

DEVELOPMENT OF A DATA GOVERNANCE FRAMEWORK FOR SMART CITIES

T. Osu^{1*}, D. Navarra¹

¹Dept. of Computer Science, University of Liverpool, Liverpool, L69 3DR UK -
tope.osu@icloud.com, diego@studionavarra.co.uk

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ABSTRACT:

The world is experiencing an unprecedented rate of urbanisation, with 70% of its population expected to live in urban cities by 2050 (United Nations, 2018). This is driving demand for smart city development projects, that address city related issues such as traffic congestion, inadequate housing, excessive crime rates, strains on utilities like energy and water, amongst others. The volume and analysis of data associated with these activities, call for a mechanism for managing data in smart cities.

This paper is aimed at developing a data governance framework for managing data generated by smart cities, and improving the way they operate as well as the quality of life of their citizens. The paper will highlight the characteristics of smart cities, the importance for cities to become smart, how the smartness of cities can be measured, and which cities around the world are considered smart. It will also discuss why data is important for the success of smart cities, the types and sources of data typically present in smart city settings and the data management challenges that plague smart cities globally.

A sequential mixed methods research approach incorporating qualitative and quantitative data collection and analysis methods was employed, following a multi-step approach starting with analysis of existing frameworks and interviews with subject matter experts. This was followed by a survey of industry professionals, for insights on key framework components, and the use of case studies and questionnaires for framework evaluation.

Throughout the research process, the focus of smart cities on people rather than technology was prominent. As such, the most important theme of the framework was identified as “People”, particularly in their roles as data stewards and data owners. The remaining five themes of the recommended data governance framework are, Process, Technology, Data, Protection and Valuable Insights.

1. INTRODUCTION

With more than 50% of the world’s population already living in urban areas and the rate predicted to grow to 70% by 2050 (United Nations, 2018), city operations globally are experiencing a significant increase in demand for space utilization, crime management, transportation, food, air quality and even clean water. Although COVID-19 might have a reverse effect on urbanization, it actually adds another level of complexity to the challenges of city operations as they strive to utilize technology and data to not only manage the spread of the virus, but also to drive the decentralization of business activities from city centres and promoting the concept of remote working. The quest to solve the diverse and complex challenges faced by city operations, has seen the demand for smart city solutions increase drastically with the smart cities market expected to grow from \$410 Billion in 2020 to \$820 Billion by 2025 (GlobalNewswire, 2020).

Underpinning the ability of smart city solutions to solve these challenges, is the large amounts of data generated by cities and the analysis of that data for the development of initiatives that significantly improve quality of life (Aher, 2018), as well as the experience of businesses. As such, as urban areas embark on a transformation journey to becoming smart, a key requirement is the ability to capitalise on data generated by both people and internet enabled objects (Internet of Things, IoT), dispersed across cities. Similar to urban population, connected IoT devices are also experiencing an unprecedented growth and predicted to

amount to 50 billion in quantity by 2030 (Statistica, 2021). These connected devices produce data with a variety of characteristics, from single metric of a machine’s health to streaming video feeds of crowds of people that require real-time analysis.

Consequently, this research paper aims to analyse the data requirements of smart cities and to propose a suitable data governance framework for the making of data-driven decisions, improving operational efficiency as well as ensuring data quality and regulatory compliance. The framework provides an efficient mechanism for harnessing urban data and creating intelligence to support the improvement of city operations departments and the services they offer. The research approach taken is spread over three steps as depicted Figure 1 below,

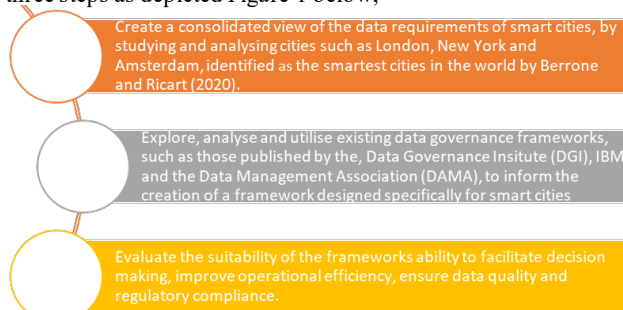


Figure 1. Research Objectives

* Corresponding author

Following the review of the background research material on smart cities and their data management challenges, the paper describes the approach taken for the selection of suitable data management principles and their appropriate consolidation into a data governance framework.

Evaluation of the framework is performed, by assessing its suitability for governing data in three of the world's leading cities in sustainability and citizen quality of life, as identified by Berrone and Ricart (2020), London, New York and Amsterdam. Thereafter, the paper concludes with its findings and offers recommendations for areas of further research.

2. LITERATURE REVIEW

2.1 Smart Cities

Despite the varying and subjective views on what constitutes a smart city, a common factor in most definitions is “People” and how the complex network of the city's resources come together to improve the quality of their lives. Gassmann, Böhm and Palmić (2019) in their book about the digital innovation in cities, depict the smart city as one that aims to solve many of the problems plaguing global urbanization. In the book, they highlight city related challenges imposed by population growth on city operations and resources, resulting in problems such as traffic congestion, excessive crime rates, inadequate housing strains on utilities like energy and water, lack of social inclusion, increasingly diverse lifestyles, air and noise pollution, etc. These along with a myriad of other city related challenges, are increasingly being addressed by innovative digital solutions designed to increase the smartness of cities and improve the quality of life of citizens.

Lehr (2018, p. 3) highlights the importance of having citizens at the heart of all smart city related solutions. Rather than simply using technology to develop smart city solutions as the end goal of innovations, truly smart cities use technology as an enabler for creating solutions that not only improve the community, but also produce better governance, services, opportunities and social equity for all community members.

Many countries such as India are experiencing an unprecedented growth in population, with more and more of their citizens migrating from rural areas to urban cities. To address the challenges of urbanization in India, in 2015 the Prime Minister embarked on a mission to transform 100 Indian cities into smart cities, with smart solutions designed to improve the physical, institutional, social and economic infrastructures of the cities (Ministry of Housing and Urban Affairs, Government of India, 2021). These smart city projects will deploy a multitude of innovative solutions with the objective of increasing city smartness, in terms of design, utilities, housing, mobility and efficient use of technology. The end game of these projects is the better management of complexity, increase in efficiencies, reduction of expenses and ultimately, improvement in the quality of lives (Kandpal, 2019). One of the fortunate Indian cities to be part of this program, is Allahabad where smart city solutions such as intelligent traffic management systems, smart parking systems, environmental sensors, waste management systems, crowd management analytics and smart mobile apps for crime monitoring/prevention are being deployed (Kandpal, 2019).

2.1.1 Data in Smart Cities: Deployment of smart city solutions require a digital platform as a backbone for integrating systems across the city, thereby facilitating the aggregation of multiple data sources for analysis in support of the efficient and centralized management of city assets.

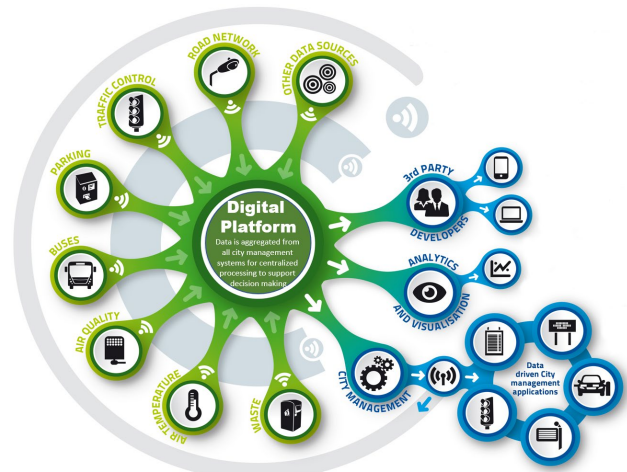


Figure 2. Smart City Platform

Smart city solutions generate huge volumes of data, that could be structured or unstructured, originating from a variety of disparate sources and potentially requiring real-time analysis. This level of complexity poses data management challenges around quality, integration of data sources and types, privacy and security, as well as the selection and prioritisation of solutions to effectively and efficiently address stakeholder needs.

According to the Data Governance Institute (2020) organisations and cities alike, need formal processes on how to manage data, realize value from it, minimize cost and complexity, manage risk and ensure regulatory compliance. These can all be achieved through the effective application of appropriate data governance frameworks.

2.2 Data Governance

Data governance is a concept that has grown in importance and significance over the past few years, in line with the rapid explosion of a myriad of game changing technologies. This growth, coupled with the rise of big data and the fact that organizations need to trust their data, prior to investing in its analysis for data-driven decision making, makes data governance important. Ladley (2012) defines data governance as,

“the organisation and implementation of policies, procedures, structure, roles, and responsibilities which outline and enforce rules of engagement, decision rights, and accountabilities for the effective management of information assets.”

Within this context, data governance is the use of authority in combination with policies, for the purpose of ensuring that information assets are both properly and effectively managed.

In this section, two industry recognised, and widely utilised data governance frameworks are reviewed to understand their structure and composition in terms of their chosen data management components.

2.2.1 The DGI Data Governance Framework: The Data Governance Institute (DGI) is a vendor-neutral organisation that provides freely available information on best practices, and valuable guidance about data governance (DGI, 2020). The DGI framework provides a logical structure for the classification, organisation and communication of activities that involve the use of enterprise data for making data-driven decisions.

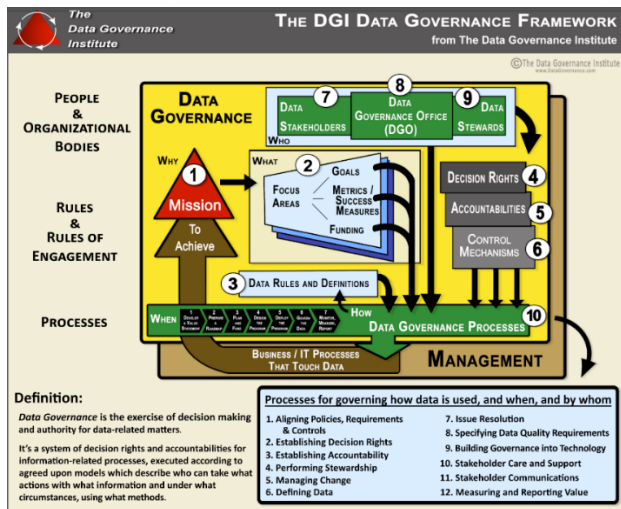


Figure 3. DGI Data Governance Framework

As seen in the DGI data governance framework graphic in Figure 3 above, the framework consists of ten distinct and universal components, all of which to some extent can be expected to be present in all types of data governance programs. According to the DGI (The Data Governance Institute, 2020), frameworks help with organizing how we think and communicate about complicated or ambiguous concepts. They also provide a practical and actionable mechanism, data stakeholders from across any organization (including city operation teams) to come together with clarity of thought and purpose for the management of data.

2.2.2 DAMA DMBOK2 Framework: The Second edition of the Data Management Body of Knowledge (DAMA-DMBOK2) provides a comprehensive view of the challenges, complexities, and value that can be expected from the effective management of data (DAMA International, 2017). DAMA-DMBOK2 provides all stakeholders involved in the management of data with a robust framework to aid the management of their data and to increase the maturity of their information infrastructure. The framework brings together key elements that comprehensively describe the challenges of data management and how they should be addressed by,

- Defining a set of guiding principles
- Implementing enterprise data management best practices, methods and techniques, functions, roles, deliverables and metrics
- Establishing a common vocabulary to facilitate the flow of data across multiple systems

As shown in Figure 4 below, the framework consists of 11 data management functional areas, that if successfully implemented, will help city operations teams more effectively and consistently utilise data insights to solve city related problems.



Figure 4. DAMA-DMBOK2 Framework (DAMA International, 2017)

2.3 Towards a Data Governance Framework for Smart Cities

With smart cities made up of multiple systems that govern various aspects of city management such as the movement of people, information and goods; the creation and distribution of energy, water and food; the equitable and effective provision of education and healthcare; and the provision of public safety and opportunities for social inclusion (Nahrstedt et al., 2017), the scale and complex dynamics associated with the integration of these systems pose significant challenges to the management of data.

If data governance can be used to successfully manage data generated by individual systems, it should be possible to scale it up for managing data generated by the multiple systems that support citywide operations. Successful smart cities will have to efficiently aggregate a myriad of solutions, in order to improve overall quality of life of citizens and the ease of doing business.

This research will prove that extending the application of data governance across the multiple systems that come together to create smart cities, will facilitate data-driven decision making improve operational efficiency, ensure data quality and regulatory compliance.

3. RESEARCH APPROACH

A sequential mixed methods research approach which integrated qualitative and quantitative data collection and analysis methods, was used to manage the process of exploring the concept of smart cities and their data management requirements from the perspectives of professionals in both fields. The research process started with a knowledge discovery phase that involved extensive literature review and interviews with SMEs in the fields of Smart City and Data Governance. This provided guidance with the identification of focus areas and the design of a survey questionnaire that was subsequently shared with industry professionals, to gather information about their perceptions of the characteristics of smart cities and their data management requirements.

The Zachman framework, which is an ontology that enables the comprehensive and composite description of complex ideas (Zachman, 2008) using communication interrogatives (i.e., What, how, where, who, when and why), was used to formulate the questions of the questionnaire. The questionnaire was created on the Qualtrics experience management platform (Qualtrics, 2020), and delivered primarily through channels such as Smart city related LinkedIn groups and cold emails sent to professionals globally in smart city related organizations and government agencies.

In total, 286 professionals attempted the survey, out of which 148 provided responses valuable to the research and 113 consented to the use of their data for the purposes of the research. The research results that follow are based on the 113 participants, a diverse group of professionals, with representation from 18 sectors (varying from health/wellbeing, liveability, tourism, to technology, energy and water) and 51 cities (27 countries) across the world.

4. DATA ANALYSIS AND FINDINGS

4.1 Smart City Characteristics

The first key objective of the survey questionnaire was to understand from the perspective of industry professionals, their perception of the characteristics of a smart city. The responses to the questionnaire provide some insights into how these characteristics can be analysed from the following perspectives.

4.1.1 Definition of a smart city: There are quite a few definitions of smart city, most of which are subjective and vary from city to city depending on the social, economic, physical, and institutional make-up of the underlying city. One key constant in the definition, tends to be a focus on people, and this resonates with the diverse audience of the survey participants as shown in the word cloud in Figure 5, with the People-Centric theme being the most referenced.

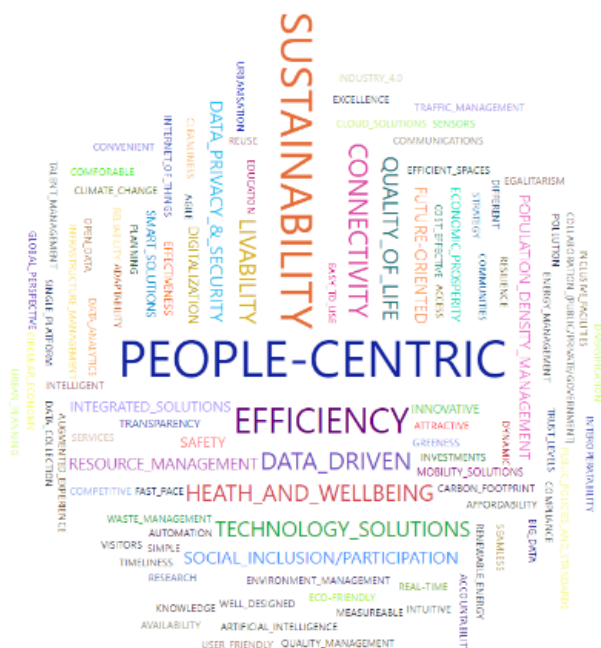


Figure 5. Smart City Characteristics

Pulling together the top 10 themes from survey responses to questions relating to smart city characteristics, a potential comprehensive definition could be crafted as follows,

*“A highly **Connected** city where **Technology** and **Data** are **Securely** utilized, to create **Efficient**, **Liveable** and **Sustainable** environments, where **People** can experience utmost **Health**, **Wellbeing** and **Quality of life**”.*

4.1.2 Criteria for measuring the smartness of cities: The survey questionnaire also explored factors that should be measured, for identifying the smartness levels of cities. And in addition to being people-centric, connected and sustainable as highlighted in the definition, references were also made to the availability of smart, integrated and mobility related solutions, the quality of air, the efficient management of resources and social inclusion and participation of citizens in community related activities. Almost half of the survey participants, identified Singapore as the smartest city in the world, followed by London and Tokyo (Figures 6 below).

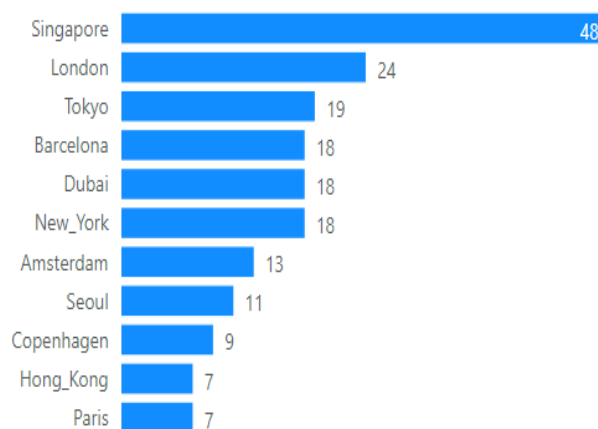


Figure 6. Top 10 Smartest cities

5. A DATA GOVERNANCE FRAMEWORK FOR SMART CITIES

A data governance framework designed specifically for smart cities, will enable the city to extract the most possible value from its data assets, thereby supporting decision-making processes, improving operational efficiency and ensuring regulatory compliance, for the ultimate purpose of improving the quality of life of its citizens, visitors and businesses alike. In particular, the implementation and use of the framework will facilitate,

- Collection and storage of data in a consistent manner across the city
- Categorization and standardization of data using appropriate data classification techniques
- Use of control and monitoring solutions, for data protection using appropriate governance and security measures
- Transformation and integration of multiple data sources
- Analysis of data for creating value and informing decision making processes

5.1 Framework Components

Using techniques such as quantitative and thematic analysis, the feedback collected through the survey of industry professionals on smart cities and their data management requirements, resulted in the identification of 15 aspects of data management perceived to be the most important and relevant to smart city operations management. In recognition of the MDM Institutes definition of data governance, which is the formal orchestration of People, Process and Technology, to help organisations leverage data as an enterprise asset (The MDM Institute, 2016), the People, Process and Technology themes were used to form the foundational triangle of the data governance framework. Data, Valuable Insights and Protection were subsequently added, creating a total of six themes, under which the 15 identified aspects of data management were grouped and used to create the data governance framework as shown in figure 10 below.

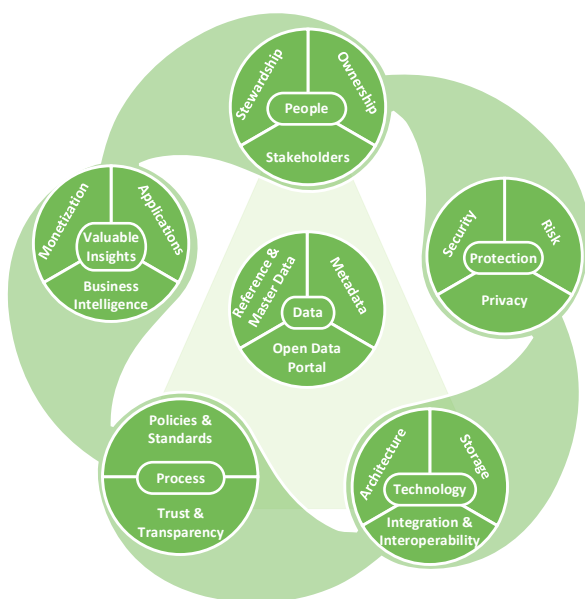


Figure 10. Data Governance Framework for Smart Cities

5.1.1 People: The People theme of the data governance framework relates to the teams that will be responsible (data stewards) and accountable (data owners) for the city's data sets. The theme consolidates the data management aspects of Stewardship, Ownership, and other general data stakeholders, that together create a framework for exercising authority through the application of policies and standards, in order to ensure proper management of data sets. Under this theme, smart cities should create a data governance advisory committee made up of data owners, as a governing body responsible for providing strategic guidance, prioritization of projects and initiatives and approval of data policies and standards across the city.

Under this theme, a stewardship council of data stewards from all business areas should be tasked with the duty of embedding approved data related policies and standards across all city agencies. The Data Stewards, in their capacity as members of the Stewardship council, will work together to recommend improvements and/or additions to data related policies and standards, that will be channelled to the data governance advisory committee for review and approval (Plotkin, 2014). The data stewards, in addition to their role as enforcers of data policies and standards, will be also be responsible for the examination of data sets against predefined criteria for accuracy, completeness and integrity.

5.1.2 Process: The Process theme of the triangle, which relates to rules, regulations and oversight, will be used to describe an understanding of how data will be stored, moved, changed, accessed and secured. In addition, for compliance reasons, a focus on processes related to control, audit and monitoring will also be required.

In complex environments, such as smart cities, multiple interconnected systems and platforms will be used for managing the transactional and operational activities of various organizations. Such environments will require efficient processes for organising, managing, governing, and facilitating the use of data sets. These efficient processes can be provided through a standardized data governance framework with a formal and unified set of policies and standards, enforced by a cross functional leadership body to ensure consistency in the processing of data across all city agencies.

Without such a framework and appropriate levels of authority, individual agencies or analytical groups across the city will unilaterally make decisions in their own interests, which could potentially result in a fragmented state with data definition conflicts and source of truth issues (Allen and Cervo, 2015).

5.1.3 Technology: The Technology theme relates to the physical hardware and systems that will form the infrastructure for the data governance framework, ensuring the integration and interoperability of multiple data sources for the realisation of a single source of truth data platform. It plays a vital role at various stages of the data governance journey, from data storage and data protection to the generation of valuable insights.

Under this theme, the system architecture will be designed to facilitate the seamless integration of the multitude and variety of data sources in the smart city environment. This will also consist of a set of rules, policies, standards and data models for governing and defining the data types and how they will be collected, used, stored and managed. It will also depict the flow of information between users and business processes.

The technology theme will focus on integration, as it pertains to the consolidation and transformation of data into consistent formats, to facilitate data flow within and between data stores, applications, and organizations across the smart city. While interoperability on the other hand will enable systems to have clear and shared expectations for the contents, context and meaning of data exchanged between themselves (Data Interoperability Standards Consortium, no date).

5.1.4 Data: As cities continuously strive to become more attractive places to live, their reliance on data-driven solutions to improve their operations and the services offered to their citizens is rapidly growing. As such, the data theme is placed in the centre of the framework to highlight its importance in the ecosystem of smart cities.

The Master data aspect of this theme represents the implementation of a structured approach for defining and managing the critical data sets of a city, such that there is a single point of reference (one trusted source of truth). Examples of such data sets are parties (e.g., citizens, vendors, suppliers, employees, etc.), places (e.g., regions, office locations, tourism sites etc.) and things (e.g., products, assets, documents, accounts, etc.).

The Metadata aspect identifies, defines, and classifies data within subject areas, thereby enabling users to manage the context as well as the content of data sets. This data management technique is useful for providing information about the city's various data sets and can be considered a critical element for maintaining the value of data.

Another key component of the data theme is the Open data portal, which provides the public with free access to city related data. This will facilitate the sharing of data and enable various entities to work together to improve the use of city related data to support the development of new innovative city improving solutions. Smart cities around the world are increasingly depending on open data portals to help accelerate innovation, by making data freely accessible to the people most capable of creating smart solutions.

5.1.5 Protection: The data protection theme of the framework consolidates the aspects of data management that relate to security, privacy and risk management. The global proliferation of data has significantly increased its perceived value, thereby making it a fundamental requirement to ensure that it is securely protected. This is critical from both the perspective of public and private sector organisations, especially for the protection of their citizens and customers personal information. According to Bennett (2019), good data governance, characterised by organisations ability to control data by securing, protecting, managing and optimising its value, is the key to realising the intrinsic benefits of data.

Information about what data is held, how it is classified, where it is stored, how it is used and who it is shared with, are all critical aspects of data governance covered under the data protection theme. A focus on this theme, will also facilitate compliance with the applicable privacy regulations and ensure the existence of processes to obtain appropriate consents and manage access and delete rights as required.

5.1.6 Valuable Insights: The city is awarded the necessary applications and tools to support the making of data-driven decisions with confidence, under this theme. This theme provides the necessary insights to simplify and provide confidence in making difficult decisions, that could potentially have severe impact on operations or compliance efforts. The suite of applications managed under this theme will add value at various stages of the data governance journey, from data ingestion, data cataloguing, data preparation, data quality management to data analytics and business intelligence.

Business Intelligence and data analysis will help with both improving existing solutions and creating new innovative solutions that range in scope from crime prevention and traffic management, to healthcare and waste reduction. This theme will help pave the way for transparency and facilitate public distribution of data, creating an open and trustworthy environment where citizens are aware of the information the city collects.

In addition, the actionable information produced under this theme for descriptive, predictive and prescriptive purposes, will aid the commercialization of data.

5.2 Framework Evaluation

The final stage of the research process included a two-step evaluation of the data governance framework, which involved the assessment of its ability to manage data in the cities of London, New York and Amsterdam, three of the world's leading cities in sustainability and quality of life (Berrone and Ricart, 2020), followed by critical feedback from SMEs who provided an average evaluation score of 78% across nine dimensions.



Figure 11. Framework Evaluation by Subject Matter Experts

The evaluation indicated that the framework is comprehensive, innovative, useful, and valuable for the management of data in smart cities. In addition, the evaluations also confirm that:

- The enormous amounts of data generated by smart cities, can indeed be efficiently managed, organised, and mined by a data governance framework
- Smart cities can indeed facilitate their ability to make data-driven decisions, improve operational efficiency, ensure data quality and regulatory compliance with the use of a data governance framework
- It is indeed possible to govern the data requirements of a smart city with a single data governance framework

6. CONCLUSION

Smart city solutions generate huge volumes of data, that come in structured or unstructured formats, from a variety of disparate sources and require real-time analysis. The level of complexity associated with these solutions, poses data management challenges around quality, integration of data sources and types, storage, privacy, and security. The aim of this research paper was to analyse the data management requirements of smart cities and to propose a suitable data governance framework to aid the making of data-driven decisions, improving operational efficiency and ensuring data quality and regulatory compliance. This was achieved through extensive background research of smart city data management requirements, analysis of existing data governance frameworks, and systematic selection of the most relevant functional areas of data management based on feedback from industry professionals. The selected functional areas were subsequently grouped under the six themes (i.e., People, Process, Technology, Data, Protection and Valuable Insights) that make up the framework.

An evaluation of the framework proved that it can be used to govern the huge amounts of data generated by smart cities, by facilitating data-driven decision making, improving operational efficiency, ensuring data quality and regulatory compliance. An area of future research could be the development of a step-by-step guide to support the implementation of the framework, using a dynamic and systematic approach that will ensure sustainability of the creation of value from data generated in smart cities.

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