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The information and communication technology domains for enabling a smart city

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Abstract

The concept of a smart city (SC) is increasingly complex due to its socio-technical diversity and definitions. Consequently, there continue to be mixed reactions to cities and countries' claims of the concept. From the information and communication technology (ICT) perspective, there seems to be no guidelines for assessing the claims of SC. Following the qualitative approach, this study proposes a four-domain model from an ICT perspective: transport, health, education, and security. Additionally, the study highlights the factors that essentially influence each domain, including citizen engagement, telecommunication, big data, and artificial intelligence. The contribution of the study lies in the uniqueness and the interdependence of the domains, in the context of SC. The model provides a holistic approach that can allow for a wide view of the domains and how they can be strategically enabled through the smart essentials. This includes highlighting the implications of the study.

Keywords: smart city, ICT domains, enterprise architecture

Introduction

Generally, the concept of a Smart City focuses on developing and advancing a locale (Agarwal, Benmamoun & Anjum, 2024). Mohseni (2021) alludes that the lack of a unanimous definition of the Smart City concept shapes the scope and focus. However, the Governments of cities, including academics' views of Smart City domains, are increasingly varied. Consequently, some cities' aspirations are plummeting despite their urge for advancement, development, and growth. The challenges can be associated with two fundamental factors: (i) there is no universal classification of domains for a Smart City (Kirimtat et al., 2020; Yin et al., 2015), and (2) there are no criteria or mechanisms for determining domains, from the information and communication technology (ICT) perspective.

From the ICT perspective, domains help create boundaries, based on which context is drawn, and content is measured. Based on the context and content, relevance can be assessed and credence associated to determine the levels of smartness of a city. This premise makes domains critical towards achieving a successful Smart City (Anthopoulos, 2015). Therefore, a lack of clarification of the domains can hamper assessment and progression from an ICT perspective. On this basis, governments and scholars tried to induce domains from various angles. Sánchez-Corcuera et al. (2019) acknowledged the importance of domains and highlighted healthcare and education as examples.

Even where the definition or categorisation of Smart City domains has been attempted, they have focused on non-ICT-based standpoints. We provide some examples from over a decade. Bawany and Shamsi (2015) identified four domains: health, education, transportation, and power grid. Ramaprasad, Sánchez-Ortiz and Syn (2017) categorised the economy, utilities, quality of life, and governance as the domains. Sánchez-Corcuera et al. (2019) referred to healthcare and education as the domain. In Fan et al. (2023), smart utility, smart transportation, smart homes, and smart healthcare were the domains. There seems to be consistency in identifying some domains such as transportation, energy, healthcare, and public services (Mazzetto, 2024).

Assessment of the implementation of the Smart City concept is critical primarily because it helps to document strengths and weaknesses, including achieving different target goals (Patrão, Moura & Almeida, 2020). Based on the identified gap, the study aimed to define Smart City domains from an ICT perspective. This includes providing the missing links to enhance the context, content, and relevance in assessing Smart City for improvement. Thus, the research questions are: What are the ICT domains? And how can they be used to enable and support a Smart City from an ICT perspective?

Some of the implications and consequences have been highlighted in the literature in the last decade, yet the gap has not been addressed. Fan et al. (2023) suggest that by assessing each domain and its specific context, direction can be provided and challenges addressed. Defining or categorising the ICT domains reveals their dependencies (Buhnova et al., 2022). Also, the domains enable information architecture, which facilitates information sharing, to improve a Smart City. Bawany and Shamsi (2015) argued that by sharing information, the city can gain insight and identify impending problems with the intent of responding before these problems occur or escalate.

This article is organised into seven main sections for ease of flow and understanding. It began with an introduction that provided a comprehensive synopsis of the study. Thereafter, existing works were reviewed to support and justify the claim that there is a need to conduct this study. The third section discusses the vehicle used in conducting the study. In the fourth section, the research questions are answered by presenting Smart City domains from an ICT perspective. Despite the comprehensiveness of the study, there are limitations, which pave the way for future research, which are covered in sections five and six, respectively. The article is concluded in the last section.

Literature review

Smart City is a concept born from an interdisciplinary term, and it embraces several definitions as of today (Agarwal, Benmamoun & Anjum, 2024; Dashkevych & Portnov, 2024; Israilidis, Odusanya, & Mazhar, 2021). Generally, the concept focuses on the development and advancement of a locale. Mohseni (2021) alludes that the lack of a unanimous definition of the Smart City concept shapes the scope and focus. Consequently, Governments of Cities, including academics' views of the concept, are increasingly varied. On the one hand, many cities across the world are either claiming or aspiring to be a smart city. On the other hand, some cities' aspirations are plummeting despite their urge for advancement, development, and growth. These are challenges that can be associated with two fundamental factors: (i) there is no universal definition for a Smart City (Kirimtat et al., 2020; Yin et al., 2015; Angelidou, 2014), and (2) there is no assessment mechanism or model for determining the smartness, from readiness to maturity levels.

From the information and communication technology (ICT) perspective, a definition is a foundation backbone based on which boundaries and context are drawn, and content is measured. It is on this basis that both governments and scholars have induced several definitions. Harrison et al. (2010) defined a Smart

City as a connection between the physical, social, business, and ICT infrastructure, to leverage a collective and improve the smartness of an urban area. In Kondepudi's (2015) definition, a Smart City is a modern city, enabled by IT solutions to improve service delivery and citizens' quality of life. Also, the definitions can be viewed from both the developed and developing world's perspectives (Kondepudi et al., 2015). Vitally, none of these definitions are based on empirical evidence (Lim, Cho & Kim, 2021). This makes assessment skewed or inconsistent, especially when terms of reference become essential.

Assessment of the implementation of the Smart City concept is critical, for it helps to document strengths and weaknesses, including achieving different target goals (Patrão, Moura & Almeida, 2020). Some readiness assessments either focused on ICT-related factors (Ibrahim, El-Zaart & Adams, 2018) or non-ICT influencing attributes (Achmad, Nugroho & Djunaedi, 2018). Thus, Sharifi (2019) suggests levels of approaches that could cover the mix of technical (ICT) and non-technical assessment attributes. As the challenges persist, Hajek, Youssef and Hajkova (2022) therefore proposed that assessment should be based on existing infrastructure and technology services. Despite the challenges being highlighted by studies, it is difficult to find a readiness assessment model that focuses on both technical and non-technical factors. Also, across the world, assessment tools have been developed but for specific cities in countries, such as Australia, Iran, South Africa, United Arab Emirates (Enwereji & Uwizeyimana, 2022; Shwedeh et al., 2022; Noori, de Jong & Hoppe, 2020). This necessitates employing the enterprise architecture to embed the assessment approach, due to its holistic affirmative and it covers both technical and non-technical aspects of an environment.

Owing to its premise, enterprise architecture (EA) is increasingly evolving with a focus on managing complex ICT-related solutions, including processes and infrastructures (Niemi & Pekkola, 2016). The EA approach coverage and focus are essential for smart cities, to contain their complexities, from strategic to operational levels (Pourzolfaghar, Bastidas & Helfert, 2020). In Anthony Jr. (2021), the proposition is that EA can address the complexity and system integration faced in the transformation of cities. Also, the concept of a smart city can benefit from EA, as Iyamu (2023) puts it, the EA is founded on its primary aim and strengths, which are to bridge the gap between technical and non-technical facets and to enforce change from the current to the desired state. Holistically, EA provides a set of definitions, models, and detailed descriptions of the structure, encompassing factors such as technical infrastructure, capabilities, processes, and data (Anthony Jr. & Petersen, 2023).

Research Methodology

A qualitative method was employed in this study. This is because of its constructive approach to inquiry, and it allows emphasis on the depth and richness of context in gaining a better understanding of a social phenomenon rather than merely quantifying occurrences (Lim, 2024). According to Hatch (2023), to foster a rich understanding, the qualitative method enables individuals to study objects by asking the "what", "why", "when", "where", "who" and "how" behind social behaviours and interactions. The method is appropriate for this study, primarily because the objective is to identify ICT domains critical for smart city enablement, which require a social constructivism approach.

The case which is under study is the ICT domains for enabling a smart city. The case is studied through the document analysis technique. The document analysis technique was employed in the data collection. Document analysis is a data collection technique that reviews and analyses documents such as books, academic conferences, journal articles, and institutional reports (Morgan, 2022). Mwita (2022) asserts that the documentation technique is underused among qualitative methods, but its strength lies in allowing researchers to collect data from areas where participants cannot provide data in person due to various

reasons. In this study, documentation was opted for primarily because it allows for the broader coverage and progression of the smart city concept, both in developed and developing countries. Across the world, the term smart city is associated with different meanings, which manifest from how it's understood, developed and implemented. The document analysis technique allows for a critical review of the individuals' experiences and perspectives of smart cities as developed and implemented in their environments.

In Mwita (2022), it is suggested that when applying the document analysis technique, a plan must be articulated in terms of which documents to gather and review, including the sources from which the materials are accessed. In this study, only peer-reviewed academic documents in the form of journals, book chapters, books, and conference papers were considered. This was to ensure the credibility of the content, as the above-mentioned materials go through a rigorous review process before publication. The documents reviewed were accessed from the academic library databases, namely: Emerald, Scopus, IEEE Explore Digital Library, ProQuest e-book central, and Taylor and Francis. These databases were selected due to their vast and frequent reputable publications on information technology and information systems matters. Searching for documents in the databases was guided by the study keywords: smart city, information technology, information technology domains, and enterprise architecture. To enable ease of management, documents acquired were labelled numerically in ascending order and thereafter placed into the keyword-named folders respectively. This process was necessary to prepare documents for analysis. In total, forty-one (41) documents were collected.

For the analysis of the documents, the interpretive hermeneutics approach was employed. Interpretive hermeneutics refers to the interpretation of written texts like documents to gain a deeper meaning of people's actions, processes and beliefs (Virkler & Ayayo, 2023). According to Gillo (2021), hermeneutics is an approach to understanding a phenomenon by comprehensively reviewing existing literature about the problem under study. In this study, a comprehensive review was guided by the hermeneutic cycle (Gadamer, 1988), which is an iterative process. Themes were identified as per the objective: namely, Internet of Things (IoT), stakeholders and citizens engagement, policies and governance, and telecommunications infrastructures. After identifying themes, the researchers analyse the data back and forth, reading additional materials about smart city domains to enhance understanding.

Background

In many countries, cities are known to be highly overpopulated settlements due to urbanisation. The high population in cities puts pressure on the limited natural resources and infrastructure available, making the provision of services to citizens and businesses in various areas challenging. Kirimtat et al. (2020) explained that because of constrained resources in cities, services in areas such as health, education, environment and transportation are challenging.

This study presents a Smart City Enterprise Architecture (SCEA). The SCEA comprises four fundamental domains: Transport, Healthcare, Education, and Security. In this study, these domains are considered foundational services for a smart city's livelihood. Thus, the SCEA provides a holistic city-wide view, consisting of four domains with distinctive deliverables. Based on the deliverables, models are developed for assessing a Smart City. As illustrated in the Figure, each model is influenced by smart essentials, including citizen engagement, telecommunication, big data, and artificial intelligence. These components are considered smart city essentials because they cross-cut every domain, making them key ingredients in the realisation of every domain.

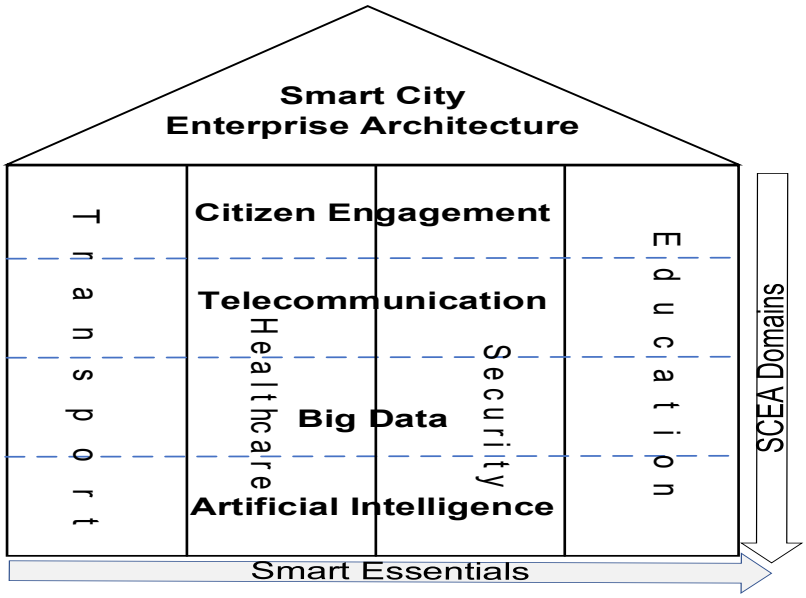

Figure 1. Smart city domains

The domains

The project consists of four pillars referred to as domains. Although each domain is a distinct project, they form part of the main project. The domains are briefly described.

i. Smart City: Transportation

The transportation system plays a critical role in any city as it represents how people will be moving around to access goods and services around the city. Currently, city transportation is faced with traffic congestion, making intermodal and multimodal mobility challenging for the citizens. The situation worsens during peak hours of morning and evening when individuals drive to and from work and school. As a result, the municipality needs to incorporate digital solutions to manage the city's transportation system. According to Li and Padwal (2020), a smart city must have an intelligent transport system that provides innovative services related to various modes of transport to ensure more organised and intelligent transport networks.

ii. Smart City: Healthcare

Healthcare services are fundamental for citizens' well-being. Mohammadzadeh et al. (2023) asserted that as urban populations continue to grow and healthcare demands increase, the smart city approach to healthcare is likely to become increasingly important. In a smart city, healthcare services such as ambulances, paramedics and first-aid support should be readily accessible. Therefore, there is a need to explore the use of sustainable healthcare technologies that can allow people to act proactively in eliminating health risks and promoting well-being. Thus, the objective of this domain is to explore factors influencing the adoption of healthcare records to improve healthcare service delivery across public and private hospitals.

iii. Smart City: Education

A smart city requires people who are educated and knowledgeable about smart solutions and processes. As a result, there is a need to have educational programs and curricula that enable people to acquire the skills that are critical for the development and growth of a smart city. Skills such as data analytics, machine learning, cybersecurity and robotic process automation are the focal point of smart city development. Thus, there is a need to have hands-on, practical educational initiatives that allow for practical skills acquisition. This concept focuses on exploring how universities and other educational institutions can offer smart

education initiatives. The objective of this domain is to determine critical skills for smart city development that can be integrated into university curricula.

iv. Smart City: Security

A smart city needs to be safe for its citizens. However, with the integration of sensors in most of the processes, there is a need to have measures in place to ensure safety and protect people's privacy. Verma et al. (2019) reported that when the city goes smart, its residents may suffer from various privacy and security issues due to smart city applications and technology vulnerabilities. Therefore, there is a need to conduct a study on how citizens' protection and privacy will be ensured with their data being collected every time from interconnected points. The objective of this domain is to develop a security framework that can be used to guide safety and privacy policies.

Implications of the study

The outcome of the study, ICT domains for Smart City, as detailed in the section above, has implications for three main groups: enterprise architects, governments, and citizens. The implications are from both technical and non-technical viewpoints, as discussed below.

Enterprise architects

Information technology domains are complex, consisting of various activities and processes. The complex nature represents a significant challenge in the management of cities that require a coherent and structured approach to provide digitally enabled services (Bastidas et al., 2023). Due to their complex nature and challenges that manifest, it is imperative to have enterprise architects for the domain's design and development. According to Kotusev and Kurnia (2021), enterprise architects focus on an overarching organisation-wide IT planning of all EA domains, including business, applications, data, integration, infrastructure and security. Enterprise architects are responsible for understanding both business and technical needs and thereafter designing and implementing strategic solutions for a smart city. To achieve organisation-wide planning, enterprise architects collaborate with various stakeholders to understand the current state of the city and to develop future technical and non-technical infrastructure.

Government

Smart city domains depend on the technical and non-technical infrastructures to function and operate efficiently. The acquisition and management of these infrastructures can be a challenging and costly activity. On the other hand, the government provides support and security for the operationalisation of the domains. Lai et al. (2020) reported that technical infrastructures such as advanced sensors, analytics tools, and artificial intelligence fulfil and support a wide range of services in a smart city. In addition to the technical infrastructure, the government must invest in the non-technical infrastructure, such as governance. Governance refers to the policies and standards that protect and guide the use of resources in a smart city. In the absence of governance structures, it becomes impossible for a smart city to exist.

Citizens

As the end users and recipients of service delivery, citizens are key stakeholders in a smart city setup. From both strategic and operational perspectives, citizens interact with the various ICT domains through the smart essentials for service delivery purposes. Their interaction is mediated through smart technical infrastructures, which could be challenging for many citizens. Consequently, there is a need to introduce and educate citizens about new technical infrastructures and their supporting processes (Kummitha, 2025). When citizens are not engaged with or educated about the city's smartness, it leads to resistance. Patel et

al. (2024) explained that in a smart city, additional skills training may be needed for citizens to effectively utilise digital engagement platforms and scrutinise the flow of information.

Limitations and further research

Despite its cohesiveness and comprehensiveness, the study has some limitations. The primary limitation lies in its lack of empiricism. Thus, future studies can focus on or explore natural settings involving human-to-human, human-to-technology, and technology-to-technology interactions. Also, a sociotechnical theory such as activity theory and actor-network theory could be applied to underpin future studies, to gain a deeper understanding of why things happen in the way that they do, in using ICT solutions to support and enable the Smart City concept.

Conclusion

The study posed two fundamental questions: (1) What are the ICT domains? (2) How can the domains be applied in enabling and supporting a Smart City from an ICT perspective? The first question is answered by defining and developing a Smart City Enterprise Architecture (SCEA) model (Figure 1). The model consists of four fundamental domains from an ICT standpoint, which include Transport, Healthcare, Education, and Security. The SCEA provides a holistic city-wide view of distinctive deliverables of the four domains. The answer to the second question is to gain an understanding of how smart essentials, which include citizen engagement, telecommunication, big data, and artificial intelligence, influence the domains' deliverables. The smart essentials are horizontal across the domain, as shown in the model. Thus, smart essentials form the criteria for assessing a Smart City. This helps to enhance the context, content, and relevance in assessing Smart City for improvement. This study, therefore, contributes to the assessment of Smart City maturity. Also, it fortifies the use of ICT to advance Smart City enablement and sustainability. Theoretically, this study adds to existing literature in the areas of Smart City and ICT advancement.

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