STUDIA UBB NEGOTIA, LXX, 1, 2025, pp. 27-59
(RECOMMENDED CITATION)
DOI:10.24193/subbnegotia.2025.1.02

THE KEY FACTORS FOR A SUSTAINABLE SMART CITY – A CASE STUDY OF 22 INTERNATIONAL SMART MUNICIPALITIES

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Article History: Received: 20 January 2025; Reviewed: 24 February 2025; Accepted: 10 March 2025; Available online: 26 March 2025.

ABSTRACT. This article examines the core components and global initiatives driving smart city development, focusing on sustainability and safety & health. Drawing insights from literature and case studies of 22 international smart cities, the main objective of the research is to identify key projects shaping Smart Environment/ Sustainability and Smart Living/ Safety & Health. Notable examples include Tel Aviv-Yafo's solar roof and Dubai's Smart Healthcare Model. The findings emphasize a global commitment to citizen-centric, environmentally conscious urban environments, showcasing diverse approaches and technological innovations. The article offers actionable insights for aspiring smart cities, emphasizing a phased, collaborative approach and technological integration. Key observations include the global movement towards sustainability, diverse smart city initiatives, and the importance of cross-sector collaboration. The presented model serves as a blueprint for cities, addressing specific steps like assessment, goal setting, and learning from global best practices. Beyond current practices, the article suggests future research directions, including assessing long-term impacts, addressing privacy concerns, and exploring

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governance models. The article advocates ongoing research to guide policymakers in the dynamic landscape of smart cities, promoting sustainability and innovation.

Keywords: smart city, digitalization, sustainability, sustainable development.

JEL classification: O38, H11, I18, Q58

Recommended citation: Trinca, V-T., Stegerean, R., Petre, A., Nistor, R.L., *The key factors for a sustainable smart city – a case study of 22 international smart municipalities,* Studia UBB Negotia, vol. 70, issue 1 (March) 2025, pp. 27-59, doi:10.24193/subbnegotia.2025.1.02

Introduction and review of literature

In the rapidly evolving landscape of urban development, the concept of smart cities (SC) has emerged as a transformative force, integrating technology to enhance sustainability, efficiency, and the overall quality of life for citizens. This article delves into the theoretical underpinnings of smart cities by conducting an extensive analysis of published literature, with a focus on keywords such as "SC," "sustainability," and "digitalization". Our exploration unveils key components integral to SC frameworks, including Smart Government, Smart People, Smart Economy, Smart Environment, Smart Infrastructure, and Smart Living.

The utilization of cutting-edge technologies to revamp urban infrastructure and enhance the overall well-being of citizens is unquestionably a prevailing contemporary practice. This trend is substantiated by numerous initiatives undertaken by research teams, businesses, and municipal governments at local, national, and global scales. The idea of smart cities and innovative technologies offers a multitude of benefits. Key enhancements encompass improved quality of life, reduced energy consumption, swifter and safer transportation, increased green spaces in densely populated urban areas, intelligent infrastructure solutions, rapid communication with authorities, resolution of urban challenges, an eco-friendly environment, and the creation of living spaces for future generations (Kumar et al., 2016; Důbravová & Bureš, 2023).

Smart Cities leverage Information and Communication Technologies (ICT) to improve the quality of life for their residents. The concept of SCs has undergone significant development over the past two decades. Various definitions for SC can be found in the research literature. For instance, as defined by Bakıcı et al. (2013, p. 139), a SC is a highly technologically advanced

urban center that employs new technologies to connect people, information, and city infrastructure, with the aim of creating a sustainable, environmentally friendly city, fostering competitive and innovative business, and improving the overall quality of life (Anthopoulos, 2015; Herscovici et al., 2022).

A SC is characterized by a sophisticated framework that embodies a new level of intelligence achieved through the interconnected utilization of resources. This intelligence is harnessed for analytical, modelling, optimization, and visualization services. Moreover, it involves the capacity of individuals to acquire, advance, and implement cutting edge technologies. It is important to note that a SC not only relies on traditional and modern media infrastructure, such as transportation and communications technology, but also thrives on a foundation of social capital (Hollands, 2008; Giffinger & Gudrun, 2010; Harrison et al., 2010; Schaffers et al., 2011; Chourabi et al., 2012; Schaffers et al., 2012; Mocholí, 2016; Sarmiento, 2017; Sikora-Fernández, 2017; Valderrama, 2017; European Commission, 2020; Caragliu et al., 2021; Mejia et al., 2022).

A city is deemed "smart" when it combines conventional infrastructure and investment in human resources to foster sustainable economic growth and a high standard of living, all underpinned by integrated control technology (ICT). In this context, a SC can unite its physical surroundings, which encompass its natural assets, with its community, businesses, and human capital to enhance services and infrastructure, ensuring ongoing sustainability (Win & Tonyali, 2021; Demertzi et al., 2023).

Climate change requires European cities to improve their quality of life while lowering their costs. They require innovative and successful digital initiatives. Climate change has been acknowledged as a significant public health (PH) issue. Evidence-based PH practices should guide urban planning. Current determinants of environmental health and climate risk pose a serious threat to public health (Lapão et al., 2023). The essence of the SC is sustainability, and its main condition is a functional PH. The strategic plan is to integrate public health into the SC concept to help mitigate PH crises such as the COVID-19 pandemic (Lapão et al., 2023).

Consumer healthcare technologies have grown rapidly in recent years, driven primarily by the widespread use of mobile devices and the Internet. The development of Smart Consumer Healthcare Technologies (SCHT) has raised awareness of health and wellness management has changed, empowering people to track and compare. One of the key advantages of SCHT is its ability to democratize health care, making it more accessible and affordable. This allows consumers to monitor their health from the comfort of their own homes, reducing their reliance on costly doctor visits and hospital stays. SCHT also increases the accuracy of health information by enabling consumers to collect

and track health information over time, which can be shared with health care providers. Consequently, this helps health professionals make informed decisions about treatment options. Another notable advantage of SCHT is its ability to support chronic disease management (Herencsar, 2023).

The "Smart City" expression was initially coined by (Drohojowska, 1995) in 1991. While researchers are progressively gaining awareness of smart cities, the first notable surge of interest in this topic can be traced back to around 2011. The authors also developed a graph based on the research encompassed by Web of Science, which clearly underlines their statement.

Information security holds a critical role in smart cities, ensuring higher levels of confidentiality, availability, and integrity. It is also instrumental in maintaining the stability required by national services and organizations to sustain viable and livable intelligent urban environments. While smart cities aim to enhance productivity and efficiency, the neglect of cybersecurity could pose significant risks to both residents and authorities (Demertzi et al., 2023).

For instance, the rapid growth of the Internet of Things (IoT) introduces new vulnerabilities that malicious actors can exploit. With billions of interconnected "things" deployed in smart cities worldwide, numerous potential weaknesses and techniques come into play (Valaskova et al., 2020).

In summary, according to (Ganguly et al., 2019), the most substantial security challenges in SC environments include:

A vast and intricate attack surface: As cities become smarter, they incorporate more systems and "systems of systems," which increases the risk and impact of potential attacks. This necessitates more stringent control and visibility. Additionally, integrating solutions from various vendors amplifies the complexity, especially during rapid technological transitions. Inadequate oversight and organization: Complex systems require more robust management and governance capabilities. Keeping leadership well-informed about intricate occurrences will demand additional resources and capabilities (Ganguly et al., 2019; Demertzi et al., 2023).

The so-called digital revolution has ushered in numerous scientific breakthroughs, enhancing the efficiency and functionalities of conventional technology. One prominent outcome of this progress is represented by the development of SC infrastructure (SCI). Smart municipalities, in particular, have expanded the horizons of traditional municipal infrastructure by integrating cyber-physical systems (CPS). These systems have the potential to enhance sustainable initiatives on the long term, the overall performance as well as growth. As both legacy and novel systems are adapted to embrace technological modernization, the introduction of CPS highlights the increasing importance of analyzing the potential attack surfaces of these devices (Wright et al., 2022).

The structure of the article and is presented below:

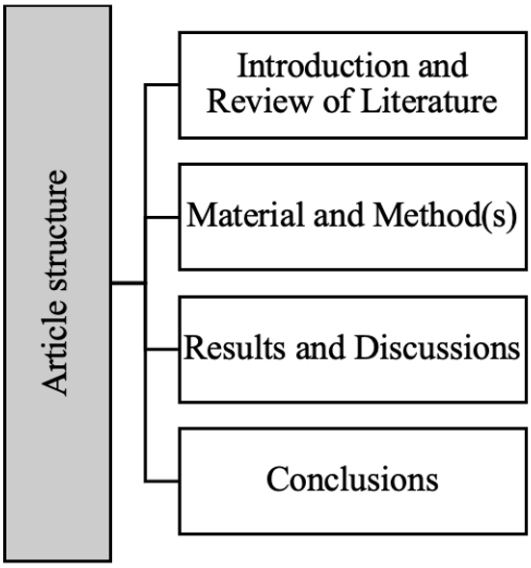

Figure 1. The structure of the article

The research aim of this study is to distill valuable lessons and create a model that can guide other municipalities aspiring to embrace the smart city paradigm. Through this research, we not only showcase exemplary projects but also identify key observations and propose future research directions to contribute to the continued evolution of smart cities worldwide.

To provide practical insights, we present a comprehensive study based on published literature, official websites, reports and news about 22 international smart cities, analyzing their projects and initiatives in the realms of Smart Environment/ Sustainability and Smart Living/ Safety & Health.

Material and Method(s)

In the process of researching the theoretical aspects, we have consulted the published literature using keywords such as "SC", "sustainability", and "digitalization". From the researched literature, we have identified the key components of a smart city, and these are: Smart Government, Smart People, Smart Economy, Smart Environment, Smart infrastructure and Smart Living. The entire process of identifying these components has been published elsewhere (Stegerean et al., 2022; Trincă, 2023).

As shown by Figure 2, the number of publications regarding the smart city topic increased significantly in the last ten years underlining the importance for further researching this topic from various angles. The overview of publications and citations on the topic of smart cities was initially developed by (Blazek et al., 2022), yet it only contained information up until 2022. We updated it, considering data from the Web of Science Core Collection, ending the data gathering at the end of July 2024.

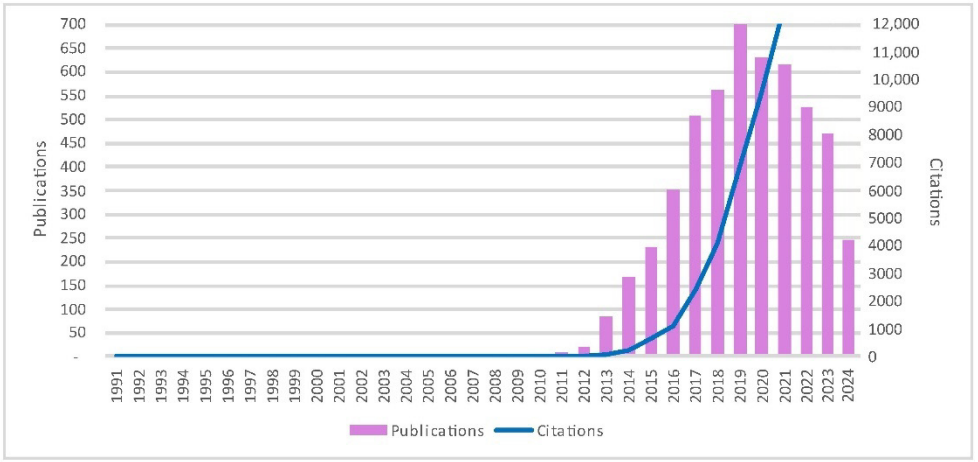

Figure 2. An overview of publications and citations on the topic of smart cities
Source: authors' work, updated from (Blazek et al., 2022, p.2)

In order to underline the most important terms and the connections between them, we developed a bibliometric analysis of the co-occurrence network of terms in the highly cited articles from the Web of Science Core Collection on the topic of smart cities, published in the last decade. The VOSviewer software solution was used as it was proven to be a reliable tool for creating cluster maps (van Eck & Waltman, 2010).

As it can be seen in the figure above, there are four major clusters, with the one associated with the smart city term being the predominant one. Another cluster is associated with the term technology, while the other two are associated with the terms application and system. These terms are the most frequent ones in the publications regarding smart cities and play a pivotal role in any digital economy.

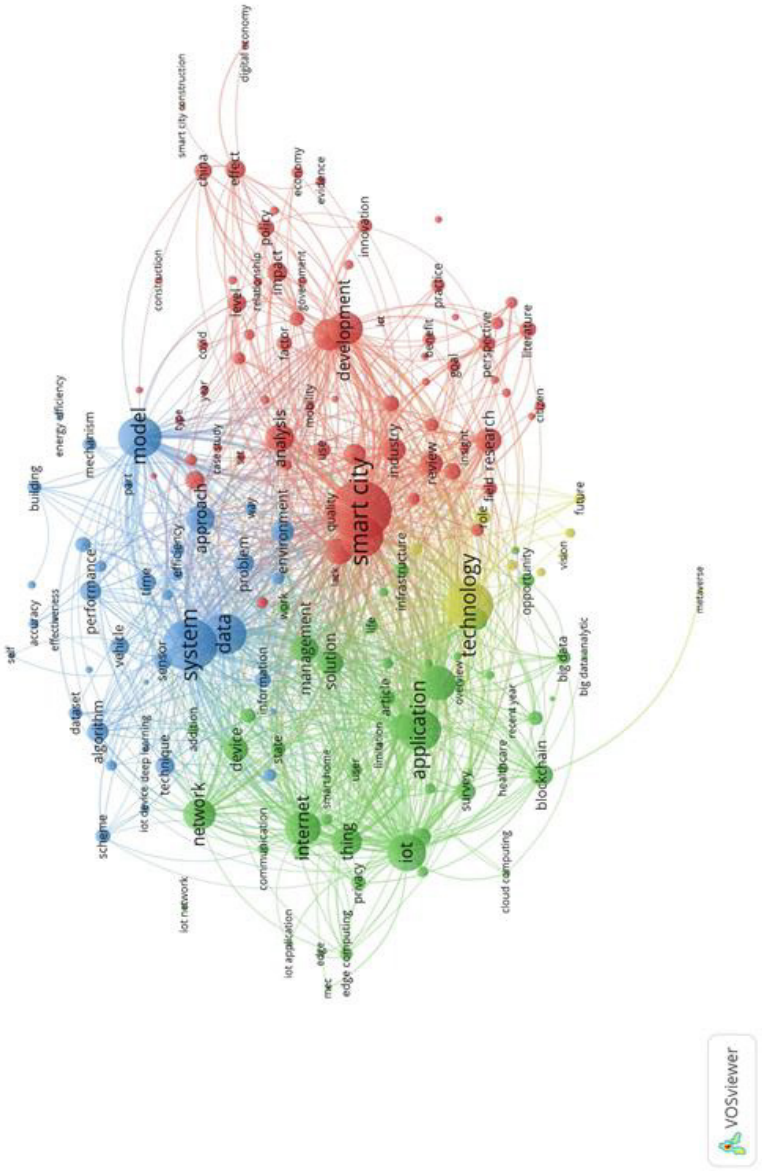

Figure 3. A bibliometric analysis of the co-occurrence network of terms in the highly cited articles from the Web of Science Core Collection on the topic of smart cities, published from 2014 onwards
Source: authors' work, using the VOSviewer software

These cities that were selected for the analysis emerged from articles published on the smart city topic, and these particular municipalities were chosen as they encompassed all six components of the SC framework. The common elements that are shared by these cities are the integrated approach of implementing the smart city framework, their intensive use of digital technologies and the visible results the municipalities have from the framework's adoption.

By studying the relevant literature, data was gathered a sample of 22 smart cities that are dispersed around the world, to develop a model that could be applied by other municipalities. The information regarding the smart initiatives implemented by these cities was easy to access, as the digitalization process increased the transparency and the popularization of each municipality's projects. When elaborating the sample, we took into account elements such as notoriety, frequency and impact, as well as the aspect mentioned before, the presence of the key elements of any smart city within their development strategy.

The cities that are part of this study are located across five continents as follows: Asia (Dubai, UAE (Ok & Yoo, 2017); Gyenggi province, South Korea (Ok & Yoo, 2017); Hong Kong, China (Anthopoulos, 2017); Seoul, South Korea (Anthopoulos, 2017; Ok & Yoo, 2017); Tel Aviv-Yafo, Israel (Herscovici et al., 2022)), Australia (Melbourne, Australia (Anthopoulos, 2017; Sancino & Hudson, 2020)), Europe (Amsterdam, The Netherlands (Schuurman et al., 2012; Ok & Yoo, 2017; Sancino & Hudson, 2020); Barcelona, Spain (Ok & Yoo, 2017; Bibri & Krogstie, 2020); Bristol, UK (Sancino & Hudson, 2020); Brno, Czech Republic (Fialová, et al., 2021); Geneva, Switzerland (Anthopoulos, 2017); Guimarães, Portugal (Fonseca et al., 2022); London, UK (Anthopoulos, 2017; Ok & Yoo, 2017; Bibri & Krogstie, 2020); Milton Keynes, UK (Sancino & Hudson, 2020); Nice, France (Ok & Yoo, 2017); Rotterdam, The Netherlands (van Zoonen, 2016); Tampere, Finland (Anthopoulos, 2017); Vienna, Austria (Anthopoulos, 2017)), North America (Chicago, USA (Sancino & Hudson, 2020); New York City, USA (Schuurman et al., 2012; Anthopoulos, 2017; Shah et al., 2019); Washington DC, USA (Anthopoulos, 2017)) and South America (Curitiba, Brazil (Sancino & Hudson, 2020)).

The fact that the municipalities are located across the planet shows that we are facing a global issue regarding smart cities and there are some common approaches that can be underlined.

Results and Discussions

As the topic of smart cities is vast and many authors have approached it from many angles in recent years, we decided to focus our attention towards two of the most important smart city components: Smart Environment/ Sustainability and Smart Living/ Safety & Health. The first component is in the spotlight nowadays

as the globe is tackling global warming and the majority of countries have already set up targets and measures for a carbon neutral future. On the other hand, the quality of life of citizens that live in cities around the world is a constant challenge and goal to achieve for municipalities.

In our quest to develop a model that will serve as a guide of implementing good practices for every aspiring smart city, we focused on the list of international smart cities that were found in the researched literature.

When taking into account the Smart Living/ Safety & Health component, we discovered common aspects like the adoption of smart surveillance systems and apps for quality of life. The similar projects implemented by the studied municipalities from an environmental/sustainable point of view consisted of smart waste systems and environmental projects, along with smart energy management approaches.

Two tables were developed, encompassing the most relevant examples of projects implemented by the municipalities, regarding the Environment/ Sustainability and Smart Living/ Safety & Health smart city components. In the research process that proceeded the development of the tables, we considered three main sources of information: published articles, official governmental websites and newspapers or blogs.

Table 1 presents the most relevant examples of sustainable smart city projects that were implemented, most of them focusing on the environmental issues. As previously mentioned, the sources were placed in three categories. From this point of view, 91.67% of the sources were from the official governmental websites and 8.33% from newspapers or blogs.

The sample represented by the 22 cities is presented in the table below in an alphabetical order, as they do not have a different degree of importance, and all of the initiatives are to be considered.

When analyzing the data gathered and presented in the table below, we can underline that some approaches towards sustainable projects are similar, while others are particularized on the specific needs and requirements of that community. One of the main goals of the cities is represented by a direction towards environmentally friendly development, that responsibly manages resources, minimizes waste and encourages the recycle and reuse of certain goods. Specific references are made to the concept of circular economy that encourages the reuse of materials and product, by keeping them in circulation for as long as possible. This economic model helps cities tackle the climate challenges and is present in the strategies of Rotterdam, Amsterdam, Geneva, and Vienna. Smart waste management projects were implemented by the cities that were previously mentioned, along with Brno, Chicago, Melbourne, Tampere and Hong Kong. Rotterdam and Brno also have specific projects dedicated to sustainable water initiatives.

Table 1. Examples of the Environment/ Sustainability component in the international smart cities

No.	City, Country	Examples of Projects	Source
1	Amsterdam, The Netherlands	The concept of a Circular City is centered around minimizing waste and pollution through a strategic focus on reducing, recycling, and reusing resources. This approach aims to create a sustainable urban environment by implementing circular economy principles that contribute to a more efficient and environmentally conscious city.	(Amsterdam Smart City, 2022)
2	Barcelona, Spain	The establishment of a low emissions traffic zone aligns with the sustainable development goals outlined in Agenda 2030. Initiatives like Energia Barcelona underscore our commitment to energy conservation. Additionally, the implementation of an air quality monitoring system ensures a proactive approach to environmental stewardship, further contributing to our sustainable development objectives.	(Barcelona City Hall, 2022)
3	Bristol, UK	Reducing carbon emissions, enhancing building efficiency with insulation, implementing smart energy management systems, and integrating renewable electricity sources are key goals for environmental sustainability.	(Tuppen, 2011)
4	Brno, Czech Republic	Leveraging smart resources is crucial for creating a more sustainable city. This involves integrating technologies and data-driven solutions to optimize resource use in areas like energy, water, transportation, and waste management.	(Intelligent Cities Challange, 2022)
5	Chicago, USA	The Chicago Climate Action Plan outlines strategies for addressing climate challenges, including a waste strategy aimed at sustainable waste management practices. The plan also emphasizes initiatives to reduce carbon emissions and increase the use of renewable energy sources, contributing to the city's commitment to environmental sustainability.	(City of Chicago, 2022)
6	Curitiba, Brazil	Implementing low-carbon solutions, like renewable energy sources, energy-efficient technologies, green infrastructure, sustainable urban planning.	(Smart Cpts in Curitiba, 2022)
7	Dubai, UAE	The Dubai Plan 2021 is a visionary initiative with the goal of transforming Dubai into a smart and sustainable city. This comprehensive plan includes optimizing energy resources as a key focus area. Additionally, the implementation of the Sustainable City within DubaiLand exemplifies concrete steps taken to realize these ambitions, fostering a more sustainable and environmentally conscious urban environment.	(United Arab Emirates' Government, 2022)

No.	City, Country	Examples of Projects	Source
8	Geneva, Switzerland	Collecting used smartphones contributes to sustainable practices by promoting the recycling and reuse of electronic devices, reducing electronic waste. "My Solar Square Meter" is an innovative concept that allows individuals to subscribe to a solar share in one of the township's participatory power plants. This initiative enables community members to collectively invest in and benefit from solar energy generation, fostering a more sustainable and renewable energy future.	(République et canton de Genève, 2022)
9	Guimarães, Portugal	Aligning with the Sustainable Development Goals, the city is dedicated to designing projects that transcend city boundaries, encompassing a broader regional scope. This approach ensures a comprehensive and inclusive impact on sustainable development across the entire region.	(Intelligent Cities Challange, 2021)
10	Gyenggi province, South Korea	The 2022 Gyeonggi Environment Safety Forum serves as a platform for discussions and exchanges on environmental safety matters in the Gyeonggi region. It provides an opportunity for stakeholders to share insights, innovations, and strategies aimed at enhancing environmental safety and sustainability.	(Gyeonggi-do Provincial Office, 2022)
11	Hong Kong, China	The commitment to reduce carbon emissions by 20% and recover 1.5 million tons of waste underscores a proactive approach to environmental sustainability. The Climate Action Plan 2050 likely outlines a comprehensive strategy for addressing climate challenges and achieving long-term sustainability goals. Additionally, the focus on green buildings suggests an emphasis on constructing and maintaining environmentally friendly structures to further contribute to a more sustainable future.	(Innovation and Technology Bureau of Hong Kong, 2020)
12	London, UK	Efforts toward reduced energy usage, emissions, and investment in low-carbon infrastructure. Other initiatives include: Cleantech work (environmental technologies), Green Finance and Social Value projects.	(Greater London Authority, 2022a; Jackson-Obot, 2022)
13	Melbourne, Australia	The concept of an "Urban Forest Visual" refers to an initiative or project that aims to visualize and promote urban forests, emphasizing the importance of green spaces and tree coverage in urban environments. "Smart litter bins" typically refer to technologically advanced waste bins equipped with sensors and technology to optimize waste collection processes.	(City of Melbourne, 2022)
14	Milton Keynes, UK	The Community Action Platform for Energy (CAPE): community-driven projects, education, and efforts to enhance energy awareness and conservation at the local level.	(Daga, 2022)

No.	City, Country	Examples of Projects	Source
15	New York City, USA	The Office for Climate and Environmental Justice was created, that entirely focuses on sustainability projects.	(Mayor's Office of New York City, 2022)
16	Nice, France	The Climate Air Energy Territorial Plan (PCAET) is a strategic framework designed to address climate, air quality, and energy challenges within a specific territorial area. This comprehensive plan typically outlines specific objectives, actions, and policies aimed at mitigating climate change, improving air quality, and promoting sustainable energy practices at the local or regional level.	(Cities for Digital Rights, 2022)
17	Rotterdam, The Netherlands	Projects like the Floating Farm and Recycled Park/Clean Rivers projects, with a dedicated focus on the concept of Circular Economy.	(Rotterdam Innovation City, 2022b; Rotterdam Partners, 2022)
18	Seoul, South Korea	The "Roads Recharging Vehicles During the Drive" project is an innovative initiative where roads are equipped to recharge vehicles while in motion, contributing to sustainable and eco-friendly transportation. The "Seoul-type Sustainable Development Implementation System" refers to a system implemented in Seoul that focuses on incorporating sustainable development practices across various aspects of urban planning and governance. This system likely involves strategies and policies to promote environmental sustainability, economic development, and social well-being in Seoul.	(Morningstar, 2021)
19	Tampere, Finland	Enhancing the energy efficiency of existing building stock is a crucial strategy to mitigate emissions resulting from energy consumption. This involves implementing measures and upgrades to reduce energy waste, optimize systems, and introduce sustainable technologies, contributing to a more environmentally friendly and energy-efficient built environment.	(City of Tampere, 2022)
20	Tel Aviv-Yafo, Israel	Engaging in a solar roof project, implementing a Green Label for Businesses to promote eco-friendliness, and fostering sustainable communities through initiatives like Community Gardens are integral components of the commitment to environmental responsibility and sustainable neighborhoods.	(Tel Aviv City Hall, 2022)
21	Vienna, Austria	"Repair not replace" emphasizes the importance of repairing items rather than discarding them. The expansion of solar energy involves increasing the use of solar power as a renewable energy source.	(UIV Urban Innovation Vienna, 2022b)

No.	City, Country	Examples of Projects	Source
		Creating green fuel from residual waste involves converting waste materials into environmentally friendly fuel sources, providing an alternative to traditional fossil fuels and promoting sustainability through the reduction of waste, electric powered waste collection, green streets and neighborhood oasis.	
22	Washington DC, USA	The Sustainable DC 2.0 Plan is a comprehensive strategy aimed at fostering sustainability and resilience in Washington, D.C. This plan outlines ambitious goals, including a targeted reduction of emissions by 31%, a significant increase in the use of renewable energy, and a plan to cover 37% of the city with trees. These initiatives collectively contribute to a more environmentally friendly, resilient, and sustainable urban environment.	(Department of Energy & Environment, 2021)

Source: authors' work

The most encountered topic among the sustainable initiatives of the 22 cities, was the one of energy. As energy costs constantly increase, along with the demand, the need of other energy sources is an important one. Renewable energy projects like solar panels are mentioned, along with projects associated with reduced energy consumption trough efficient and green buildings. In the case of 73% of the 22 studied municipalities energy related projects and initiatives are mentioned, thus supporting the fact that this was the most encountered topic.

The second most encountered projects were the ones associated with air quality and the reduced level of emissions, in more than a third of the cities. In this case, a remark should be made, the one that the emissions and air quality issues are also tackled in projects associated with the Smart Infrastructure/ Mobility/ Transport component of the smart city concept. From an efficient transportation system, with electric and hydrogen-powered vehicles, ridesharing initiatives and dedicated lanes, significant improvements are made in terms of air quality and emissions reduction.

The topic of green urban spaces and gardens, or even urban forests is specifically mentioned in the plans of almost a third of the studied cities. Projects that increase the number of trees planted, the spaces dedicated to citizens, like community gardens, green streets and even floating farms are ideal for offering better air quality and a more pleasant space to live in.

Offices dedicated to climate and the environment, forums, plans, and systems that are associated with sustainable development were established by municipalities like New York City, Gyeonggi Province, Nice, Rotterdam, Dubai, Seoul, Washington DC, Hong Kong, Milton Keynes and Chicago. With these cities

being located in different continents across the globe, we can emphasize that sustainability and climate-related issues are issues that concern all regions of the world.

These projects collectively represent a global movement towards creating more sustainable, resilient, and environmentally conscious cities, incorporating diverse strategies, technologies, and community-driven efforts to address the complex challenges of our time.

Table 2 systemized the data collected for the Smart Living / Safety & Health component. 65.52% of the sources were from official government websites, 31.03% from newspapers or blogs, and 3.45% from published articles.

Table 2. Examples of the Living / Safety & Health component in the international smart cities

No.	City, Country	Examples of Projects	Source
1	Amsterdam, The Netherlands	Smart Health Amsterdam serves as the network for fostering innovation in the Life Sciences & Health sector through data and AI-based technologies.	(Amsterdam Economic Board, 2022)
2	Barcelona, Spain	Establishing the European Medicines Agency (EMA) in Barcelona could significantly enhance the environment for health startups. Furthermore, a Smart Intensive Care Unit with innovative features such as smart beds and lighting is in place.	(CatalanNews, 2018; Novoseltseva, 2020)
3	Brno, Czech Republic	Honeywell collaborates with prominent health providers to enhance digitalization in healthcare. In the initial phase with the University Hospital Brno, the focus is on skin patches for real-time monitoring of patient vitals, seamlessly uploading data to a mobile app. Ongoing efforts will extend this collaboration to the Department of Internal Cardiology, integrating automated call systems and innovative smart voice technology.	(Scott, 2022)
4	Bristol, UK	Establishing a platform for collaboration among key health and care leaders, fostering integrated health and social initiatives.	(Health and Wellbeing Board, 2022, 2023)
5	Chicago, USA	Chicago has inaugurated its inaugural smart medical district, pioneering a digital infrastructure and service ecosystem dedicated to health innovation.	(SmartCitiesWorld news team, 2019)
6	Curitiba, Brazil	Establishing a city communication infrastructure tailored for health center units.	(Silveira, 2014)
7	Dubai, UAE	Introduced in 2013, the Dubai Smart Healthcare Model revolutionized patient interactions by enabling self-check-ins through a touchscreen	(KPMG, 2015; The First Group, 2022)

No.	City, Country	Examples of Projects	Source
		system using identity cards. This innovative approach also incorporates consolidated digital health records, telemedicine services, healthcare analytics, and overall smart healthcare solutions, enhancing the efficiency and accessibility of healthcare services in Dubai.	
8	Geneva, Switzerland	GDHub endeavors to transform guidelines and policies into actionable insights, fostering effective coordination, governance, collaboration, and, ultimately, measurable impact.	(Geneva Digital Health Hub, 2022)
9	Guimarães, Portugal	Guimares has two public medical facilities, one private hospital, and numerous clinics to meet all of the requirements for healthcare.	(International Living, 2022)
10	Gyenggi province, South Korea	A smart app service is available to display convenience facilities catering to individuals with mobility impairments. Additionally, there is a data-driven system for monitoring infant health.	(Gyeonggi-do Provincial Office, 2021; Korean Ministry of Land, Infrastructure, and Transport, 2022)
11	Hong Kong, China	The Electronic Health Record Sharing System has been implemented, facilitating seamless sharing of health records. Additionally, a Big Data Analytics Platform has been launched to support healthcare-related research endeavors. The integration of telehealth, videoconferencing, and remote consultation services further enhances the accessibility and efficiency of healthcare delivery.	(Innovation and Technology Bureau of Hong Kong, 2020)
12	London, UK	myhealth.london.nhs.uk - website for finding healthcare services; Championing healthcare innovation is a key focus, highlighted by the Mayor's London Health Board. Additionally, a new initiative, the London Digital Partnership Board for health, is actively promoting advancements in digital healthcare solutions.	(Greater London Authority, 2022b; Smart London, no date)
13	Melbourne, Australia	Cortical Labs in Melbourne is pioneering the development of "DishBrain Intelligence," a groundbreaking initiative that converges soft tissue and silicon. Leveraging stem cells, they are creating a neural network equivalent that resides on a laboratory slide, aptly named the "DishBrain." This innovative approach represents a unique intersection of biological and artificial intelligence technologies.	(Vogles, 2023)
14	Milton Keynes, UK	Milton Keynes University Hospital (MKUH) has partnered with digital innovator Haltian to trial the Empathic Building Smart Hospital solution. This cutting-edge platform is crafted to enhance productivity and efficiency by leveraging data-driven insights.	(Milton Keynes University Hospital, 2022)

No.	City, Country	Examples of Projects	Source
15	New York City, USA	The NYS Scanner app is designed for scanning Covid vaccination cards, including Excelsior Passes Plus and SMART Health Cards. Additionally, it integrates an Enhanced 911 System that precisely determines the caller's location through the GPS functionality on their smartphone.	(Smart City Solutions, 2021; New York State, 2023)
16	Nice, France	Recognition was granted to initiatives related to connected health and aging well at the Lisbon Web Summit in November 2017.	(Office de Tourisme Métropolitain Nice Côte d'Azur, 2022)
17	Rotterdam, The Netherlands	LSH010 is a Rotterdam municipality initiative. With LSH010, the municipality brings together businesses, organizations, and institutions in Rotterdam's economically booming Life Sciences & Health sector. This is accomplished by the municipality doing the following: • Offering a (international) platform to Rotterdam-based businesses • Bringing together many parties, whether online and offline • Sharing information and working cooperatively on significant problems and innovations • Providing assistance to new and expanding businesses	(Rotterdam Innovation City, 2022a)
18	Seoul, South Korea	"On Seoul Health On" project focuses on empowering individuals for self-health management. Through this initiative, individuals take charge of their well-being by actively engaging in health management practices.	(Korean Ministry of Land, Infrastructure, and Transport, 2021)
19	Tampere, Finland	The Tays RDI-Center at Tampere University Hospital is spearheading the vision for everyone in the city to predominantly utilize digital services by 2025. This forward-looking initiative includes the development of new digital well-being services aimed at enhancing the overall health and welfare of the community.	(Business development, HealthHUB and Hospital District of Tampere Region, 2022)
20	Tel Aviv-Yafo, Israel	Volunteering and Social assistance; Emergency Buddy - medical assistance and preventing homebound loneliness Municipal Employment Centre - for at-risk children and youth who have endured mental, emotional, or social trauma	(Tel Aviv City Hall, 2022)
21	Vienna, Austria	E-Health encompasses both the treatment process and patient management, utilizing information and communication technologies (ICT) for enhanced healthcare services.	(UIV Urban Innovation Vienna, 2022a)

No.	City, Country	Examples of Projects	Source
22	Washington DC, USA	The mission of the DC Health Benefit Exchange Authority is to execute a healthcare exchange program in the District of Columbia in alignment with the Affordable Care Act (ACA). This mission aims to guarantee access to quality and affordable healthcare for all DC residents. The online platform (dcgealth.dc.gov) serves as a comprehensive resource, providing all necessary information to residents. Additionally, the Digital Vaccine Record (DVR) is a part of this initiative, contributing to streamlined and efficient healthcare record keeping.	(DC Health, 2023; DC Health Link, 2023)

Source: authors' work

The smart cities studied in the research have a constant focus on innovative initiatives regarding the health aspect. From a general perspective that is present in the case of Nice and Guimarães to more specific projects that will be detailed below.

More than 40% of the studied municipalities have developed applications dedicated to medical assistance, vaccine and health cards evidence, enhanced emergency calling locating services, aiding citizens with mobility impairments, infant health monitoring, digital health records, telemedicine, self-check-ins and self-health management, just to name a few. These cities include Tel Aviv-Yafo, New York City, Gyeonggi province, London, Dubai, Seoul, Geneva, Washington DC and Hong Kong.

Smart platforms that serve as a network for all institutions, businesses and organizations that are related to both health and life sciences in order to collaborate and encourage innovative projects, while tackling with the inevitable challenges that come with the adoption of digital technologies in the health sector. The fact that multiple actors can be brought together using both online and offline approaches will result in more targeted projects that suit the needs of the entire community. Among the cities that fostered these initiatives, we can recognise the Dutch municipalities of Amsterdam and Rotterdam, together with the British cities of London and Bristol.

Smart hospitals are an important aspect that is present within communities that adopt the smart city framework. A specific example can be outlined in Barcelona, with the Intensive Care Unit (ICU) that incorporates various digital innovations, such as smart beds that are aimed at facilitating the patient's status and that is linked to a smart display that aides hospital personnel constantly monitor the progress. Smart lightning that is able to resemble the day-night cycle is also an important feature of the smart ICU. In Brazil, the municipality of Curitiba

developed and implemented a complex infrastructure for communication that is aimed to help the various health institutions across the city, with dedicated solutions according to their specific needs. The Tays RDI-Center at Tampere University Hospital is another relevant example for digital technologies adoption and their objective to predominantly use them by the year of 2025. An innovative initiative is developed in Melbourne, and it involves the creation of a neural network equivalent, using stem cells and combining silicon with soft tissue in a special combination of technology and biology. Data-driven approaches are being implemented at the University Hospital located in Milton Keynes, in a fruitful collaboration between the private sector and the health provider. The platform that was developed by the hospital and a private organization specialised in digital technology innovation is able to increase productivity and efficiency levels with the use of data processed by the software in an approach to better serve the needs of patients and use resources responsibly. Another University Hospital that is constantly collaborating with the business sector for integrating innovative technologies in the treatment process of patients is the one located in the Czech city of Brno. In this case, the constant monitoring of the patient status and vital signs is performed with the use of digitally enabled patches that are applied directly on the skin of the patient. Moreover, these patches are able to transmit data in real-time to a mobile application that can be monitored by medical personnel. As heart-related conditions are a constant challenge for medical professionals, the hospital considers the use of digital innovations in another department of the institution, the one of internal cardiology. With the seamless integration of automated systems for calls and the use of smart voice enabled technologies within the operations of this department, significant benefits would be brought for patients, employees and the medical institution. The city of Chicago made a bigger step in terms of smart health, by developing an entire medical district, dedicated to the integration of novel technologies and innovations dedicated to cater to the treatment of patients in an improved way. By designing an entire area dedicated to healthcare institutions, universities and innovators, the so-called Illinois Medical District encourages a faster pace in the development and adoption of various health initiatives.

The above table illustrates a global landscape of innovative healthcare and technology initiatives implemented in various cities and countries. These projects reflect a commitment to leveraging technology, data-driven solutions, and collaborative efforts to enhance healthcare services, foster community well-being, and address emerging challenges. The diversity of approaches, from smart city initiatives and digital healthcare platforms to ground-breaking medical research and community-focused projects, underscores the multifaceted nature of efforts to improve healthcare delivery and promote well-being. These

innovations collectively contribute to the global pursuit of more efficient, accessible, and patient-cantered healthcare systems, emphasizing the importance of technological innovation and cross-sector collaboration in shaping the future of healthcare.

To achieve the results observed in the studied smart cities, the local government of an aspiring city can undertake a strategic and phased approach, considering the following key steps in Figure 4:

1. Assess and plan ahead	• Clearly establish the challenges that may be faced along with the top priorities for the municipality. • In order to establish a clear image of the road ahead, various stakeholders should be consulted, from academics, entrepreneurs to citizens.
2. Establish clear goals	• Setting the main goals and objectives that the municipality has in order to become smart should be a constant priority.
3. Take the example of other cities	• Various notable examples of successful municipalities that implemented the framework exist, such as the ones presented in the study. The ones that are the most appropriate should be studied, from cities comparable to the municipality.
4. Develop a clear strategy	• A smart city strategy should be elaborated, taking into account the six smart city components. • The projects should follow a phased implementation, based on the needs and priorities of the municipality.
5. Integrate solutions based on digital technologies	• Constant investments in different technologies are required in order to be able to keep up with the rapid changes and innovations. • Dedicated hubs that gather universities, the private and public sectors, along with start-ups should be established, in order to foster innovation.
6. Collaborate with other institutions and establish partnerships	• PPPs, or Public-Private Partnerships constitute an important aspect, as many times private companies can have both more expertise and funding for a certain domain. • Partnerships with municipalities from around the world should be encouraged in order to develop relevant projects and learn from best practices.
7. Engage the citizens	• The members of the community should be both informed about the smart city projects, as well as consulted and engaged. • Taking into account the feedback from the citizens is important, thus implementing a solution dedicated to receiving suggestions and complaints is to be considered.
8. Invest in sustainable projects	• In order to reduce both costs and the carbon footprint for the municipality, renewable energy projects such as solar panels should be integrated on public buildings. • Waste collection and management is a top priority for any smart city, thus an intelligent waste management system that encourages citizens to take into account the reduction of the environmental impact is to be implemented.

9. Allocate funds for both healthcare and safety of residents	• Telemedicine solutions and other smart health projects are to be financed in order to increase the variety of health services provided to the community. • The safety and wellbeing of residents can be improved trough the integration of sensors and smart security systems that are aimed both at protecting the citizens along with increasing their quality of life.
10. Update the smart projects based on constant monitorization	• A software that integrates data analytics about the smart city projects should be considered for a comprehensive monitoring and evaluation of the initiatives. • As technology evolves in a rapid pace, along with the dynamics of the municipality, a smart city is expected to adapt and make adjustments of the projects constantly.
11. Elaborating dedicated policies and regulations	• Both privacy and security concerns, along with the ethical ones should be taken into account in the process of elaborating policies and regulations dedicated to the smart framework.
12. Secure the necessary funding and investments	• Technological breakthroughs, along with complex smart city infrastructure require multiple sources of funding as the costs are notably high. Such sources include both public and private funds, various grants offered by local, regional or global institutions, along with revenue that is generated by the smart initiatives, such as solar panels.
13. Train and develop the skills of the city's workforce	• Constant training initiatives should be encouraged, in order to provide the municipality's workforce with the necessary resources for developing skills aimed at both supporting as well as maintaining the smart projects.

Figure 4. The key steps an aspiring city has to approach to integrate smart city solutions
Source: authors' work

By combining these elements into a well-structured and adaptable SC strategy, an aspiring city can work towards achieving the positive outcomes observed in the studied smart cities. It is crucial to tailor the approach to the city's unique characteristics, challenges, and goals, fostering a sustainable, innovative, and citizen-centric urban environment.

In the present research, the landscape of smart cities worldwide was explored, focusing on two critical components: *Smart Environment/Sustainability* as well as the *Smart Living/ Safety & Health*. This is the first study to develop a comprehensive model based on successful practices in these areas that could serve as a guide for other municipalities aspiring to become smart municipalities.

The selected 22 smart communities displayed a variety of innovative projects, reflecting a global commitment to addressing *environmental challenges*, enhancing *sustainability*, and improving the *quality of life* for the inhabitants. The findings were organised into two tables, highlighting exemplary projects in each component.

For the *Smart Environment/ Sustainability Component* we can underline the most innovative approaches that the cities adopted. The elaboration of a green label that is dedicated to environmentally friendly private organisations constitutes an important milestone for Tel Aviv-Yafo and stands as an example for other cities as it determines businesses adopt sustainable approaches and it offers citizens valuable information about what type of approach has that organisation taken.

Another notable project is the one of the world's first floating farm that operates in Rotterdam since 2019. This project contributes towards lowering emissions generated by transportation as the farm is close to the customers. It also contributes to the circular economy as the livestock of the farm can be fed with grass from the city's sport fields. By being developed on water, the farm is not affected by the amounts of precipitation and by how much the sea level fluctuates.

An initiative that can engage the entire community to contribute towards renewable energy is the one introduced by the municipality of Geneva. By giving the possibility to all citizens to invest in collective solar power plants and benefit from the outcomes of the energy generated, the city made the entire process more accessible especially for the residents that do not have the space or resources to integrate solar panels at their household. This type of project can be replicated by other cities as it would give more confidence to citizens to invest in a project that is developed by the local government.

The *Smart Living/ Safety & Health Component* there are several notable projects that can be highlighted in terms of how innovative they are. To begin with, the integrated approach of the city of Chicago that established a smart medical district dedicated to healthcare institutions, academia, start-ups and businesses that operate in the health sector, to encourage innovation. With the appropriate support and infrastructure, projects like the "DishBrain Intelligence", that combines biology and digital technologies to create a neural network equivalent using stem cells, are possible. This initiative that was developed in laboratories located in the city of Melbourne constitutes a relevant example of how new discoveries in health and technology can be made in a city that focuses on this component of the smart city framework.

A consistent *health infrastructure* that integrates the health records of the patients in a digital format, innovative telemedicine approaches, stores and processes the data collected by medical devices, streamlines the treatment process and operations of the medical organizations, facilitates the work of health personnel and offers more appropriate forms of treatment for the residents of the smart municipality. In this specific case, the project that begun in 2013 in the United Arab Emirates has to be highlighted. Dubai was an early adopter of the SC approach, as in the year of 2013 there was not such a

significant popularity of the subject as it is encountered today. The Dubai Healthcare Model is centred upon offering to citizens a more accessible way to medical services with the utilization of various digital technologies, while also focusing on making the services more efficient from an operational perspective.

Emergency healthcare services are vital for any community. As digital transformation and novel technologies were introduced in the medical field, hospitals that integrated them improved their operations and increased the quality of treatment offered to patients. A notable example for this aspect is the one of the Smart Intensive Care Unit from the Hospital Vall d'Hebron that is located in the Spanish city of Barcelona. The unit was opened in 2018 and it revolutionised the way in which medical decisions are made as the innovative equipment that was integrated enabled medical professionals to have access to real-time data of the patients.

Similar approaches of integrating innovative equipment in hospitals were also encountered in the case of two other countries Czech Republic and the United Kingdom, specifically in cities of Brno and Milton Keynes. In the case of Brno, the collaboration between the University Hospital and a company focused on technology made the integration of real-time patients' data access possible through the use of connected skin patches with sensors and a dedicated mobile application, thus offering similar conditions to the ones from the Hospital Vall d'Hebron in Barcelona. Milton Keynes University Hospital also collaborated with a technology provider that enabled the adoption of an integrated system that optimises the operations of the medical institution in terms of patient flow, efficient use and management of the available equipment and facilities.

After reviewing the innovative projects that were implemented by the 22 studied cities, some key observations can be made. To begin with, a global movement that focuses on the development of municipalities that are more sustainable, resilient, as well as environmentally friendly through the utilization of innovative digital technologies can be recognised. More municipalities from across the globe are adopting smart city solutions in an approach to respond to the current challenges and to better address the inhabitants' needs.

Even though the core concepts of the SC framework are similar across the cities, different approaches are encountered when a more detailed analysis is performed. This idea suggests that in order to achieve the benefits brought by innovative technologies, local governments should take into account the particularities of the community, the region and the economic context when developing smart projects.

A common element that binds together all smart city initiatives is the one of technological breakthroughs that are part of any project. Municipalities have understood that through the utilization of innovative digital technologies

within any operation or service they can be integrated in, significant positive results can be achieved, especially in terms of sustainability, efficient resource management and an optimised way of providing public services to the community members.

To successfully execute SC projects, it is essential to employ a cohesive approach that integrates new technologies and tools while engaging a variety of stakeholders. This process unites the endeavors and initiatives of different parties within a collaborative decision-making framework. It is through the interaction among these stakeholders that deployment models for Smart Cities take shape, defining the roles of each participant and the necessary equilibrium between them to attain the city's goals (Zona-Ortiz et al, 2020; Mejia et al., 2022).

To successfully execute SC projects, it is important to employ a cohesive approach that integrates new technologies and tools while engaging a variety of stakeholders. This process unites the endeavors and initiatives of different parties within a collaborative framework that is aimed at facilitating the process of taking decision. Through the constant interaction among these various stakeholders the viable so-called deployment models for smart municipalities take shape, defining the roles of each participant and the necessary equilibrium between them to attain the city's goals (Zona-Ortiz et al., 2020; Mejia et al., 2022).

Thus, the primary purpose of local government in facilitating smart development involves fostering innovative solutions which leverage ICT to encourage collaborative efforts in creating urban services and products. The main purpose of SC management dedicated to enhance and integrate various city management processes, harnessing human as well as social capital for better outcomes that ultimately lead to an improved life quality level for inhabitants.
Some key elements in the elaboration of smart city solutions can be condensed as follows:

- Formulating a comprehensive strategy for the long-term, that is founded on a though analysis of the municipality's strategic vision, its unique challenges and opportunities, and urban dynamics.
- Embracing openness, accessibility, and information sharing within and outside the organization to promote cooperation, integration, and transparency.
- Establishing inclusive processes that engage various stakeholders, including private individuals, in the processes of initiation, production, as well as in delivering both public services and goods through SC solutions.
- Combining both "new" online interventions and "traditional" offline methods, for instance, to rectify and mitigate potential disparities in the use of ICT in the education sector as well as to enhance the acceptance rate of intelligent initiatives within projects of urban development that integrate a sustainable component (Butnariu & Gusul, 2021).

The fruitful collaboration between the municipality, academia and private organisations is vital for the effective development of SC approaches, especially when referring to sustainable projects or projects targeting the community's health and life quality levels. From a policy elaboration approach that involves also the community members and companies, to projects in which the expertise and experience of the private sector are combined with the administrative capability of the local government, the partnerships between the public sector and the private one have demonstrated to contribute towards successful, sustainable and resilient projects that are appreciated by the citizens, local businesses and ultimately, the local administration.

Conclusions

The findings from this particular study offer some valuable insights for municipalities aiming to embark on the smart city journey. The objective of the study has been achieved, as the development model presents successful projects that were implemented worldwide as well as valuable insights dedicated to aspiring communities.

By studying successful projects that were implemented worldwide, cities can adapt, develop and implement innovative solutions that are tailored to their particular situation in terms of long-term goals and challenges faced. The recent innovations in digital technologies and the medical field combined with the global movement towards sustainable goals provide the ideal blueprint for creating smarter communities and urban settings, that are resilient to challenges and include approaches centred upon the residents.

The current research in the field of smart cities may advance through diverse approaches. To begin with, there is a constant interest for a comprehensive assessment that examines the long-term impacts of SC approaches, especially focusing on *environmentally centred projects, healthcare* initiatives, and the *quality of life* level of inhabitants of the smart communities. By taking a detailed look on how these projects influence the *citizen engagement* level and *social equity* municipalities can develop more tailored social projects that directly address the specific needs that the residents may have.

When referring to *environmentally* or *sustainability* centred initiatives, there are some successful examples to be outlined, such as the implementation of the concept of circular economy in the municipalities of Rotterdam, Amsterdam, Geneva, and Vienna. Smart waste management solutions were encountered in the previously mentioned cities, along with Brno, Chicago, Melbourne, Tampere and Hong Kong. Rotterdam and Brno additionally have adopted specific

projects related to sustainable water initiatives. Offices targeting climate and the environmental issues, forums, plans, and systems that are connected to sustainable development were established by local administrations such as New York City, Gyeonggi Province, Nice, Rotterdam, Dubai, Seoul, Washington DC, Hong Kong, Milton Keynes and Chicago.

SC technologies that are being considered and implemented today, are based especially on data-driven solutions. With this aspect, *data privacy and security* concerns emerge. Further studies on how effective *cybersecurity* measures can be implemented by local governments can constitute a direction for further research. As data security challenges can affect the entire digital infrastructure of the city, a dedicated focus towards solutions that address these challenges should be at the top of the priority agenda for any municipality.

Governance models dedicated to smart cities should also be explored further, focusing on the effective collaboration between the local administration and the private sector especially when there exists a need for special expertise in complex projects, experience and founding.

When *smart health solutions* are considered, the attention paid on the patients' needs, feedback and wellbeing should be the primary focus, while the technological advances are to be integrated in order to increase efficiency, better manage resources, streamline operations and better serve the treatment needs of the beneficiaries, while helping medical professionals take informed decisions based on real-time data. Notable examples include the "DishBrain Intelligence" project from Melbourne, the Dubai Healthcare Model that was implemented from 2013 onwards, the first Smart Intensive Care Unit from the Hospital Vall d'Hebron in Barcelona. Similar approaches were also encountered in Brno and Milton Keynes.

By performing additional comparative studies across smart communities around the globe, specific patterns and models of best practices can be outlined, while taking into account both cultural and economic factors. The main role of communities as well as *citizen engagement* within the development process of smart communities should be further investigated, along with the effects brought by the integration of digital and innovative technologies in education and within the development of the workforce.

The evaluation of how effective both *communication and collaboration* are between the local administration, businesses, universities, and members of the community is crucial for a successful adoption of smart city approaches. Better understanding of how cities manage knowledge transfer, effective policy and regulation elaboration trough networks that facilitate collaborations between municipalities constitute another significant research opportunity.

In terms of *funding* the smart projects, as resources of local communities are limited and not that high, the research of innovative financing models such as Public-Private Partnerships (PPPs) is beneficial in order for many investments for the city to be finalised in a shorter timeframe. Moreover, researching how novel digital technologies can improve the response to a local crisis and enhance the properness of the community is essential for ensuring a resilient city.

This study also has some limitations that are to be addressed. To begin with, the list of international cities that constitute the basis for the analysis includes only 22 entries. This number can be seen as being not that high and a more comprehensive future research that includes a larger number of cities should be taken into account. The information regarding the analysis came from published literature, official websites and newspapers or blogs, so this research did not directly evaluate the perception of the residents towards the smart city initiatives. It would constitute a great research challenge to conduct such a study as the cities are dispersed around the globe, yet the current research can serve as a starting point for other authors that focus on this subject. Ongoing exploration in these areas will not only contribute valuable insights but also guide policymakers and support evidence-based processes of taking decisions in the dynamic landscape of smart cities.

Future research perspectives include a study that focuses on the implementation of Smart City/ Smart Village approaches within a specific country, Romania being the one that is being taken into account.

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