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Data Driven Approaches for Smart City Planning and Design: A Case Scenario on Urban Data Management

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Abstract

Purpose

Due to the use of digital technologies in smart cities, municipalities are increasingly facing issues related to urban data management and are seeking ways to exploit these huge amounts of data for the actualization of data driven services. However, only little studies discuss challenges related to data driven strategies in smart cities. Accordingly, this study presents a data driven approaches (architecture and model), for urban data management needed to improve smart city planning and design. The developed approaches depict how data can underpin sustainable urban development.

Design/methodology/approach

Design science research is adopted following a qualitative method to evaluate the architecture developed based on top-level design using a case data from workshops and interviews with experts involved in a smart city project.

Findings

Findings from the evaluations indicate that the identified enablers are useful to support data driven services in smart cities and the developed architecture can be employed to promote urban data management. More importantly, findings from this study provides guidelines to municipalities to improve data driven services for smart city planning and design.

Research limitations/implications

Feedback as qualitative data from practitioners provided evidence on how data driven strategies can be achieved in smart cities. However, the model is not validated. Hence, quantitative data is needed to further validate the enablers that influence data driven services in smart city planning and design.

Practical implications

Findings from this study offers practical insights and real-life evidence to define data driven enablers in smart cities and suggest research propositions for future studies. Additionally, this study develops a real conceptualization of data driven method for municipalities to foster open data and digital service innovation for smart city development.

Social implications

The main findings of this study suggest that data governance, interoperability, data security, and risk assessment influence data driven services in smart cities. This study derives propositions based on the developed model that identifies enablers for actualization of data driven services for smart cities planning and design.

Originality/value

This study explores the enablers of data driven strategies in smart city and further developed an architecture and model that can be adopted by municipalities to structure their urban data initiatives for improving data driven services to make cities smarter. The developed model supports municipalities to manage data utilized from different sources to supports the design of data driven services provided by different enterprises that collaborate in urban environment.

Keywords: Smart city planning and design; Data driven enablers; Interoperability, Data security, Risk assessment, Data governance.

1. Introduction

The increase in urbanization has challenge the sustainability of cities globally and this is placing substantial pressure on municipalities to increase resilience and sustainability of cities. Hence, making cities smarter by providing advanced urban services to improve citizens' quality of life can enhance resource and infrastructure usage toward improved sustainability (Wenge *et al.*, 2014). The United Nations (UN) predictable that 66 percent of the world population will reside in urban location by 2050. Thus, smart city has become an interesting topic linked to evolving technologies and urban sustainability (Zuccalà and Verga, 2017). Although, smart city was coined in the year 1990s to model how urban development is aligned to globalization, innovation, and technology. But, over the years smart city has become the focus across the world due to increased urbanization (Ju *et al.*, 2018). Smart cities concept has emerged to transform municipal areas into digitally connected spaces (Amiri and Woodside, 2017).

The digital transformation of cities into smart cities could help to solve the issues that are arising due to increased urban population (Gebka and Castiaux, 2019; Kühne and Heidel, 2021). To this end, Information and Communication Technology (ICT) has been employed to improve quality of life and living conditions as well as promote environmental protection. Such adoption of ICT enables municipalities to become a smart city and enhance the lives of citizens with the deployment of technology (Kühne and Heidel, 2021). Smart city is defined as the use of digital technologies within the working environment and public areas to transform citizens life aimed at improving the use of city resources and enabling sustainable development (Mohamed *et al.*, 2020). In the past decades smart city strategies have emerged as a development of earlier effort to modernize and digitize urban design and planning (Muschkiet *et al.*, 2022), with the goal of achieving environment-friendly urbanization (Liu *et al.*, 2017).

Cities becoming smarter cities has led to the generation of data referred to as "Big data" which are used to facilitate the development and sustainability of smart cities around the world (Lu *et al.*, 2019). The data generated within these cities when analyzed and processes could produce new insights which could provide value for citizens. The use of data in such a perspective is termed as data driven (Kühne and Heidel, 2021). Although, research and development related to data driven approaches in smart cities are increasing there are fewer contribution aimed at providing theoretical understanding of urban data management. To have an in-depth theoretical understanding of data driven strategies the knowledge of the characteristics and enablers of data driven strategies in smart cities needs to be explored (Bokolo, 2022).

While some cities have the capability to carry out a robust data management environment that enables data driven services, many do not. Most cities are constrained by limited data access, issues in exchange of data, and use of data including ownership, lack of confidence and trust (Sutherland and Cook, 2017), and other technical challenges such as security and interoperability. Likewise, some cities lack the capability to fully understand the intrinsic complexities of collecting, maintaining, and utilizing data for both strategic and operational decision making (Sutherland and Cook, 2017). Only few studies in the literature, provide tangible experiences from actual real case scenarios (Osman *et al.*, 2022). Providing evidence from case-based research is needed to examine the interrelationship between the enablers of data driven smart city. Filling this gap, this current study aims to demonstrates how to enable data driven services in smart city with evidence from case scenario. This article attempts to fill this gap in the literature by examining the following research question.

RQ1: What data driven enablers impact smart city planning and design?

RQ2: How to facilitate the interchange of data for effective urban data management in smart cities?

To answer this research question, a data driven architecture and model that comprises of enablers is proposed. The data driven architecture facilitates the interchange of data for effective urban data management in smart cities. Design science research is adopted, and a case scenario is employed to collect data for validation. The rest of the study is structured as follows. In section 2 the literature review is discussed. Section 3 presents the developed data driven architecture and model. Next the method is presented in section 4. Section 5 presents the findings. Section 6 describe the discussion. Lastly, section 7 is the implications and conclusion.

2. Literature Review

This section provides background of smart cities, overview of smart city design and planning, the role of big data in making cities smarter, and data driven strategies in making cities smarter.

2.1. Smart City Design and Planning

Urbanization has importantly improved modern economy and enhanced human capability to transform society and achieve increase in standard of living (Fujimoto *et al.*, 2016; Ju *et al.*, 2018). However, the progression of urban development around the world also brings new issues, such as pollution, deplete of natural resources, etc. To resolve these issues, the idea of "Smart City" was coined to denote the process by which a city can make appropriate changes to reduce those issues (Wenge *et al.*, 2014). Although, the progression of smart cities started in 1990s when the phrase was proposed to highlight urban development towards globalization, technology, and innovation. A smart city is an urban environment that deploys Information Communications Technologies (ICT) and other associated technologies to improve performance effectiveness of city operations and Quality of Services (QoS) provided to citizens (Silva *et al.*, 2018). Smart city refers to an advanced modern city that uses technologies and systems to promote Quality of Life (QoL), functioning efficiency of urban services, competitiveness, while ensuring that natural resources are available for present and future generations in terms of environmental, social, and economic aspects (Heo *et al.*, 2014).

Besides, a smart city can be referred to as a complex ecosystem embodied by the intensive use of technologies to make cities more sustainable and attractive. Additionally, municipalities are deploying digital technologies to become smart cities. Smart city planning and design involve the deployment of scientific and technical activities in connection with diverse urban-related elements, such as waste, energy, land use, transportation, infrastructure, etc. Several techniques are employed to facilitate smart city planning and design such as geographic mapping and analysis, modeling, energy demands and consumption, prediction, land-use impacts analysis, mobility and traffic patterns recognition, power and water supply analysis, simulation, environmental monitoring, patterns recognition and so forth. Smart city planning and design depend on urban computing and intelligence to support well-informed decisions associated to different areas of the municipality. It also involves the process of generating, analyzing, processing, and integrating vast amount of data from various sources within the city to help address issues related to urbanization and sustainability (Albuquerque *et al.*, 2021).

2.2. Data Driven Strategies in Making Cities Smarter

Urban leaders are increasingly adopting digital technologies to collect, aggregate, process, analyze, and share existing and/or new data to get insights (Sutherland and Cook, 2017). Although technology is seen as a platform needed to actualize innovation, data can be seen as the heart of digital transformation of cities. This highlights the relevance of data for sustainable urban development. The availability of such data sources has resulted to data driven advances (Albuquerque *et al.*, 2021), and can also stimulate innovation and to develop new digital platforms aimed at improving citizens quality of life. It can also improve urban internal processes and put into action collaborative opportunities for businesses to create new and innovative services for its citizens (Abella *et al.*, 2017). In response, cities are progressively implementing and leveraging big data to effectively address complexities they fundamentally embody and to assess, monitor, and improve their sustainability performance termed as data driven strategies. Data driven strategies can be defined as initiatives deployed in which value can be created through data as a strategic and essential resource (Muschkiet *et al.*, 2022).

Likewise, due to the increased data generated within cities businesses and governments now seek to apply data driven strategies to improve the efficiency and quality of city services (Barns, 2018). A data driven strategies in urban context enables municipalities to use digital technologies for data management aimed at the adoption of data driven solutions for enhancing the living standards of citizens towards to actualization of social, economic, and environmental sustainability. Likewise, data driven strategies enabling large-scale decision-making processes across various city domains for optimizing and enhancing planning and design of the city. Data driven strategies support digital services in smart cities to create new business models, transform enterprise processes, and increase civic engagement (Dhungana *et al.*, 2016). The data driven strategies aim to get the right amount of data from the right source and at the right place to make evidence based planned decisions in relation to sustainability of the city. Data driven strategies provide access to data that enables seamless administration and planning of the city services (Watson *et al.*, 2021; Alvsvåg et al., 2022).

Furthermore, data from smart city can be aggregated to manage urban's assets in creating a sustainable environment, enhance the quality of life, and improve service efficiency, and economic viability (Heo *et al.*, 2014). According to Brutti *et al.* (2019) data gathered in smart cities are used to optimize efficiency in achieving sustainability and competitiveness, to deploy multi-functionally in providing solutions to reduce sustainability issues. Moreover, data is employed to ensure there are seamless synergies across and within city services and in driving innovation through open data (Brutti *et al.,* 2019). But, the efficient management of generated data is challenging, especially since data is produced from different devices within the city (Mukhopadhyay and Bouwman, 2019). Nevertheless, data is collected from different stakeholders from diverse domains that can be integrated to develop new applications to address increasingly complexity challenges faced by cities, such as in traffic management, efficient energy management, pollution reduction etc. (Vögler *et al.,* 2016).

Additionally, another challenge confronting smart cities is the data collected from different systems are in different type, sensitivity, and importance which introduces interoperability issues, data quality, and security issues for municipalities (Bokolo *et al.*, 2022a). Collecting and processing of generated data can lead to risk and privacy issues that should be addressed to achieve a sustainable smart city (Silva *et al.*, 2018). However, research related to data aspects which provides real-time insights that support cities in becoming smarter, have seen rather little investigation. Thus, it is essential to develop and utilize more innovative solutions and advanced approaches to foster urban data management for smart city planning and design. Therefore, this current study develops a data driven model for smart city design and planning and further presents an architecture to facilitate the interchange of data for effective urban data management in smart cities.

3. Developed Data Driven Approaches (Architecture and Model)

3.1. Top-Level Design for Data Driven Architecture

In developing the data driven architecture the top-level design approach was employed as suggested by Fang *et al.* (2021). The top-level design adopts the principle of technological and business integration from the top to the bottom based on a stepwise refinement. The top-level design approach is more advantageous to be employed in developing the data driven architecture to support smart city planning and design as it facilitates the description, modelling, and representation of the relationship between subsystems and captures all layers, and all components of deployed. In this study, a data driven architecture is developed which comprises of seven layers and four enablers. The architecture is developed to support data driven smart city planning and design for urban data management. The developed architecture which illustrates how ICT and big data make cities smarter is shown in Figure 1.

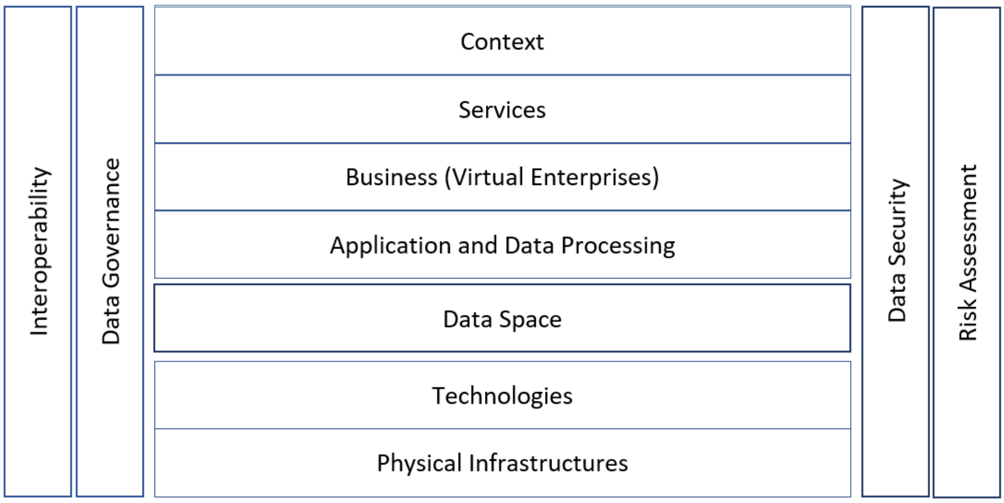

Figure 1. Developed data driven architecture

Each of the layers of developed architecture are discussed below.

3.1.1. Context Layer

The context layer comprises of the key aspects, concerns, and main requirements of all stakeholders within the city. It also comprises of drivers, enablers, quality factors, and main goals of the municipality administration.

3.1.2. Service Layer

The service layer describes data driven services provided by all actors that operates within the city. Also, the service layer uses data sources from different platforms provided from different partners. The services layer is mostly determined by the city`s objectives and is aimed at providing data driven services to citizens.

3.1.3. Business Layer

The business layer highlights all organizations that co-operates to provide various data driven services aimed at supporting the smart city planning and design. This layer is envisioned to include all stakeholders or actors that work together to provide a data driven service to citizens. The business layer enables new constellations of partnership, easy creation of innovative services, innovative mutual business models, and evolution of digital services.

3.1.4. Application and Data Processing Layer

This layer focuses on data management, analysis, processing, and integration. The application and data processing comprise of all open-source solutions, digital platforms utilized by the enterprises to support the provision of data driven services to citizens. This layer involves different centralized and distributed systems deployed to provides tailored solutions for different sectors within the city. This layer also supports the provision of digital services, such city dashboards, marketplaces, energy management systems, digital micro payment, weather forecast services, energy trading, traffic monitoring systems, disaster warning systems, data analytics, resilience systems, visualization, etc.

3.1.5. Data Space Layer

The data space layer is the brain of the entire data driven ecosystem. These collected data from the technological layers are stored in the data space layer. Data space layer define the meta data and data that support data driven services and open innovations for smart city planning and design. This layer gathers different types of data through such as open data (e.g., weather forecast, energy trading, etc.), real time data (e.g., sensor data, data from IoT, etc.), mobility data, data from social networks, batch/historical data, directories, and registers, etc.

3.1.6. Technologies Layer

The technologies layer mostly captures the hardware and software deployed to support applications and data processing layer for achieving data driven services for smart city planning and design. The technologies may vary from micropayment technologies, cloud-based technologies, wireless and wired local access networks, 5G network technologies, cellular networks, sensory networks, and telecom/internet core networks, etc.

3.1.7. Physical Infrastructures Layer

The physical infrastructures layer involves all physical hardware infrastructures deployed within the city to support data driven services. It mainly captures all smart metering devices, sensors, equipment, traffic counter sensors, air quality sensors, moisture, temperature, light, pollutions sensors etc. deployed within the city. This layer comprises of sensors and other smart devices deployed for data acquisition, network infrastructures for data transmission, and related hardware and software for brief data storage. This layer also comprises of the deployed telecommunication protocols used by the integrating technologies adopted within the city to interconnect various devices, sensors, equipment needed in the city.

3.2. Data Driven Enablers for Smart City Planning and Design

This section presents the enablers that impacts data driven strategies for smart city planning and design. The identified enablers (as seen in Figure 1) comprise of data governance, interoperability, data security, and risk assessment are discussed below.

3.2.1. Data Governance

In providing services to citizens and other stakeholders in cities there is need for availability of quality data to meet stakeholders' requirements and achieving municipality's objectives (Walravens *et al.*, 2021). Data governance refers the exercise of authority and control, planning, enforcement, and monitoring over the management of data assets. It aims at specifying the business terms, administrative structures, data owners, processes, metrics, policies, and rules for the whole data lifecycle which comprises of data collection, storage, usage, security, archiving, and removal (Choenni *et al.*, 2022). Hence, data governance relates to who holds the decision rights relating to data source and who is responsible for decision-making regarding data access and usage (Saxena, 2017). According to Khatri and Brown (2010); Paskaleva *et al.* (2017) data governance comprises of *data principles, metadata, and data lifecycle. Data principles* which involve the describing data role as an asset. *Data quality* involves designing the requirements of planned use of data. *Metadata* describes the content or semantics of the data so that it is understandable by stakeholders. *Data access* specifies data access requirements, and *data lifecycle* describes the definition, creation, usage, and retirement of data. Based on the above, the following proposition is stated:

P1. *Data governance initiatives adopted will significantly influence smart city planning and design for urban data management.*

3.2.2. Interoperability

Interoperability is one of the issues facing municipalities since they utilize data from diverse data sources (Andročec, 2017). Thus, without devices from different providers to connect seamlessly and efficiently, smart cities cannot be fully attained (Costin and Eastman, 2019). Accordingly, interoperability refers to the ability of two different devices and networks to communicate with one other and exchange information through common models of representation (Berre *et al.,* 2007; Mulero *et al.*, 2020). Interoperability is crucial to manage systems of systems and to open prospective to competitive solutions (Dhungana *et al.*, 2016). In addition, use of legacy systems, constrained and resources data heterogeneity lead to vertically siloed data applications (Bokolo *et al.*, 2022b). As data in these applications are generally "locked" in their domain such as one system resulting to vendor lock-in (Walravens *et al.*, 2021), or one service provider, and cannot be reused and shared by other application, system, or provider (Brutti *et al.*, 2019). Interoperability is an issue in smart city planning and design due to lack of data standards and inadequate technical ability to access data, and fragmented usage and development of software platforms (Sutherland and Cook, 2017). Thus, this study proposes that:

P2. *Interoperability initiatives deployed will significantly influence smart city planning and design for urban data management.*

3.2.3. Data Security

As ICT becomes more infused in city infrastructures and citizens day to day activities, it is projected that new security issues will emerge (Berkel *et al.*, 2018). Similarly, as data is crucial to underpin successful smart city deployment for a city to be smart. Citizens should be self-assured that data collected from them are secured (Braun *et al.*, 2018). Data security is concerned with protection of data and its critical elements including the computer systems (hardware and software) that use, transmit, and store data. Data security aims at protecting data assets, whether in transmission, processing, or storage (Choenni *et al.*, 2022). Nevertheless, threats to data integrity might affect municipality's goal of being smart. City data should be protected to ensure the confidentiality, integrity, authenticity, and availability (AlDairi, 2017). Confidentiality requires that only the sending entity and the intended receiving entity should be able to gain access to the contents of the message (Berkel *et al.*, 2018; Choenni *et al.*, 2022). Whereas authenticity aids to set up the confirmation of identities ensuring that the source of the message is properly identified (Santana *et al.*, 2018). Similarly, integrity guarantees that message contents are not altered even if the message is accessed by an unauthorized user. Lastly, availability confirms that data should be accessible to authorized user 24/7 (Verma *et al.*, 2019; Choenni *et al.*, 2022). Based on these arguments, the following proposition is made:

P3. *Data security strategies implemented will significantly influence smart city planning and design for urban data management.*

3.2.4. Risk Assessment

Risk is a combination of uncertainty with the effect of outcome involved and is mostly thought of as the uncertainty relating to negative consequences of utilizing a service or product (Mustafa and Kar, 2017). Likewise, risk is referred to as something or an event that may go wrong. It is a combination of the probability of an event and its impact. All innovations have risks and opportunities. Inadequate risk management results to total failure in IT based services (Nam and Pardo, 2011). Basically, risk assessment aims to systematically evaluate possible threats in a quantifiable approach based on potential physical impacts an attacker can inflict by exploiting vulnerabilities of data driven infrastructures and systems (Li *et al.*, 2018). Thus, risk assessment offers the medium for municipality authorities to meet the challenges of ever-evolving cyber threats that occurs in cities to guarantee the benefits derived from data produced from city services (Mustafa and Kar, 2017). Therefore, this study proposes that:

P4. *Risk assessment initiatives deployed will significantly influence smart city planning and design for urban data management.*

Accordingly, based on the data driven enablers (data governance, interoperability, data security, and risk assessment) for smart city planning and design presented in developed architecture (see Figure 1) and discussed in this section, a data driven model is proposed as seen in Figure 2 to provide data driven strategies for smart city planning and design.

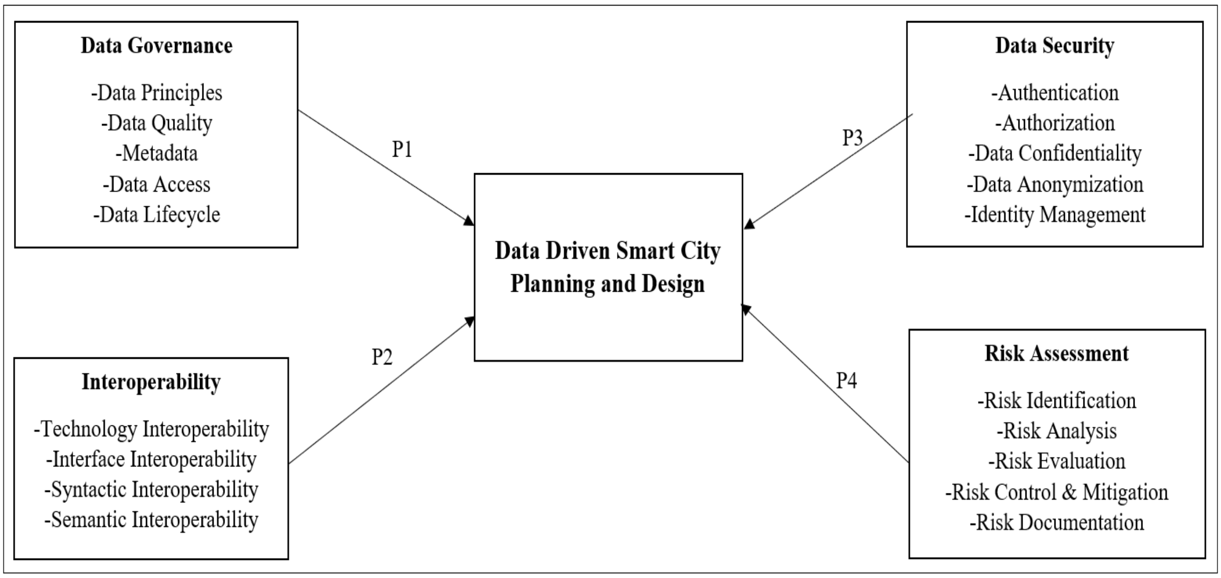

Figure 2. Developed data driven model

Figure 2 depicts the research model for data driven services for smart city planning and design.

4. Methodology

4.1. Research Design

This study employs design science research as an appropriate research method to create meaningful and practitioner-based artifacts (Hevner *et al.*, 2004). Design research depend on design principles for the design of IT artifacts. According to Sein *et al.* (2011); Osman *et al.* (2022), the design method of any IT artifact should be theory-ingrained and practice-inspired. Overall, the design science research methodology employed is based on Peffers *et al.*'s (2020) design method which is appropriate for the design of IT artifacts which comprises of six steps. The first step involves identifying the research problem and its significance, which in this study relates to data driven smart city planning and design. Secondly, defining the need for related supportive approaches and determining the research objective to facilitate ideation towards the development of a data driven architecture for smart city planning and design. Thirdly, the data driven architecture was designed based on findings from the literature to make certain that the architecture focus on the described issues of designing data driven services in smart cities. In step four, the developed architecture was presented and demonstrated to colleagues involved in the smart city project (https://cityxchange.eu/) funded by EU from 2018-2023, in the geographical area of Ireland and Norway to discuss the applicability for smart city planning and design.

In step five, qualitative data from a case was used to validate the data driven architecture by conducting workshops and interviews with smart city experts involved the one of the work packages (D7.4: Monitoring and Evaluation Dashboard) (https://cityxchange.eu/knowledge-base/monitoring-and-evaluation-dashboard/). Different evaluation cycles were carried out with using case data from workshops and interviews with smart city experts involved in the +CityxChange smart city project. The scale of data collected were mostly qualitative data as regarded to the how data within the project was collected, monitored, evaluated, and reported to the project partners and the EU Smart City Information System (SCIS). The last phase aimed at publishing the findings from on data driven strategies for smart city planning and design in a reputable journal (Digital Policy, Regulation and Governance).

4.2. Background of Case Scenario Approach

A case scenario is a suitable approach for exploring the condition where boundaries of evidence are not evidently defined. Thus, case scenario approach has been considered as suitable for finding out the real situation of an occurrence. A case scenario is chosen as the method to present the findings from the workshops and interview. In this study, the case scenario analysis methodology is used for exploring the data driven smart city planning and design and to present urban data management in the +CityxChange smart city project.

4.3. Data Collection and Analysis

Qualitative data was collected during several workshops and expert interviews with partners in the +CityxChange smart city project. Open-ended questions were used as it allows the generation insight into the concerns, motivations, and challenges faced by the partners involved in the smart city project to gain insight on how data driven strategies can be actualized in smart cities. The interview sessions were held with multiple representatives involved in the project between June 2019 occasionally till May 2020 in a physical location and later digital due to the COVID19 pandemic. The profiles that participated in the interviews range from urban architects, data architect, ICT practitioners, sustainability experts, and smart urban developers.

The workshop and interviews lasted between one to two hours in English language and were transcribed for analysis. Based on the insights from the literature and qualitative data, several data driven strategies (modelled in Figure 3) were identified that can aid smart city planning and design. No software was employed for data analysis as coding of all data (documents, workshop/interview transcripts) was done manually using descriptive and narrative analysis. The data was coded based on the architecture layers and enablers (see Figure 1). To minimize research bias, all findings were illustrated in ArchiMate (See Figure 3) and referred to some key participants as follow-up and confirmation of the findings represented in ArchiMate.

5. Findings

5.1. Smart City Planning and Design Case Description

This study is linked to the +CityxChange smart city project which main vision intends to support the co-creation of a sustainable future. Using digital technologies, the project aims to improve the quality of life for citizens, producing more energy than consumed, and lastly sharing these experiences with cities across Europe and the World. The main framework of the project comprises of 3 main areas. The first is prototyping the future via an *integrated planning and design*, the second is by enabling the future by creation of a *common energy market* and lastly accelerate the future through *communityxchange*. The suggested architecture layers as seen in Figure 1 helped to address the 3 main areas of the +CityxChange smart city project. More information on the project data can be seen in the project knowledgebase (https://cityxchange.eu/knowledge-base/).

Overall, the outcome of the +CityxChange project is to develop solutions for positive energy blocks leading to positive energy districts and cities through decision support tools which facilitate informed decisions to be made by all stakeholders within the community. Present a method to creating a positive energy block through flexibility and peer-to-peer energy trading, local renewables efficiency measures, local storage, and energy reduction. Finally, employing a top-down community engagement driven approach by the local authority and bottom-up citizen engagement method to educate, inform, and drive behavioral change.

5.2. Case Scenario Modeling of Smart City Planning and Design

In this study the collected data relates to "integrated planning and design" which is one of the goals of the +CityxChange project (as previously stated). The findings as related to integrated planning and design is modelled in ArchiMate as seen in Figure 3. The integrated planning and design use case aims to depict the modeling of ICT components for sustainable energy production and consumption within the city. The use case models show how the +CityxChange project can prototype a sustainable future through innovative deployment of digital technologies to enabled to urban data management for decision support for all stakeholders within the city (Petersen *et al*., 2021).

Thus, findings from the workshops and interview sessions are illustrated in ArchiMate modelling language within the developed architecture (see Figure 1). The findings are modelled based on the developed architecture layers (*context, services, business, application and data processing, data space, technologies, and physical infrastructures*), as seen in Figure 3. The findings also present data driven strategies for the enablers (*data governance, risk assessment, data security, and interoperability*), within the architecture (Petersen *et al*., 2021).

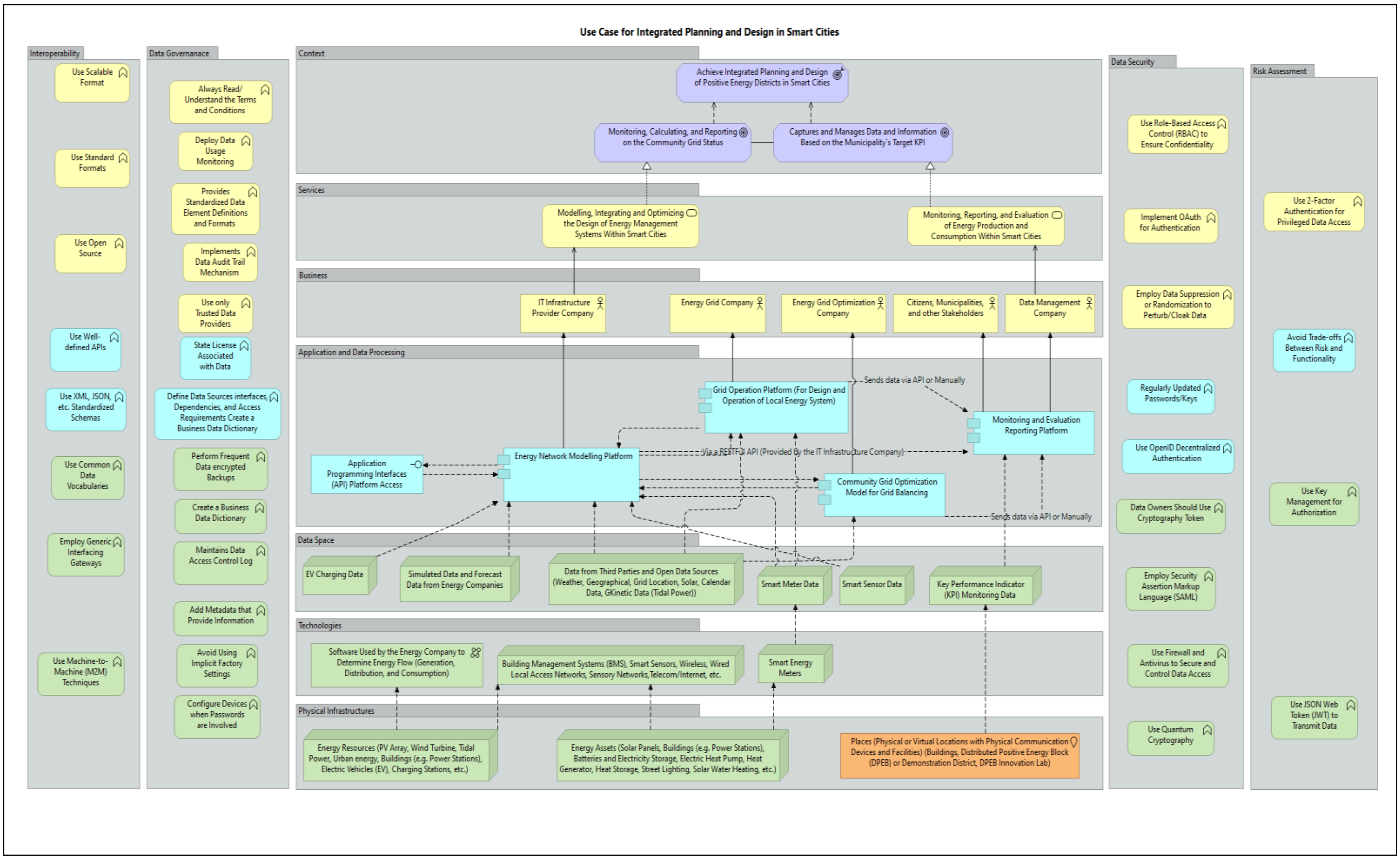

Figure 3. Use case for integrated planning and design in smart cities

Figure 3 depicts the use case for integrated planning and design in smart cities. Findings from Figure 3 also illustrates how five different enterprises operating within the city to facilitate the interchange of data for effective urban data management in smart cities. Thereby allowing cross collaboration and connection to provide data driven services to citizens such as modelling, integrating, and optimizing the design of energy management systems and monitoring, reporting, and evaluation of energy production and consumption within smart cities. A detailed description of the findings as related to the integrated planning and design in smart cities is shown in Table 1.

Table 1 Findings of integrated planning and design case description

Architecture Layers	Components and Description
Context	This is the main target which comprises sustainable energy management towards smart city planning and design. The components comprise. ➢ Monitoring, calculating, and reporting on the community grid status. ➢ Captures and manages data and information based on the municipality`s target KPI. ➢ Achieve integrated planning and design of positive energy districts in smart cities.
Services	Mainly comprises of the data driven services provided to citizens towards the integrated planning and design of sustainable energy for actualization of Distributed Positive Energy Block (DPEB) within smart cities. The components comprise. ➢ Modelling, integrating, and optimizing the design of energy management systems within smart cities. ➢ Monitoring, reporting, and evaluation of energy production and consumption within smart cities
Business	Comprises the enterprises that collaborates to achieve integrated planning and design in DPEB towards a sustainable energy efficient city. The components comprise. ➢ IT infrastructure provider company ➢ Energy grid company ➢ Energy grid Optimization company ➢ Citizens, Municipalities, and other stakeholders ➢ Data management company
Application and data processing	The digital platforms utilized to support the integrated planning and design consist of Application Programming Interfaces (API) platform access, energy network modelling platform, grid operation platform, community grid optimization model, and monitoring and evaluation reporting platform. In summary it entails. ➢ APIs are employed to provide access to different data sources needed to provide innovative energy centric solution within the city. ➢ The energy network modelling platform is used to design how each prosumer building within the city consumes and/or produce energy. ➢ The grid operation platform aids the management of grid operation towards the design and operation of local energy system. ➢ The community grid optimization model aids grid balancing across the city. ➢ Lastly, the monitoring and evaluation reporting platform helps to provide sustainable energy reporting to stakeholders.
Data space	Involves numerous data sources utilized for integrated planning and design. The specified data sources utilized for integrated planning and design comprise. ➢ EV Charging data source. ➢ Simulated data and forecast data from energy companies. ➢ Data from third parties and Open Data sources. ➢ Smart meter and smart sensor data. ➢ Key Performance Indicator (KPI) monitoring data.
Technologies	This comprises of hardware and software used by the company captured in the business layers which comprise. ➢ Energy systems and smart meters. ➢ Software used by the energy company to manage sustainable energy generation, distribution, and consumption. ➢ Also, comprises building management systems, smart sensors, wireless, wired local access networks, sensory networks, telecom/internet, etc. ➢ Smart energy meters installed within buildings in the city.
Physical Infrastructures	These comprises of energy resources, energy assets, and places. ➢ The energy resources comprise of Photovoltaic (PV) array, wind turbine, tidal power, urban energy, buildings e.g., power stations, electric vehicles (charging stations)).

	➢ The energy assets comprise of solar panels, smart buildings (e.g., power stations), batteries and electricity storage, electric heat pump, heat generator, heat storage, street lighting, solar water heating, etc.). ➢ Place or venues which comprises of virtual/physical locations with physical facilities and communication devices to promote citizen engagement and participation for co-creation of smart cities.

6. Discussion

The data produced in smart city can be utilized to develop innovate data driven services to enhance citizens' quality of life. But only fewer studies have paid attention to research related to explore how smart city planning and design can be actualized using data driven approaches. Therefore, this study identifies the data driven enablers that impact smart city planning and design and facilitate the interchange of data for effective urban data management in smart cities. The design science research was chosen to design and evaluate a data driven architecture. Accordingly, the design science research process suggested by Peffers *et al.* (2020) was followed to evaluate the data driven architecture (see Figure 1), as design science research offers a generally accepted iterative approach for design-oriented study with the goals to address institutional problems. Data was collected from workshop and interview sessions via multi-cases of integrated planning and design in the +CityxChange smart city project. The findings were modelled in the developed data driven architecture to understand how data is distributed among different digital platforms to help cities creates value for key stakeholders such as urban administrators, citizens, organizations, service utility providers, communities, etc. Furthermore, a model was also developed to explore the enablers that influence data driven strategies for smart city planning and design.

In relation to the data driven architecture the findings suggest that the architecture layers (*context, services, business, application and data processing, data space, technologies, and physical infrastructures*) are relevant for facilitating the interchange of data for effective urban data management for smart cities planning and design. The findings indicate that the architecture is useful to support data-driven service design in real-world environments. Additionally, findings from this study confirms the suitability of data driven enablers (*data governance, risk assessment, data security, and interoperability*) impact of data driven services in smart cities. Findings from the literature suggest that data governance defines roles and assigns responsibilities for decision areas and activities related to data usage and access (Weber *et al.*, 2009). These findings are analogous to results from prior studies (Khatri and Brown, 2010), which stated that governance refers to the way the administration ensures that strategies are established, monitored, and realized. It establishes city-wide guidelines and standards for data quality and assures compliance with urban strategy and laws governing data use (Wende, 2007).

Consistent with the findings of previous studies (Li *et al.*, 2016; Mustafa and Kar, 2017), risk assessment is an important predictor that influences data driven services towards cities becoming smart. This finding indicates that risk assessment and mitigation is an important role that should be addressed in the evolution of smart cities. Similarly, this finding is in line with the results of other studies (Pa *et al.*, 2015; Berkel *et al.*, 2018), which revealed the need to measure the effects or losses of enterprise or city systems to identify of risks, prioritize ranking, and then quantify the risks. Consistent with the existing literature (Khan *et al.,* 2017; Schieferdecker *et al.,* 2017), the effect of data security and data driven services for smart city attainment is perceived to be significant. Based on findings from AlDairi (2017), data security is important in urban environment due to advancements in making city smarter which has resulted to security and privacy issues. Likewise, with the emergence of open data and open governance in smart cities citizen centric services are susceptible to new security and privacy challenges (Khan *et al.,* 2017).

Findings showed that interoperability of data and system significantly impacts data driven services in smart cities. The finding is analogous with the results reported by Noura *et al* (2019). This finding supports and provides empirical evidence for the argument that 40 % of the potential benefits of smart city can be obtained with the interoperability between different data systems (Noura *et al.,* 2019). Therefore, as predicted the interoperability of systems in smart city is important due to the emerging need to integrate legacy and new systems to expand city capability by using opportunities presented by novel digital innovations (Karpenko *et al.,* 2018). Smart city systems need to be interoperable to attain seamless service integration across urban boundaries and beyond (Andročec, 2017; Brutti *et al.,* 2019).

7. Implications and Conclusion

7.1. Theoretical Implications

Research and development in smart cities have gained increased popularity in governmental, industrial, and academic circles. While urban population grows, the resources and infrastructures needed to support citizens and stakeholders are mostly inadequate, resulting to degraded services. Smart city refers to the integration of physical and social infrastructures to enhance the quality of urban services. ICT provide significant tools to support the sustainable use of resources to improve citizens' quality of life and provide information to city managers to make improved investment decisions. But the actualization of smart city is faced with issues such as data management which relates to security, privacy, etc. Yet, only fewer studies have explored data driven strategies for smart city planning and design. Respectively, this study develops an architecture and further explores the enablers (interoperability, data security, risk assessment, and data governance) that influence data driven smart city planning and design. Additionally, a model is presented based on the enablers to improve data driven services in smart city.

Findings from this study offers insights and preliminary information to define data driven perspective for smart city planning and design and suggest propositions for future studies. The insights and lessons learned from this study can be employed as guidelines for deploying secured data to enhance data driven services. The developed data driven model offers the scientific community further reference and insight to current issues related to data governance and how it relates to smart cities policies. The data driven model presented can be valuable for the data analyst, city administrators, and practitioners in making operational, tactical, and strategic decisions. The data driven model can help city managers in strategies that can be adopted to address risk in smart cities. Moreover, the model can also help academicians in discussing open research questions and challenges towards improving data security in smart cities.

7.2. Practical Implications

Over the years cities around the world have begun to devise and deploy smart urban visions that promote the adoption of data and digital technologies to resolve urban policy challenges related to water and air quality management, mobility, energy usage, or public safety, amongst others (Bunders and Varró, 2019). The enormous data generated during smart city operation are seen as an asset for a city (Fang *et al.*, 2021). Therefore, this paper provides an understanding on data driven enablers for urban data management processes which is important to ensure smart city planning and design. A data driven architecture was developed to aid professionals and domain experts to get an overview and classification of existing interoperability solutions in smart city and select suitable method to help increase interoperable isolated data in cities. The findings of this research contribute to decision makers understanding of smart city planning and design. Thereby supporting urban administrators in designing data-driven solutions. Secondly, from a practical point of view this paper focuses on improving urban data management and support practitioners in offering initial guidance for assessing the opportunities and issues associated with data-driven strategies in smart cities.

The developed architecture can be used to assess the maturity of a smart city based on the enablers and strategies presented in the data driven model as modelled in Figure 3 to aid city's transformation into a smarter city. Besides, the developed data driven architecture can be utilized as an urban mobility tool by decision makers and urban management authorities to explore and better understand how an interactive dashboard platform can be deployed depicting how data from different sources can be used for generating integrative visualizations to promote strategic and operational management of smart city planning and design. More importantly, the architecture significantly contributes to increasing interoperability between several data and reducing silos and barriers to allow for seamless data use in creating value added service to citizens and stakeholders. Furthermore, findings from this study can help cities understand how isolated, non-interoperable systems, and siloed data can be collected, managed, stored and used in ways that bring value by providing an approach that promoted data driven strategies.

7.3. Conclusion

Currently, the attainment of environmental, societal, and economic goals is not scalable as municipalities expand and are challenging to predict precisely. Hence, smart city is proposed to achieve a sustainable society. Where a smart city is a sustainable urban area where every aspect of municipal life is supported by ICT and governed in a resourceful way, through integrated services that improves mobility, energy systems, air quality, climate change, water, etc. To accomplish this goal, integration of data from several distributed sources needs to be utilized, and huge volumes of data is generated, processed, shared, and utilized. Likewise, the development of smart cities and the subsequent increase of data have prompted the attention of academicians since data is seen as the intelligence of smart cities. Hence, data driven enablers in smart cities is worthy of investigation. But this area has not fully been explored in the literature, therefore this study proceeded to present a data driven architecture and model based on enablers that influence data driven services for smart city planning and design.

Design science research method was adopted following a qualitative method to evaluate the data driven architecture developed based on top-level design using case data from several workshops and interviews with experts involved in a smart city project in Ireland and Norway. The developed data driven architecture provides an outline for city planners to implement innovative risk reduced, quality data management, secured, and interoperable data centric solutions for citizens and stakeholder. Data driven strategies are expected to further increase smart city realizations and improvements, thus helping urban administrators in actualizing a sustainable innovative service for their city and beyond. Irrespective of the contribution of this article, this study was not without limitations. First, only qualitative data was collected to evaluate the applicability of the developed data driven architecture. The data driven model propositions was not validated. Therefore, in future longitudinal studies based on quantitative data are needed to validate the data driven model. Data will be collected from stakeholders and practitioners in urban administration to help validate the model prepositions in confirming each of the derived enablers that influence smart city planning and design.

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