, & Baskerville, 2016), as it provides valuable feedback for the further development of the artifact. Without a sound evaluation, the DSR process could merely be based on theoretical assumptions about the benefits of design artifacts. That is, whether a new technology "works" would simply be an assertion rather than empirical evidence (Venable et al., 2016). In our case, we were guided by a formative evaluation, which provides empirically based findings for assessing and improving the artifact. A group of practice experts evaluated the artifact for comprehensibility, applicability, and completeness. The rigor cycle provided the necessary scientific methods for data collection and analysis in qualitative and quantitative form.

6.1. Evaluation method

Salah, Paige, and Cairns (2014) describe three approaches to evaluate conceptual models: (1) evaluation by the author using the literature, (2) evaluation by experts in the artifact's field of application who were not involved in the development of the artifact, and (3) real-world application of the model. Evaluation by domain experts is well suited for evaluating the artifact, as data are collected through semi-structured expert interviews. Expert interviews are an appropriate research method to evaluate artifacts such as models and frameworks because they tend to be conceptual and highly novel in character (Hevner et al., 2004; Peffers et al., 2007; Sonnenberg & Vom Brocke, 2012). Semi-structured expert interviews included standardized questions to evaluate the UDGRMs design principles and open questions to enable the experts to express their thoughts freely and generate exploratory new ideas to improve the artifact further. The overall evaluation process is illustrated in Fig. 6.

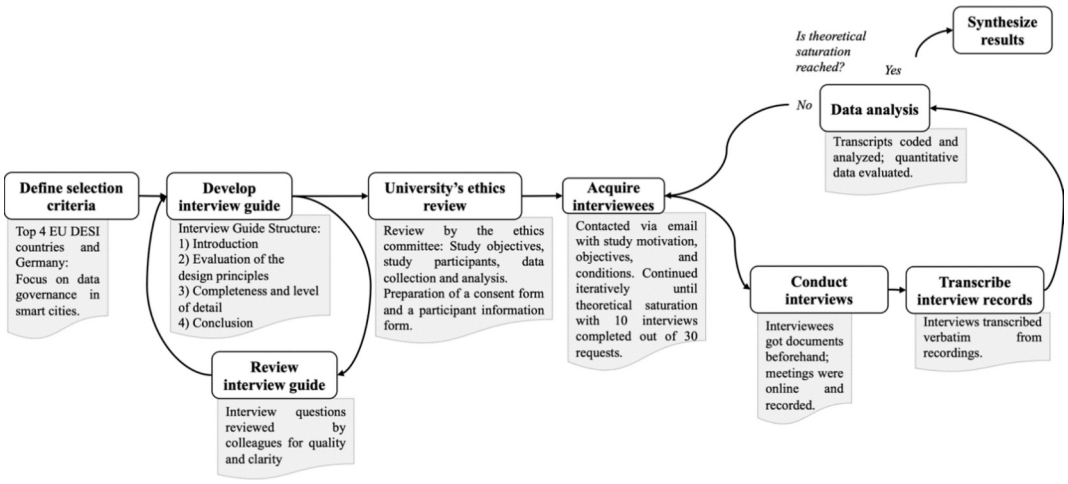

Fig. 6. Evaluation process.

Although we allowed the interviewees enough flexibility in their thoughts, the basic structure of expert interviews made the interview findings comparable. Thus, we developed an interview guide to help conduct the interviews in a targeted and structured manner and to ensure thematic comparability. An interview guide ensures that no important aspects are left out of the interviews (Edwards & Holland, 2013). Its thematic focus is based on the evaluation criteria of reference models, frameworks, and conceptual artifacts of DSR (Frank, 2006; Hevner et al., 2004; Peffers et al., 2007; Salah et al., 2014; Sonnenberg & vom Brocke, 2012). We divided the interview guide into four sections (see Appendix A for the full version). The first section (1) captures interviewees' demographics. Here, interviewees introduced themselves, indicated their professional roles, and described the city's data governance activities. The second section (2) contains an evaluation of each design principle of the UDGRM in terms of its usefulness and ease of implementation based on two questions answered on a five-point Likert scale. The scale for usefulness ranges from 1, "Not at all useful," to 5, "Very useful." For ease of implementation, the scale progresses from 1, "Not at all simple," to 5, "Very simple." Additionally, adoption intention is assessed with ratings from 1, "Not at all likely," to 5, "Very likely." Measuring these variables was relevant to determine whether the reference model's listed design principles met urban data governance objectives. Furthermore, understanding the simplicity of implementation helps determine best practices for a data governance program, showing the effort behind the design principles. With this information, cities can tailor their implementation plan for their data governance program. Beyond that, these variables help establish the direction the artifact needs to be developed and improved. After evaluating the individual design principles, the experts assessed the UDGRM with a question on how likely it is to be used as a guide in the city, capturing adoption intention. A five-point Likert scale was also used, where five means "most likely." The closed questions in section (2) of the interview guide include comment fields for the experts to explain their decision. In this way, the quantitative assessment and the qualitative feedback are combined to generate concrete insights for evaluating the artifact.

The evaluation of usefulness, simplicity, and adoption intention is inspired by the technology acceptance model (TAM) (Davis, 1989), which creates a systematic and comparable model for understanding the perception of the model. Overall, the use of the TAM provides a structured and evidence-based approach (Davis, 1989; Davis & Granić, 2024; Marangunić & Granić, 2015) to evaluate the model, which enables the acceptance and adoption by urban experts to be systematically assessed and the potential for improvement to be identified. Furthermore, the standardized variables make the model evaluation results comparable and enable consistent scoring across several respondents.

Subsequently, the interview guide captures the completeness and level of detail of the UDGRM with open-ended questions (section (3)) and ends with space for topics not discussed during the interview (section (4)). To ensure the understandability of the questions, colleagues at the authors' research institutes reviewed the interview guide. In addition, the study was reviewed and approved by an independent university ethics board regarding the study objectives, respondents, and data collection and analysis. An informed consent form and a respondent information form were provided.

Similar to the first set of interviews to understand the problem space (Section 4.2), we used the DESI to find comparable policy, administrative, structural, and procedural conditions in the cities. The DESI annually assesses the digital performance of EU countries in terms of connectivity, human capital, use of internet services, integration of digital technologies, and digital public services. We focused on two areas in the DESI (European Commission, 2022): the four leading countries (Finland, Denmark, the Netherlands, and Sweden), which bring essential experience in data governance through their advanced expertise in digitalization, and the midfield of the DESI represented by Germany; Germany has taken up the challenge of data governance through smart city projects and digitalization projects in the administration. Finally, working at a German university, we have direct contact with German cities, which helped accelerate the acquisition process. We focused on cities that stand out for data governance and management activities in these countries. We identified these with the help of the smart city community and our research institutions' network, as well as through internet research. We emailed the responsible experts in the cities and explained the study's motivation, objective, and conditions.

The interviewees received the interview guide, the UDGRM description, and the respondent information form in advance and were asked for permission to process and record the data. Before proceeding with the questions in the interview guide, we briefly introduced the UDGRM to the interviewees to clarify any ambiguities. The interviews took place online. After each interview, we transcribed the recording, analyzed the quantitative part of the questionnaire, and coded the qualitative information using a structured coding (Saldaña, 2013) approach with the software MAXQDA (2022). This iterative procedure continued until theoretical saturation was reached.

We aimed to capture a diverse sample of European cities. However, as Table 3 shows, our final sample primarily includes German cities. While we contacted cities from the leading DESI countries, making up 40 % of our outreach, 90 % of the interviews were with German cities, and only 10 % represented cities from these top DESI nations.

One reason may be that we may not have been prioritized as a request from abroad due to a lack of personal networks with these cities,

Table 3
Interview overview of evaluation.

	Total	Germany	DESI top 4
Contacted cities	30	18	12
Conducted interviews	10	9	1
Declined	2	2	0
Ignored	18	7	11
Interviewees	12		
Average duration in min.	53		
Interview language	German (8), English (2)		

and our emails may have ended up in spam filters. In addition, some cities may not have seen a clear benefit in participating in our study, reducing their willingness to respond. Prioritization of other projects and limited availability of resources such as time and staff, especially when cities were busy with critical local initiatives or political issues, may also have played a role. Finally, late responses or staff changes in some cities made communication more difficult, as successors did not respond to our requests.

We acknowledge that this sample composition may affect the generalizability of our evaluation. Germany's specific administrative structures, legal frameworks, and cultural attitudes may have influenced respondents' perspectives. These potential limitations are discussed in more detail in Section 7.

6.2. Evaluation results

According to the Federal Institute for Research on Building, Urban Affairs and Spatial Development, a city with 20,000–100,000 inhabitants is considered a medium-sized city, one with 100,001–480,000 a smaller metropolis, and one with more than 480,000 a large metropolis (Bundesamt für Bauwesen und Raumordnung, 2024). Therefore, the sample comprises 10 % medium-sized cities, 70 % smaller metropolises, and 20 % large metropolises. All respondents are directly involved in data governance and management in their city at various levels. For example, the data governance managers are mainly responsible for driving the implementation of data governance in the city but do not have a leadership role. Digitization managers have a leadership role and oversee the city's digitization efforts, including data governance and strategy. Chief digital officers are the strategic and visionary shapers of the city's digitalization, including data governance and strategy. On average, respondents have been in their current position for 3.3 years; however, their experience in the public sector is much higher, with some having more than 15 years of professional experience. The detailed characteristics of the sample are listed in Appendix B, Table B.1.

For the adoption intention of the UDGRM, the experts responded by stating how likely the reference model would be used in the city (see Table 4). A generally high probability of being used was indicated, with 80 % of experts rating it as "likely" and 20 % as "moderately likely." The mean value is 3.70, and the standard deviation is relatively low at 0.48, which indicates a high level of consistency in the experts' opinions.

The qualitative analysis of the comments on this assessment unearthed several notable expert opinions. By making minor adjustments in line with the city's specific structure, the model can effectively accompany and expand existing processes. The model serves as a source of inspiration for data governance and encourages reflection on aspects of urban planning that have not previously been considered. The model also helps clarify and explain the need for data governance, especially to policymakers.

Table 4
UDGRM Adoption intention.

	$\bar{x}$	s	∧	∨	$\tilde{x}$	Σ
Adoption intention	3.7	0.48	3	4	4	37

Notes: $\bar{x}$ = mean, s = standard derivation, ∧ = minimum, ∨ = maximum, $\tilde{x}$ = median, Σ = total.

The UDGRM was generally received positively, mainly because of its scientific origins rather than traditional consultancy knowledge. The experts considered it a valuable tool, especially for cities still in the early stages of data governance. The illustration using the pillar model was particularly successful, showing that the "house" collapses if one of the "pillars" is not sufficiently implemented. The breakdown of the personnel landscape, the organizational landscape, and the IT architecture was also considered fundamental, as it shows the foundations that must be built to implement the various requirements successfully.

Despite the positive response, the experts considered a one-to-one implementation of the model unlikely, as they perceived it as "rough" and lacking the necessary level of detail. Overall, the interviewees emphasized that cities prefer to rely on solutions that have proved successful in practice in other cities. Therefore, the experts strongly recommended introducing the UDGRM in a pilot project as soon as possible.

Table 5 presents each design principle with calculated statistical values, demonstrating clear understanding among experts, as indicated by their thorough responses. The usefulness criterion reveals that 93 % of the design principles have a mean score of 4 or higher. Notably, 75 % of these principles show a standard deviation below 1, reflecting consistent expert assessments. Using the median is appropriate for the ordinal Likert scale (Jamieson, 2004), with results showing that half of the principles are very useful, 46.43 % are useful, and 3.57 % are moderately useful for the data governance program.

Simplicity reflects how straightforward the design principles are to implement. The mean value shows that 67.86 % (19 out of 28) of the principles are challenging to implement, with a low standard deviation in 60 % of these cases. The median reveals that 82.14 % of the principles are rated as not at all simple or hardly simple. Despite their usefulness, these principles require simplification for easier implementation.

Adequately capturing the reasons for the evaluation requires a detailed analysis of the qualitative data collected for each design principle in the comments field of the assessment. We ran the qualitative analysis at the dimension level for a concise presentation and used a structured coding approach (Saldaña, 2013). We created a top-level code for each dimension at the first level (Dimensions 1–8). At the second level, we organized the codes relevant to the associated design principles under this code (Design Principles 1–28). The third level comprised codes inductively derived from the context of the corresponding text. Next, we present synthesizing the experts' statements for each dimension.

6.2.1. IT architecture landscape

Comprehensive mapping is not only an inefficient and resource-intensive measure but is also highly challenging to implement. Such a mapping is optional to begin implementing data governance. Instead, the essential steps are to precisely record and document the critical aspects of the IT infrastructure. The difficulties in the management and governance of data occur mainly when the originators and users of data are not identified. Therefore, targeted management is necessary at a certain point to create a precise cartography, which can serve as the basis for improved management and effective governance. The parts of the data landscape that remain unknown risk not living up to the principles and not following governance principles (e.g., informal data governance; Mahanti, 2021b). A comprehensive IT infrastructure map would be of high added value for data governance, but focusing solely on the IT infrastructure is not the primary task of data governance. Instead, the challenge is establishing a balanced understanding and holistic control over data in an organizational context to ensure effective and legally compliant information handling.

Strong internal IT expertise undoubtedly positively influences data governance (Dama International, D. M. A, 2017; Gluchowski, 2020; Seiner, 2014). This results from gaining a comprehensive overview of the IT infrastructure and providing competent contacts available for

Table 5
Statistical summary of the interview results.

DP	Usefulness						Simplicity					
	$\bar{x}$	s	∧	∨	$\tilde{x}$	Σ	$\bar{x}$	s	∧	∨	$\tilde{x}$	Σ
ITA1	4,4	1,07	2	5	5	44	2,1	0,88	1	4	2	21
ITA2	4,5	0,97	2	5	5	45	2,4	0,7	1	3	2,5	24
ITA3	4,1	0,74	3	5	4	41	2,6	0,97	1	4	3	26
ITA4	4,5	0,85	3	5	5	45	2,8	1,23	1	4	3	28
ITA5	4,5	0,71	3	5	5	45	2,4	0,97	1	4	2,5	24
ITA	**4,4**	**0,87**	**2,6**	**5**	**4,8**	**44**	**2,46**	**0,95**	**1**	**3,8**	**2,6**	**24,6**
DA1	4,3	0,67	3	5	4	43	3	1,15	1	5	3	30
DA2	3,5	1,35	1	5	3,5	35	2,4	1,07	1	4	2	24
DA3	4,3	0,82	3	5	4,5	43	2	0,94	1	4	2	20
DA4	4,6	0,97	2	5	5	46	2,6	0,97	1	4	2,5	26
DA	**4,18**	**0,95**	**2,25**	**5**	**4,25**	**41,75**	**2,5**	**1,03**	**1**	**4,25**	**2,38**	**25**
ORG1	4,7	0,48	4	5	5	47	2,6	0,97	1	4	3	26
ORG2	4,3	0,82	3	5	4,5	43	2,9	1,1	1	4	3	29
ORG3	4,5	0,71	3	5	5	45	2,7	0,95	1	4	3	27
ORG4	4,1	0,88	3	5	4	41	3,3	1,06	2	5	3,5	33
ORG5	4,5	0,53	4	5	4,5	45	2,5	0,97	1	4	2	25
ORG	**4,42**	**0,68**	**3,4**	**5**	**4,6**	**44,2**	**2,8**	**1,01**	**1,2**	**4,2**	**2,9**	**28**
HR1	4,6	0,52	4	5	5	46	2	1,05	1	4	2	20
HR2	4,5	0,53	4	5	4,5	45	3,5	0,53	3	4	3,5	35
HR	**4,55**	**0,525**	**4**	**5**	**4,75**	**45,5**	**2,75**	**0,79**	**2**	**4**	**2,75**	**27,5**
CM1	4,2	0,63	3	5	4	42	3,8	0,63	3	5	4	38
CM2	4,1	0,99	2	5	4	41	3,5	0,71	2	4	4	35
CM	**4,15**	**0,81**	**2,5**	**5**	**4**	**41,5**	**3,65**	**0,67**	**2,5**	**4,5**	**4**	**36,5**
SM1	4,4	0,52	4	5	4	44	3,4	0,7	2	4	3,5	34
SM2	4,3	0,67	3	5	4	43	2,7	1,25	1	4	3	27
SM3	4,4	0,84	3	5	5	44	2,1	0,99	1	4	2	21
SM	**4,37**	**0,68**	**3,34**	**5**	**4,34**	**43,67**	**2,73**	**0,98**	**1,33**	**4**	**2,83**	**27,33**
LCM1	3,5	1,58	1	5	4	35	3,1	1,2	1	4	3,5	31
LCM2	4,1	0,74	3	5	4	41	3,2	1,03	2	5	3	32
LCM3	4,7	0,67	3	5	5	47	2,7	1,16	1	5	2,5	27
LCM	**4,1**	**1**	**2,33**	**5**	**4,33**	**41**	**3**	**1,13**	**1,33**	**4,67**	**3**	**30**
MT1	4,5	1,08	2	5	5	45	2,8	1,48	1	5	2,5	28
MT2	4,5	0,85	3	5	5	45	3	0,82	2	5	3	30
MT3	4,4	0,52	4	5	4	44	3,1	0,99	2	5	3	31
MT4	4,5	0,85	3	5	5	45	2,7	0,67	2	4	3	27
MT	**4,48**	**0,83**	**3**	**5**	**4,75**	**44,75**	**2,9**	**0,99**	**1,75**	**4,75**	**2,88**	**29**

Notes: $\bar{x}$ = mean, s = standard derivation, ∧ = minimum, ∨ = maximum, $\tilde{x}$ = median, Σ = total.

inquiries, enabling timely testing and implementation. The presence of internal experts provides a significant advantage when evaluating and implementing new software solutions, as the organization can understand the requirements precisely and assess them appropriately. However, developing and maintaining solid internal IT expertise is challenging, especially during skill shortages (Bauch, 2024; Feijao, Flanagan, Van Stolk, & Gunashekar, 2021; Leifels, 2020). This shortage is further exacerbated by the attractiveness of the free market economy, as it often offers more lucrative opportunities for qualified professionals. Despite these challenges, investing in internal IT expertise remains critical to ensure long-term benefits regarding effective data governance and strategic decision-making.

Acquiring open standards isn't always necessary, as finding suitable service providers can be time-consuming and resource-intensive. While standardization is crucial, it need not always rely on open standards due to the considerable effort involved. Essentially, fundamental principles at the IT infrastructure level are critical for data governance.

6.2.2. Data architecture landscape

According to the experts, standardizing data models and ETL processes is a fundamental design principle, as described in theories on data governance (Dama International, D. M. A, 2017; Gluchowski, 2020; Mahanti, 2021b; Weber & Klingenberg, 2021). Despite this recognition, they perceived practical implementation as challenging and time-consuming, given the complex and interwoven data landscape. However, using existing standards makes more sense than defining one's "own standards." Thus, promoting these principles should be an integral part of data governance.

Introducing data protection classes at the attribute level was considered valuable. However, given the effort required, the benefits may not be as great at the detailed level of data models. Data warehouses and platforms are critical components of the data landscape (Dama International, D. M. A, 2017; Gluchowski, 2020; Mahanti, 2021b). Nevertheless, their implementation involves significant labor and costs, and thus, they are not considered a top priority.

Experts emphasized the importance of metadata, which contributes to the versatile use of data beyond its pure context. They viewed metadata as a decisive enabler for various data governance activities, with specialist departments playing a pivotal role in maintaining this data.

6.2.3. Organizational structure

The experts agreed that a central authority needs to be created, even if it has different names (e.g., "data house," "data office"), with the goals to control, steer, design, monitor, and support (Dama International, D. M. A, 2017; Mahanti, 2021a; Mahanti, 2021b; Seiner, 2014). However, they also noted that although an organizational department can be set up quickly, staffing it with qualified personnel is a considerable challenge. Furthermore, the unit must be at a high level and, for example, report to the chief information officer as a staff unit. Without support at the top management level, implementation can be even more complex (Dama International, D. M. A, 2017; Seiner, 2014; Weber & Klingenberg, 2021).

While multipliers are crucial as interfaces, motivating them is challenging, and they may lack resources. A lean role is preferable, as overly detailed roles can obscure understanding. Instead of imposing roles, they should be carefully tailored to existing employees to enhance acceptance (Seiner, 2014).

Finally, while a data governance board can be beneficial, it isn't

always the highest priority since cities often have existing decision bodies supporting data governance without additional structures.

6.2.4. Human resources

A key aspect is the development of skills, which requires not only specialized knowledge but also the dissemination of broad knowledge (Gupta & Cannon, 2020; Koltay, 2016). An essential part is requiring specific training courses for all employees and building general data literacy. Internal training measures and the development of data literacy can automatically make the city a more attractive employer. Close cooperation with human resources management is essential, especially as building data literacy is firmly anchored in data governance. A well-trained workforce can increase the effectiveness of data governance and strengthen the city's attractiveness as an employer.

6.2.5. Culture management

The current situation needs more transparency in ongoing projects, successes achieved, failed projects, and the reasons for failures. Clear documentation of these aspects is essential to avoid repeated mistakes in other departments. While mistakes are unavoidable but invaluable as they serve as teaching moments (Hartl & Hess, 2017; Tuukkanen, Wolgsjö, & Rusu, 2022). The experts, therefore, advocated deliberately enabling rapid learning processes through action. However, this approach is at odds with the traditional management principles of cities, which aim to establish error-free processes to ensure customer satisfaction and to be responsible for the community. The attitude toward failure is determined mainly by the organizational culture.

Experts agree that campaigns and events promote data culture, but the efforts involved are considerable. Given limited financial resources, a lack of personnel resources makes implementation considerably more difficult, especially if external services are not considered. The governance unit could be central in representing data culture and weighing the pros and cons. However, this activity relates less to implementing campaigns and events and more to creating guidelines and holding workshops.

6.2.6. Stakeholder management

A city alliance can be highly beneficial for fostering data governance and gaining from each city's experiences. Further, involving city stakeholders is essential, especially municipal utilities, which exchange extensive data (Batty et al., 2012; Simmhan, Ravindra, Chaturvedi, Hegde, & Ballamajalu, 2018; Zanella et al., 2014). Political decision-makers and ministries' participation is primarily necessary to ensure financing for data governance measures. However, their role is more about staying informed than actively engaging in implementation.

Service providers are primarily required to adapt to specifications in the contracts resulting from the data governance strategy. Here, data governance takes on more of a monitoring function than an active shaping role.

6.2.7. Legal and compliance management

The experts considered basic legal knowledge desirable but optional for data governance. Although legal and compliance management is beneficial, active involvement in data governance is not a direct obligation. Instead, being capable of dealing with issues related to data is sufficient for legal departments. Data protection classes and licenses are considered in the context of open data, and here, an orientation toward existing licenses (Alamoudi, Mehmood, Aljudaibi, Albeshri, & Hasan, 2020; Zhu, Thomas, Moore, & Allen, 2021) rather than efforts to design new ones is useful. Data sovereignty is primarily ensured through contract design, in which implementation of new contracts is more feasible than adapting existing contracts. However, the responsibility of data governance is to provide guidelines for data sovereignty rather than to write contracts.

6.2.8. Methods and tools

A clear roadmap is essential as it provides guidance and ensures the continued pursuit of overarching goals despite adjustments (Zada, Persson, & Nielsen, 2022; Zaoui & Souissi, 2020). Experts recommend a step-by-step approach that aligns with this roadmap, emphasizing iterative processes that create blueprints and insights for broader applications.

The data catalog, a key tool, requires complex implementation involving all departments and not just the data governance team. Although the technology aspect is manageable, setting up involves extensive coordination.

6.3. Future development

The experts noted the UDGRM's well-structured and easy-to-understand nature. They perceived it as less abstract and more focused on practice and concrete applications than other approaches. The experts also emphasized the importance of considering data governance dimensions in context to derive concrete measures. Although they mentioned no specific areas as missing, they recommended that the mutual impact of the UDGRM design principles be more strongly emphasized.

The experts also suggested describing the design principles using characterizations of a mock-up city to make them more tangible. Such a tool would define the city's features and characteristics and thus provide an exemplary step-by-step guide for implementing the design principles, possibly organized as a catalog of possible solutions. Moreover, the experts noted the interview guide, with a few minor adjustments, as a tool for self-assessment to help decision-makers reflect on their current position and consider the usefulness of implementation.

In addition, the experts suggested expanding the UDGRM with a maturity model that breaks down the individual fields of action by milestones, that is, design principle (e.g., data catalog) divided into stages such as (1) decision and deployment of the data catalog software, (2) creation of guidelines for the data catalog, and (3) collection of metadata for a pilot area. Such a maturity model could be implemented using an interactive web-based tool that guides users through the UDGRM and presents corresponding elements for evaluation. In doing so, an urban data governance dashboard could be created that shows monitoring and target tracking at a glance and identifies problem areas.

Finally, the experts recommended that all terminology be presented in the city's national language to increase the possibility of acceptance. Using foreign language terms can act as a deterrent and reduce acceptance.

7. Discussion and conclusion

The UDGRM represents a holistic and actionable model for data governance in an urban context, addressing gaps in both scientific literature and practice (Bozkurt et al., 2022; Bozkurt, Rossmann, et al., 2023). In its current form, the UDGRM works as an instrument that presents the relevant fields of action and design principles of urban data governance to cities in eight dimensions. This structured approach supports the development of specific data governance programs and serves as a basis for evaluating existing measures to identify optimization potential and areas for expansion. The experts regarded the model as a beneficial guide, especially for cities less experienced with data governance, highlighting its practical relevance in structuring governance efforts, improving interoperability, and aligning municipal departments.

We developed it as part of a research project using the DSR approach, ensuring scientific rigor while directly addressing the practical challenges of urban data governance through activities in the relevance cycle. The structured development process incorporated both theoretical foundations and empirical insights, making the model adaptable to real-world governance complexities. To promote DSR in digital

governance and improve traceability, we structured this article to reflect the DSR process undertaken, based mainly on Hevner et al. (2004) and Hevner (2007).

7.1. Alignment with DSR guidelines

We checked compliance with the DSR guidelines described in Section 2 to reflect on the work critically. Guideline 1 explains that the purpose of a DSR project is to develop a purposeful artifact. This artifact can take various forms, such as a construct, a model, or a method. Innovations that define ideas, practices, technical capabilities, and products are emphasized. These innovations are created by linking IT, people, organizational context, and the social environment (Hevner et al., 2004). As we described in Section 5, the UDGRM represents a reference model for data governance in an urban context. It enables a multidimensional view that includes IT, cultural aspects, and organizational structures. Although data governance is not a new concept, the UDGRM is distinct in its focus on urban issues and its holistic approach. Its innovative character lies in integrating the different dimensions and adapting to the specific requirements of urban environments.

Guideline 2 states that a DSR project must have a problem-oriented focus. The research should specifically address a problem of practical relevance for people, organizations, and information technology. In this way, practice can benefit from an artifact, such as a model that identifies and examines problems (Hevner et al., 2004). The UDGRM fulfills this criterion by focusing on the appropriate urban data governance challenge. To this end, we extensively invested in analyzing the practical environment and the problem, which we identified through the relevance and rigor cycles, as explained in Sections 3.2 and 4.

Guideline 3 specifies that the result of the project (i.e., the artifact) must undergo a rigorous evaluation. The aim is to determine how well the artifact fulfills the expected environmental benefits (Venable et al., 2016) by assessing completeness, functionality, consistency, and usability (Hevner et al., 2004). Although the artifact undergoes an extensive evaluation, as we described in Section 6, capturing the core aspects of adoption intention, usefulness, and ease of implementation through expert interviews, the resulting outputs of the DSR process in the form of scientific publications ensures an ongoing evaluation of the ideas and approaches that lead to the final UDGRM.

According to guideline 4, a research contribution must be made. In this context, the artifact represents the contribution of the DSR project. However, methodological contributions and contributions to the knowledge base (foundations) also arise during the DSR project (Hevner et al., 2004). In this project's context, the literature review and empirical data collection in 27 EU cities revealed a gap in reference models, frameworks, and other support mechanisms for implementing data governance in cities (Sections 3.2 and 4). Therefore, the UDGRM closes this research gap by expanding the data governance and digital government knowledge base. Furthermore, the application of Hevner et al.'s (2004) framework, illustrated by a step-by-step illustration, represents an added methodological value that contributes to digital government research using DSR, highlighted by Fedorowicz and Dias (2010), Carter et al. (2022) and Goldkuhl (2016) as requiring further expansion.

Guideline 5 specifies that the development of the artifact must be based on scientific principles and research methods to ensure scientific rigor. Rigor results from effectively using the existing knowledge base and research methods (Hevner et al., 2004). The DSR process for UDGRM was firmly grounded in the rigor cycle, integrating both urban data governance research and general data governance theories, which shaped the model's design principles. The methodological toolbox included a systematic literature review, qualitative data collection with expert interviews, qualitative data analysis (cognitive mapping and coding), quantitative data analysis with statistical tools, and scientific writing.

In guideline 6, Hevner et al. (2004) describe design as a search process, with an iterative and incremental process achieving the "right" design. In the case of the UDGRM, several steps led to the version presented in this article. This process included the development of an initial framework based on scientific foundations (Sections 3.2 and 4.1), the collection of empirical data from the problem domain (Section 4.2), and the subsequent integration of both sources into the final artifact (Section 5). In addition, we engaged in continuous communication with the scientific community through ongoing publications and with the practitioner community through meetings and practitioner conferences.

Finally, guideline 7 states that the DSR project's results should be written and published reader-oriented (Hevner et al., 2004). This article presents the UDGRM to the scientific community and describes the entire research and development process. Additionally, we developed a practitioner-oriented document to ensure accessibility and usability beyond the research setting, providing clear guidance for municipal decision-makers and data governance teams.

7.2. Alignment with the RQ of the study

Regarding the RQ, we initially asked, "How can a scientifically grounded reference model improve data governance in cities?" We tackled this question by achieving the three research objectives defined in the introduction.

For research objective (1), we focused on the conceptual development of the UDGRM based on the DSR paradigm. Although Hevner et al. (2004) and Hevner (2007) provide a framework for DSR (e.g., through guidelines and the DSR cycles), they do not offer a concrete implementation plan for a research project. Our structured approach ensured that the development of the UDGRM was not only theoretically rigorous but also practically relevant, directly addressing urban data governance challenges. The iterative process of integrating scientific literature, empirical data, and stakeholder feedback allowed us to refine the model to ensure its applicability in real-world governance contexts. By demonstrating how the DSR paradigm can produce a governance model that is both scientifically grounded and practically valuable, this study contributes to the methodological advancement of digital government research.

For research objective (2), we sought a detailed characterization of the dimensions and elements of the UDGRM, drawing from scientific literature and first-hand experiences of 27 EU cities. The systematic literature review and data governance theories provided the theoretical foundation, while the interviews helped identify real-world governance barriers such as data silos, inconsistent governance policies across municipal departments, and limited data culture. The UDGRM was specifically designed to overcome these issues by defining clear governance structures, promoting standardized data-sharing mechanisms, and fostering a governance culture that enhances coordination across administrative entities. By aligning theoretical insights with practical needs, the UDGRM supports cities in improving their data management strategies and governance effectiveness.

Finally, for research objective (3), we evaluated the utility of the artifact in practice through feedback from ten experts specializing in data governance across EU cities. The evaluation assessed the model's comprehensibility, applicability, and completeness, focusing on adoption intention, design principle usefulness, and implementation feasibility. Results indicated a median adoption intention of 4 (on a 5-point Likert scale), demonstrating the model's perceived relevance. However, while the design principles were consistently rated as useful, implementation feasibility remained a challenge: most measures were rated as complex ($\leq$3), except for cultural management (rated 4), largely due to resource-intensive requirements. Experts emphasized the need for additional implementation tools, such as a detailed urban data governance roadmap, to facilitate adoption. Despite these challenges, the UDGRM was recognized as a valuable guide for cities, offering a structured approach to improving governance efficiency and data interoperability.

7.3. Contributions

This study advances urban data governance by introducing and validating the UDGRM, a structured framework addressing governance challenges. In contrast to previous work, the UDGRM integrates technical, organizational, and cultural dimensions such as organizational structure, cultural management, stakeholder management, and legal and compliance management, thus providing a holistic solution previously unavailable in the literature, as described in Section 3.2. More importantly, the UDGRM is not just a theoretical construct but a practical instrument that translates established governance principles into actionable mechanisms. By enhancing interoperability, strengthening cross-departmental collaboration, and establishing structured decision-making pathways, the model equips urban administrations with the tools needed to improve governance efficiency and data-driven policymaking.

We conducted a comprehensive analysis to ensure that the model authentically addresses the real challenges of urban administrations. Based on cognitive maps from interviews with representatives of 27 EU cities, we identified multiple structural, organizational, and cultural barriers that limit efficient data use and integration in urban environments. These findings fed directly into the development of the UDGRM and firmly anchored the model in practice. The UDGRM mitigates data fragmentation and governance inefficiencies by providing a structured approach to policy integration and long-term strategic planning.

Furthermore, our work contributes to the methodological discussion in the fields of data governance, digital government, and DSR. We demonstrate how a structured, iterative approach can lead to a practical and adaptable artifact. In contrast to ad-hoc models (Section 3.2), which lack methodological rigor, the UDGRM follows a structured DSR approach, combining theoretical grounding with empirical validation. This methodological rigor enhances the model's effectiveness in real-world application scenarios (Hevner et al., 2004; Peffers et al., 2007).

A key aspect of this study is the structured evaluation of the UDGRM by ten municipal specialists from the EU, which provides critical validation of its practical applicability. The experts evaluated the model's comprehensibility, applicability, and completeness, offering valuable feedback that informed its refinement for broader adoption. Such a structured review process has not been conducted before and adds a crucial layer of validation that underlines the model's practical relevance (Venable et al., 2016). The results confirm that the UDGRM serves as a strategic governance tool, providing urban administrations with a structured approach to improving data policies, enhancing compliance mechanisms, and fostering a more integrated governance culture.

Additionally, the UDGRM helps cities assess governance maturity, refine data policies, and implement sustainable governance improvements. Its technology-agnostic and inclusive design supports cities of all sizes in scaling governance strategies and adapting to evolving digital challenges. By integrating structured decision-making processes with empirical insights, the model enhances cities' ability to navigate the complexities of modern urban governance.

Our research bridges the gap between theory and practice by integrating established governance theories with empirical insights, addressing a critical shortcoming in existing studies (Section 3.2). The UDGRM draws upon principles from data governance research, urban data governance, and reference modeling, ensuring both theoretical rigor and practical applicability.

The UDGRM brings together technical, organizational, and cultural governance aspects into a unified framework. While previous studies focused on isolated aspects of data governance, our model captures their complex interdependencies to provide a more comprehensive solution. This integrative approach enables cities to adapt to evolving challenges while ensuring long-term sustainability in data governance.

In conclusion, our study fills a critical gap in the literature by providing a novel, evaluated reference model that bridges the divide between theory and practice in urban data governance. The UDGRM enhances the understanding of how urban data governance is currently organized and offers a practical tool for cities to optimize their data governance practices. This work lays the groundwork for future research and practice, contributing valuable knowledge to the fields of data governance, digital government, and design science research.

7.4. Limitations and future research

Despite the extensive findings, this study has limitations that can be addressed in future research. First, our evaluation results are mainly based on responses from Germany, as interviews with the top 4 DESI countries only made up 10 % of the sample. This could influence the generalizability of the results, as specific cultural and organizational circumstances in Germany may play a role. For example, according to the DESI index (European Commission, 2022), Germany has a lower level of digitalization, which could make it more difficult to implement innovative IT solutions across the country. This could explain why the design principles of IT architecture are seen as useful but difficult to implement, while they might be seen as easier to implement or less relevant in more technologically advanced countries. In human resources, the shortage of skilled workers and limitations related to wage agreements could lead to the UDGRMs design principles being considered valuable but challenging to implement. For example, wage agreements could limit flexibility and reduce the attractiveness of the public sector as an employer compared to the free market economy, where skilled IT professionals may find better earning opportunities. These are some examples of how the specific German context may have influenced the results of the evaluation of the UDGRM. Moreover, the absence of participants from leading smart cities like Vienna, London, and Barcelona may have limited our insights into advanced smart city practices. Future research should seek to broaden geographical representation, thereby enhancing the artifact's applicability and capturing a more diverse set of experiences and challenges from globally recognized smart cities.

Second, the study is limited to the EU, as we wanted to have comparable cities in political and structural terms. However, future research could make comparisons beyond this sample in an international context and possibly include approaches already accepted and established in the UDGRM. The sample could also be expanded to include city-related organizations (e.g., public utilities, universities, municipal service providers and ministries, and other public institutions), as these may already have data governance experience that could be integrated into the work.

Third, while we did not provide a detailed comparison with existing data governance frameworks and enterprise reference models, such as the DAMA-DMBOK framework (Dama International, D. M. A, 2017) or the DGI framework (The Data Governance Institute, 2023), it is essential to highlight that the UDGRM addresses unique challenges inherent in urban environments that differ significantly from corporate settings. Cities are complex ecosystems with diverse stakeholders, including multiple municipal departments, citizens, businesses, and external partners, which require a governance model that facilitates collaboration and data sharing across various entities (Bozkurt, Rossmann, et al., 2023; Marrone & Hammerle, 2018). Moreover, cities face organizational complexities like decentralized structures leading to data silos and redundancies, cultural resistance to change, and specific legal and compliance requirements distinct from those in corporate environments (Bozkurt, Rossmann, et al., 2023; König, 2021). The UDGRM incorporates dimensions such as organizational structure, cultural management, stakeholder management, and legal and compliance management to address these urban challenges. These aspects are often not fully captured in corporate frameworks designed for hierarchical organizations with fewer stakeholders and more direct decision-making processes (Khatri & Brown, 2010; Weber et al., 2009). Although some dimensions might overlap, the UDGRM differs in its design principles by providing a holistic approach tailored to the multifaceted nature of

urban data governance. This includes addressing technological barriers like outdated IT infrastructures using the layers of IT Architecture Landscape and Data Architecture Landscape and focusing on human resources to tackle the skills gap in city administrations (Bozkurt, Rossmann, et al., 2023). Future work will involve benchmarking the UDGRM against existing frameworks to elucidate these differences further and highlight the unique contributions of the UDGRM.

Through the artifact, we aim to promote research in urban data governance. This is highly relevant, given the increasing importance of data. Inspiration for further work also comes from the experts on evaluation listed in Section 6.3. Further development of the artifact includes adapting the design principles according to the assessment, deepening the details of the overall reference model to enable implementation, and adding to the improvements mentioned. Examples include a web-based interactive application of the UDGRM for self-assessment, dashboard and monitoring, road mapping, and the provision of best practices. The success of data governance in cities depends heavily on the data culture and the acceptance of the measures. Therefore, a stronger focus of the UDGRM could be on reinforcing cultural design principles. A crucial requirement is that all stakeholders, at both the top and bottom levels, are committed to implementing measures. Data governance will inevitably bring challenges that must be communicated and presented, especially the benefits and vision of data governance. Ultimately, it must be shown which changes can be successfully implemented with data governance and which goals and visions of the city will only be realized with proper data governance.

CRediT authorship contribution statement

Yusuf Bozkurt: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Alexander Rossmann:** Writing – review & editing, Supervision. **Zeeshan Pervez:** Writing – review & editing, Supervision. **Naeem Ramzan:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Interview guide for the evaluation of the UDGRM

A.1. Introduction

- What is your current position, and what are your duties?
- How long have you been working for the city and in your current position?
- Please briefly outline your city's data governance and data management activities.

A.2. Evaluation based on the TAM

In the table below, rate the UDGRM design principles along the aspects of usefulness and simplicity on a 5-point scale, with 5 being the highest score:

- Usefulness (U): How useful is [design principle] for the data governance program?
- Simplicity (S): How easy is it to implement [design principle]?

	1	2	3	4	5
U	Not at all useful	Hardly useful	Moderately useful	Useful	Very useful
S	Not at all simple	Hardly simple	Moderately simple	Simple	Very simple
AI	Not at all likely	Unlikely	Moderately likely	Likely	Very likely

Notes: AI = adoption intention.

A.3. IT architecture landscape

Design principle	U	S	Comments
The complete mapping of the IT infrastructure (incl. Processes and software)			
Ensuring a solid IT expertise in-house			
Considering open standards and independence when designing IT architecture			
Ensuring that the level of data protection is already considered at the level of the IT infrastructure			
Considering data exchange and system interfaces at the infrastructure level			

A.4. Data architecture landscape

Design principles	U	S	Comments
Standardizing data models and ETL processes			
Recording data protection levels as an attribute in the data models			
Implementing data warehouse and data platforms as central infrastructures in the data ecosystem			
Paying particular attention to metadata (quality)			

A.5. Organization structure

Design principles	U	S	Comments
Establishing data governance and data management teams in the city			
Establishing multipliers in the departments (data stewards)			
Implementing of a lean-role concept			
Establishing a data governance board			
The measures of the data governance unit are mandatory for all departments			

A.6. Human resources

Design principles	U	S	Comments
Increasing attractiveness as an employer and recruiting qualified employees			
Implementing basic (for all) and advanced (for data-intensive personnel) training program			

A.7. Culture management

Design principles	U	S	Comments
Communicating success stories, but also failures			
Promoting data culture through workshops, campaigns, events, and awareness-raising			

A.8. Stakeholder management

Design principles	U	S	Comments
Establishing a city alliance that enables cooperation and cross-city standardization			
The cooperation and involvement of politics and ministries			
Collaborating with service providers in line with the city's data strategy			

A.9. Legal and compliance management

Design principles	U	S	Comments
Teaching basic legal knowledge to crucial personnel in data-related administration			
Developing and implementing data licenses and data protection categories			
Ensuring that contracts with service providers and software vendors are designed with data sovereignty in mind			

A.10. Methods and tools

Design principles	U	S	Comments
A realistic implementation plan/road map			
A "step by step" approach to implementation			
Transferring experience and best practice solutions to other areas with blueprints			
Implementing a data catalog			

A.11. Adoption Intention

How likely is it that you will use the UDGRM in your city?

Score	Comments

A.12. Completeness and level of detail

- What is your impression of the UDGRM? How would you improve or change the model (e.g., dimensions, design principles)?

- What other tools should the UDGRM contain to be more practical?

A.13. Conclusion

- What do you think is vital for the success of data governance in cities?
- Is there anything else you would like to add that still needs to be addressed?

Appendix B

Table B.1
Interview overview.

#	CC	Pop. range	Position of interviewee (years in position)	Interview date	Scope
1	AT	200,000–250,000	Head of Statistics and Research (7)	Q4/2022	ICEIEA
2	DK	40,000 - 50,000	Program Leader, Smart Cities (5)	Q4/2022	ICEIEA
3	FI	250,000 - 300,000	Development Manager, Data (2)	Q4/2022	ICEIEA
4	FI	200,000 -250,000	Program Manager, Data-Driven City for Citizens (1)	Q4/2022	ICEIEA
5	DE	50,000–100,000	Chief Digital Officer (2)	Q3/2022	ICEIEA
6	DE	450,000–500,000	IT Architect (3)	Q2/2022	ICEIEA
7	DE	50,000–100,000	IT Architect (7)	Q2/2022	ICEIEA
8	DE	50,000–100,000	Head of Business Development and Smart Cities (4)	Q3/2022	ICEIEA
9	DE	300,000 - 350,000	Chief Digital Officer / Data Manager (3 / 1)	Q2/2022	ICEIEA
10	DE	100,000–150,000	Chief Digital Officer (4)	Q2/2022	ICEIEA
11	DE	750,000 - 800,000	Chief Digital Officer / Smart City Manager (4 / 1)	Q2/2022	ICEIEA
12	DE	550,000 - 600,000	Smart City Manager (7)	Q2/2022	ICEIEA
13	DE	1,000,000 - 2,000,000	Data Governance Lead (2)	Q2/2022	ICEIEA
14	DE	50,000–100,000	Chief Digital Officer (3)	Q3/2022	ICEIEA
15	DE	100,000–150,000	Smart City and Urban Data Manager (4)	Q3/2022	ICEIEA
16	DE	300,000 - 350,000	Head of IT / Smart City Manager (5 / 1)	Q2/2022	ICEIEA
17	DE	150,000–200,000	Data Manager (4)	Q3/2022	ICEIEA
18	DE	550,000 - 600,000	Geodata Manager / Program Leader, Smart Cities (7 / 4)	Q3/2022	ICEIEA
19	DE	50,000–100,000	Data Manager (2)	Q3/2022	ICEIEA
20	DE	1,000,000 - 2,000,000	Smart City and Urban Data Manager (6)	Q2/2022	ICEIEA
21	DE	600,000 - 650,000	Chief Digital Officer (3)	Q3/2022	ICEIEA
22	DE	250,000 -300,000	Data Manager and Data Governance Lead (2)	Q3/2022	ICEIEA
23	DE	150,000–200,000	Smart City Manager (3)	Q4/2022	ICEIEA
24	NL	150,000–200,000	Chief Digital Officer (1)	Q4/2022	ICEIEA
25	NL	650,000 - 700,000	Program Manager, Digital City (2)	Q4/2022	ICEIEA
26	NL	550,000 - 600,000	Chief Data Officer (4)	Q4/2022	ICEIEA
27	SE	100,000–150,000	Head of Data Department / Data Governance Lead / GIS Manager (2 / 1 / 5)	Q4/2022	ICEIEA
28	DE	250,000 - 300,000	Data Governance Lead (3)	Q1/2024	Eval.
29	DE	100,000–150,000	Digitalization Manager (3)	Q1/2024	Eval.
30	DE	150,000–200,000	Digitalization Manager (4)	Q1/2024	Eval.
31	DE	300,000 - 350,000	Digitalization Manager (4)	Q1/2024	Eval.
32	DE	350,000 - 400,000	Deputy Chief Digital Officer (3)	Q1/2024	Eval.
33	DE	50,000–100,000	Data Governance Lead (4)	Q1/2024	Eval.
34	DE	150,000–200,000	Digitalization Manager (3)	Q1/2024	Eval.
35	DE	1,000,000 - 1,500,000	Chief Digital Officer (4)	Q1/2024	Eval.
36	DE	1,500,000 - 2,000,000	Data Governance Lead (3)	Q1/2024	Eval.
37	SE	150,000–200,000	Data Governance Lead (2)	Q1/2024	Eval.

*ICEIEA: Identifying challenges in the environment and investigating existing approaches.
*Eval.: Evaluation.

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