Chapter 4

Smart Cities and Smart Energy: Living Spaces of The Future[1]

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Abstract

The 21st century's rapid urbanization necessitates transformative approaches to city design and administration. This article explores the convergence of smart cities and smart energy, focusing on their socio-economic impacts and technological drivers. Through a literature review and open-source analysis, the study proposes a definition of smart cities and classifies their social and economic implications. It argues that the socio-economic effects of smart cities must be examined from a multi-stakeholder perspective. While contributing to the theoretical understanding of smart cities, the paper emphasizes the need for strategies to maximize positive outcomes (e.g., economic growth, improved quality of life) and minimize negative ones. Key technological advancements, such as green roofs, autonomous vehicles, smart buildings, and e-government services, are analyzed, alongside their potential benefits and challenges. The study concludes that smart cities and economic development are complementary, with smart initiatives driving job creation, infrastructure investment, and energy efficiency while enhancing safety, environmental sustainability, and civic engagement. However, citizen involvement is crucial for building resilient, intelligent urban centers, and municipal authorities must engage citizens in decision-making processes to ensure sustainable and inclusive urban transformation.

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1. Introduction

In the early 21st century, cities are sprawling, putting enormous pressure on infrastructure and resources. The notion of 'smart cities' has developed as a response to the multi-faceted challenges posed by population explosion, climate change and resource scarcity. Smart cities optimise resource management, improve service delivery and enhance the quality of life for their citizens through the use of information and communication technologies (ICT). Smart Energy, an important component of this vision, focuses on producing, distributing and consuming energy in urban environments in an efficient and sustainable manner. This article analyses the synergistic relationship between smart cities and smart energy, and discusses its implications for future living environments.

In the coming decades, the vision of smart cities powered by intelligent energy systems is set to become a reality. Equipped with the latest technologies, these integrated urban environments are poised to improve our environmental impact. (If reducing negative impact is the main focus). The concept of smart energy is at the heart of the smart city. Furthermore, smart energy is a holistic approach to managing and optimizing the use of energy in all aspects of urban life. Through the harmonious integration of sustainable energy sources, energy-efficient buildings combined with sophisticated monitoring and surveillance systems, the smart cities of tomorrow aim to reduce carbon emissions, lower energy costs and provide a more sustainable living experience for their residents.

One of the principal drivers behind smart energy in smart cities is widespread adoption of renewable energy technologies. Solar panels adorn rooftops, wind turbines dot the skyline, and energy storage solutions including batteries and heat accumulators help to balance supply and demand. This move towards clean, decentralised energy production not only reduces dependence on fossil fuels, but also allows citizens to actively manage their energy needs.

Complementing sustainable energy infrastructures, Intelligent buildings play crucial roles in the smart city ecosystem. Armed with advanced sensors, automatic controls as well as energy management systems, they optimise energy consumption, regulate temperature and adapt to occupants' needs. By integrating smart building automation, energy-efficient appliances and smart home technologies, occupants can enjoy greater comfort, lower energy bills and a smaller environmental footprint. But the real power of smart cities lies in the seamless interconnection of these energy systems with the wider urban infrastructure. Transportation networks, street

lighting, water management and waste disposal systems are all integrated into a centralized, data-driven platform that enables real-time monitoring, predictive maintenance and dynamic resource allocation. This holistic vision not only increases efficiency, improves the overall quality of life for citizens as well.

As cities around the world embrace the smart city vision, the impact on our living spaces is growing. Imagine a future where your home automatically adjusts temperature and lighting based on your preferences and usage patterns, where your electric vehicle charges itself during off-peak hours, and where your neighborhood streetlights turn on or off based on pedestrian traffic. This is the future that smart cities and smart energy are preparing to deliver.

In the 2024 Smart City Index report produced by the International Institute for Management Development (IMD), Singapore, Zurich, Oslo, Seoul and Dubai were the cities that stood out with their smart city applications. Singapore is a leader in smart city technologies. It is at the top especially in terms of urban transport, environmental sustainability and citizen satisfaction. With its 'Smart Nation' initiative, it offers comprehensive digitalisation solutions in health, education and transport. Zurich (Switzerland) stands out with its environmentally friendly energy systems and smart waste management. It is a pioneer in citizen-oriented digital services. Oslo (Norway) stands out with its sustainability-oriented solutions. It is leading the world in using electric vehicles. It is also a strong example with its smart transport systems and practices to reduce carbon emissions. Seoul (South Korea), with its 'Smart IoT' based city infrastructure, offers comprehensive digitalisation from traffic management to public safety. It is admired for its 'Seoul Smart Citizen' platform that increases citizen engagement. It has also launched the Seoul Digital Capacity Building Training Plan for 2022. Trainers visit places frequented by the elderly to conduct individual training sessions with the elderly on directions for use smart services. Smart cities with an ageing society could follow Seoul's example to ensure that all their inhabitants benefit equally for smart city projects (IMD, 2024). It has been noted that the development of smart cities can help to reduce the gap between wealth and poverty and support citizen engagement in all kinds of social activities. At the same time, low-education employment, governmental openness and perceptions of privacy have declined in first- and second-wave smart cities as well (Lim et al. 2024). Dubai (United Arab Emirates) attracts attention with Blockchain-based government services and artificial intelligence-oriented security applications. It makes high investments in smart infrastructure projects (IMD, 2024).

The road to the future is not without its challenges. Securing vast networks of interconnected devices, guaranteeing data privacy and cybersecurity, and overcoming the logistical and financial hurdles associated with large-scale infrastructure upgrades are crucial considerations. Nevertheless, with the right policies, innovative technologies and collaborative efforts between governments, businesses and citizens, the promise of smart cities and smart energy can be realized, transforming our living spaces into more sustainable, efficient and livable environments. The following sections of this paper are organized as follows: first, we focus on smart cities and smart energy applications, then on technological developments and smart city applications that provide the infrastructure for smart transformation, then on analyzing the economic impacts of smart cities, then on examining the challenges and barriers to smart cities, and finally on presenting the results obtained from the studies conducted within the scope of the paper.

2. Smart Cities: Definition and Objectives

Smart cities are modern cities that use digitalisation, the Internet of Things (IoT), large data sets and other innovative technologies to meet the challenges of urbanisation. These cities specifically adopt solutions such as green energy, energy-efficient building designs and smart grids to achieve sustainability goals. However, criticisms such as focusing only on technological innovations and insufficient citizen participation raise new concerns such as social inequalities and cyber security risks.

The main objective of smart cities is to ensure social, environmental and economic sustainability together. Social sustainability prioritises community engagement and strengthening social ties, while environmental sustainability focuses on reducing carbon footprint and conserving natural resources. Economic sustainability, on the other hand, aims to provide fair distribution of resources and long-term growth opportunities. To achieve these goals, smart solutions are implemented to improve energy efficiency, waste management and urban infrastructure, thereby building more liveable and resilient cities.

The evolution of technology and urbanisation creates a vision of 'living spaces of the future' that offer integrated and innovative solutions in various areas such as transport, energy, healthcare and public administration. This vision uses technologies such as blockchain, IoT and artificial intelligence to optimise urban resources while making energy management more transparent and efficient. At the same time, projects that prioritise energy savings through sustainable urban planning approaches are developed and

the spread of smart cities is supported. In this way, a more livable future centred on technology and innovation is aimed. In this section, smart cities will first be defined, then the dynamics underlying the development of smart cities will be discussed, and finally, the future expectations in this area will be analysed.

Figure 1: Smart Cities

2.1. Defining Smart Cities

As Michael Batty (2013) asserts in the publication entitled The New Science of Cities, the contemporary era is characterised by an unprecedented degree of urbanisation. In other words, global urbanization has reached its peak. Cities are increasingly using the interconnected ecosystem of big data, cloud computing, and IoT (Internet of Things), as well as other innovative solutions to address various challenges and aim to enhance civil services.

The expanding urban population means that necessitate the development of methods in order to achieve greater efficiency in the execution of tasks. Digitization and initiatives to achieve maximum efficiency in urban performance have become a trend. Smart cities and regions have developed dramatically over the last 20 years (Caragliu, 2009). Smart city projects are being used to address the crisis and scarcity of resources and services, notably in the areas of the environment, transport, healthcare and education. The ongoing energy crunch, the rising traffic congestion in urban areas, and the escalating costs of conventional energy sources underscore the pressing need to devise innovative solutions in the realm of sustainability, particularly with respect to enhancing urban environments. The integration of green energy into the framework of a smart city has been demonstrated to hold considerable potential in the realms of energy efficiency, architecture and smart grid systems (Suryadevara and Biswal, 2019).

However, a paucity of understanding and a lack of consensus on the definition of smart cities can also have negative implications in practice. In the majority of cases, the concept of smart city can be optimistic in its conception, but its actual implementation can be far more controversial. In addition, a unilateral technological focus on smart city implementation and a lack of citizen-centricity can also raise serious concerns. For local and regional authorities, smart cities present either opportunities or challenges. Anvenniemi et al. (2017) highlights the importance of studying the impact of smart cities on citizens' social lives. Prosser (2018) sees cybersecurity, social fragmentation at least due to gentrification, and unsustainability as the principal vulnerabilities of the smart cities. Patel and Doshi et al. (2019) argued that the mass deployment of IoT devices can raise questions about security and protection of privacy. Trencher (2019) states that more advanced Smart City concepts, for instance 2.0, can, with comprehensive planning and design, be used as a tool to address societal challenges. The researcher also assessed smart cities as a means of resolving endogenous social issues using Fukushima to illustrate in Japan.

In terms of sustainable city performance, Kumar and De Vass (2021) looked at specific smart city constituents, such as logistics. Radchenko (2022), using concrete illustrations of pioneering smart cities, pointed out that the indiscriminate use of new technological advances can lead to a variety of negative effects if the sustainability aspect is neglected. Misinterpretation of the concept may be behind the negative effects of smart cities, lack of awareness and its all-encompassing human-centric definition, multi-stakeholder approaches to understanding the smart city concept must be considered (Radchenko, 2023).

Researchers including Popescu (2015), Khalifa (2019), Visvizi and Lytras, (2019), Trencher et al. (2019) have analyzed the potential for significant socioeconomic impact of smart cities. The difference between theorising and practising is explained by Shelton (2015). The response to the query regarding whether smart cities automatically raise their inhabitants' living standards is analyzed in the relevant report of Congress by Municipal and Regional Authorities. As the study shows, the main threats and opportunities of smart cities relate to privacy and the widening of digital divide through artificial intelligence.

Dhere and Bendale (2019) point out that it is questionable how beneficial smart cities can be for society when only the economic aspect is emphasized and the social aspect is entirely neglected or absent. Taylor (2015) stated that smart city applications, which are well-known examples, could have different impacts in the places where they are implemented. While city resources are concentrated in certain groups, some segments are impoverished and social polarization can occur.

As far as the definition of smart cities is concerned, the most important studies in this field have been carried out by Dameri (2013), Russo et al. (2014) and Ramaprasad, Sánchez-Ortiz and Syn (2017).

Rapid urbanisation has given rise to the notion of 'smart cities' providing a guiding vision for the future. Unlike traditional city centres, smart cities use technology, data and technological innovation to improve the experience of residents, enhance city operations and create a more resilient and liveable environment. Some authors even consider cities as strategic entities rather than simply geographical locations.

One of the hallmarks of a smart city is the integration of various systems and infrastructures into the urban landscape. These range from transportation and energy networks to water management and waste disposal systems. By linking these different elements through sensors, connectivity and data analysis, smart cities can optimize resource allocation, reduce waste and meet the changing needs of the population in real time.

Smart cities prioritize citizen engagement, leveraging digital platforms and interactive tools to foster participation in decision-making, feedback, problem reporting, and solution development. The ultimate goal is improved quality of life through enhanced public safety, reduced congestion, better access to services, and a more inclusive society. This goal is achieved using technologies that include IoT (the Internet of Things), AI, and even

renewable energy to analyse data to inform urban planning and service delivery.

While the specific implementation of smart city initiatives can vary considerably depending on the needs and challenges specific to a given urban area, the underlying principles remain the same: harnessing the power of both technology and innovation to create more liveable, sustainable and resilient cities. As the world grapples with the challenges of rapid urbanization, the Smart City concept is emerging as a promising solution, providing a plan for the cities of the future. If we try to find a common and simple definition that encompasses all these elements, a so-called smart city would be an agglomeration that harnesses the power of technology, information and innovation to improve the quality of life for its citizens and efficiency of the city's operations, creating a better, more sustainable and liveable communities.

To effectively deploy intelligent solutions across various domains, municipal administrations must formulate a strategic roadmap for smart city development. This framework should encompass three primary dimensions. The initial dimension involves the identification of specific issues and the necessity for innovative solutions. It is important to involve all stakeholders including residents and industries. In this way, their expectations and needs can be taken into account. The second one pertains to the formulation of policies. Robust policies are imperative to steer smart city implementations, delineate responsibilities, and develop comprehensive agendas and strategies to attain the goals set. The third dimension focuses on citizen engagement through e-government initiatives, access to open data, provision of complimentary Wi-Fi, involvement in sporting events, among other avenues. In summary, smart cities are characterized as a digitally interconnected environment that fosters access to open data for start-ups while ensuring full disclosure. It embodies an environmentally sustainable, energy-saving framework that investments in renewable energy sources, LED lighting, electric transportation vehicles and systems. Moreover, smart city prioritizes safety by implementing technological solutions aimed at crime reduction, establishing intelligent traffic management systems to minimize casualties, and leveraging artificial intelligence to anticipate and avert criminal activities proactively. A financially stable smart city boasts commendable creditworthiness and a proven track record. Furthermore, it is a socially engaged urban landscape where citizens exhibit a strong sense of civic identity and actively participate in community matters through digital interactions with municipal authorities. A smart city utilizes advanced technologies to stimulate economic progression via direct infrastructure investments and

enhanced proficiency in various technical disciplines. In essence, urban areas encounter numerous challenges, including unemployment, traffic congestion, elevated crime rates, and outdated infrastructure. Smart city initiatives hold the potential to mitigate these urban challenges by decreasing crime, lowering traffic accidents and congestion, and providing communities with novel business opportunities; smart technologies empower communities to stimulate job creation and economic growth.

2.2. Objectives of Smart City Initiatives

Within the domain of urban evolution, smart city initiatives have shown that social, environmental and economic sustainability are at the core of their objectives. In particular, social sustainability has been highlighted as a major consideration when planning future urban development, underlining the importance of integrating these economic, environmental as well as social aspects in urban planning and management. This issue has been the subject of research into whether there may be a negative impact on the environment (Monfaredzadeh et al., 2015). Smart city residents value social diversity, and social sustainability—crucial for a strong social fabric—depends on effective community engagement. However, despite its close ties to the notion of the smart city, social sustainability is given lesser attention than ecological sustainability (Yiğitcanlar et al., 2019).

Worldwide, atmospheric sustainability is recognised as one of the biggest issues. This approach is predicated on achieving a balance between ecosystem health and cost-effectiveness through the conservation of resources, the reduction of carbon emissions, and the prevention and mitigation of environmental degradation. The concept of environmental sustainability is a prominent one in the growing smart city trend, given the significant sustainability potential of cities. (Chatfield et al., 2016). The negative environmental impacts of urban areas are due to a number of factors, including urban adjustment, power and water usage, waste accumulation as well (Brauer et al., 2015).

The necessity of financial and economic resilience to facilitate long-term development in the smart city sector is indisputable. Economic stability also involves the delicate task of balancing intergenerational differences, which, contrary to popular belief, is not always quite simplistic as it might seem. This is the link that connects distributive equity, growth sustainability, optimal performance and timing preference (Anand et al., 2000). Smart City's economic systems require resource management strategies that [e.g., "maximize efficiency," "ensure equitable distribution," "promote sustainable

growth"] to ensure the distribution of money is both equal and efficient among the city's inhabitants, thereby facilitating the creation and increase of resources in a similar manner. Consequently, economic sustainability will engender opportunities to increase individual production in the future. By leveraging economic and social resources, this strategy aims to improve the existing knowledge and the skills of the smart city's inhabitants.

Smart City intends to analyse and realise relevant Smart City solutions, promoting growth and long-term evolution of the living environment. By facilitating object control, mutual interaction and the hosting of connected campaigns, smart city solutions have been found to enhance the functionality of everyday life in a variety of ways. The fundamental principle underlying the smart city vision is the extensive application of intelligent systems in all areas of the city's ecosystem, encompassing infrastructure, transportation, governance, education, agriculture, healthcare, industry, energy, environment, and the economy (Brauer et al., 2015).

2.3. Future Prospects in The Context of Future Living Spaces Objectives of Smart City Initiatives

Looking ahead to the 21st century, the convergence of technological advances and a growing urban population has given rise to a vision of "living spaces of the future" - a future where smart cities and intelligent energy systems work together to create more durable, resource-efficient and desirable environments for all. At its centre are smart cities - hubs which harness technologies, data-driven policy-making protokols and novel approaches to enhance the experience and well-being of their citizens. These smart city projects are characterised by smooth interaction between different systems and infrastructures, from transport and energy networks to healthcare and public administration.

The use of intelligent energy in smart cities is dramatically changing how we live in the future:

* Decentralized energy production: Rooftop solar panels and community renewable energy projects, also known as green roofs, enable city dwellers actively participate in energy production.

* Energy efficiency: Intelligent homes and buildings equipped with energy-efficient appliances and automatic controls reduce energy consumption and operating costs.

* Greater comfort and convenience: Smart thermostats, lighting systems and appliances offer personalized comfort and convenience while minimizing energy waste.

* Improved air quality: The transition to cleaner energy sources helps improve air quality and public health.

* Reduced carbon footprint: Greenhouse gas emissions are significantly reduced and climate change mitigated through the widespread use of renewable energy.

In the future, smart cities and smart energy solutions will become even more widespread and advanced. It is important to understand that the following list represents only a selection of the anticipated advances and innovations that are expected to occur in this particular field of study in the near future:

* Blockchain technology: It will support smart energy solutions by bringing transparency and security to energy trading.

* Internet of Things (IoT): The use of more advanced systems that monitor and optimize energy consumption will increase.

* Artificial intelligence (AI): efficiency will be enhanced by predictive analysis and automated energy management.

* Sustainable urban planning: Urban planning approaches that prioritize energy efficiency will be developed.

3. Technological Developments Shaping Smart Cities and Smart Energy

The global trend towards urbanization poses significant challenges in terms of resource management, infrastructure development and environmental sustainability. One promising approach to meeting these challenges is to build smart cities that use Information and Communication Technologies (ICT) to help make the world a better place. A key part of smart city development is smart energy, focusing on producing, distributing and consuming energy efficiently and sustainably in urban areas. This chapter examines the key technological developments shaping smart cities and smart energy, and analyzes their interconnections and potential impacts.

3.1. Intelligent Energy Concept

Smart energy is about efficiency and sustainability solutions, using information technology to produce, distribute and consume energy. Smart

energy systems aim to use energy resources more efficiently and reduce carbon emissions. The main applications of smart energy are as follows:

* Smart grids: Improves energy efficiency through real-time observation and management in energy consumption.

* Renewable energy supplies: Integration of environmentally sustainable energy resources such as wind, hydro and solar power.

* Energy storage systems: Energy supply and demand are balanced by batteries and other energy storage solutions.

* Smart metering systems: Smart meters are designed to track energy consumption and inform users.

* Energy management systems: Automation and control systems are implemented to optimize energy consumption.

Figure 2: Smart Energy Concept

3.2. Basic Technological Developments

For smart cities to progress, it is essential to bring together the Internet of Things (IoT), artificial intelligence (AI) and machine learning (ML), renewable energy integration, big data analytics, and various technologies. Monitoring and controlling urban systems with IoT enable (energy, transport, water, waste management) in real time, allowing resources to be optimised and services to be improved. AI and ML algorithms play a key role in analysing IoT data, enabling predictive maintenance, anomaly detection and optimisation of energy usage. The integration of renewable power sources including solar, wind, bioenergy and hydropower is accelerating the transition to sustainable, decentralised energy systems, supporting grid stability and reducing carbon emissions. Big data analytics enable data-driven decisions, understanding urban dynamics and optimizing resource allocation through IoT data. Smart grid technologies optimise energy distribution, while energy storing technologies (Li-ion batteries, pumped hydro storage, thermal energy storage and hydrogen fuel cells) offset for the intermittent nature of renewables. Building automation systems improve energy efficiency, while electric and autonomous vehicles are transforming transport systems. Blockchain technology enhances energy transaction transparency and security, while 5G and advanced communication networks support big data traffic, strengthening smart cities' global connectivity. In short, the synergistic interplay of these technologies is helping achieve more efficient, better sustainable and more liveable urban environments. Technological developments we have mentioned are combining to create the smart city of tomorrow, and these technologies will now be briefly examined.

* The Internet of Things (IoT): The proliferation of interconnected sensors, actuators and smart devices enables real-time surveillance and control of diverse urban systems, ranging from energy grids and transport networks to water and waste management facilities. IoT facilitates data collection, assessment and decision making, optimising resource allocation and improving service delivery.

* Artificial Intelligence and Machine Learning (AI and ML): AI and ML algorithms are crucial for analysing the large amount of data generated by IoT devices. These advanced algorithms enable predictive maintenance, anomaly detecting and optimisation models for energy consumption. AI-based traffic management systems can improve traffic flow and reduce congestion, while AI-based energy forecasting can optimize grid stability

and renewable energy integration. Accordingly, the efficiency of smart cities increases thanks to data analysis and predictive analytics.

* Integration of renewable energies: The transition to decentralised, sustainable energy systems is being driven by the increasing accessibility and efficiency of renewable energy sources such as solar, wind and geothermal. Smart grids integrating renewable energy sources increase grid stability and flexibility, which is vital for the decarbonization of urban energy systems. Renewables will play an essential part in meeting the energy needs of smart city environments. Integrating renewable energy increases energy efficiency and sustainability. The main renewable energy sources are; Solar energy (Buildings are topped with solar panels or on large open surfaces to produce energy), Wind power (Wind turbines generate electricity from wind energy and are integrated into smart grid systems), Bioenergy (Energy is produced by transforming organic waste in biomass power plants), and Hydroelectric power (Hydroelectric power plants are designed to generate energy via rivers and dams).

* Big Data Analytics: To understand urban dynamics and optimise resource allocation, the power to gather, store and evaluate large amounts of IoT information is essential. By providing information on energy consumption patterns, traffic flows, environmental conditions and citizen behavior, Big Data Analytics enables data-driven decision-making to improve urban planning and management.

* Smart grid technologies: Smart grids use advanced sensors, communication networks and control systems to optimize energy distribution, increase grid stability and integrate distributed generation resources. These technologies provide real-time metering of power consumption, demand response programmes and resilience improvements to the grid.

* Energy storage technologies: In order to balance energy supply and demand, energy storage is essential. Advances in battery technology and other energy storage solutions are key to reducing the renewable energy's unreliability. Energy storage systems enable solar and wind power to be reliably integrated into the grid, guaranteeing a sustainable energy supply. This is particularly important given the intermittent nature of renewable energy. The following technologies are used for energy storage: Lithium-ion cells (widely used for electric cars and high-volume energy storage), pumped storage (where energy is stored as water is pumped from a lower pool to a higher one, and then released when the energy is needed), thermal energy storage (where excess energy is stored as heat for heating and cooling

applications), and hydrogen fuel cells (where excess energy is used to produce hydrogen, which is then released through combustion to produce energy).

* Building automation systems: Intelligent buildings use sensors and automatic controls to optimize energy consumption and improve occupant comfort.

* Electric vehicles (EVs) and autonomous vehicles (AVs): The transition to EVs and AVs will have a considerable effect on urban transport and energy demand.

* Blockchain technology: The secure character of decentralized blockchain can increase transparency as well as security of energy transactions, particularly in peer-to-peer energy trading and microgrids, thus support citizen participation and data sharing.

* 5G and advanced communication networks: High-bandwidth, low-latency communication networks are needed to support the massive data traffic generated by IoT devices and facilitate real-time communication between different urban systems. Smart cities need to be better integrated with the outside world in order to survive intense international competition. 5G technology will be crucial to unlocking the opportunities of smart cities and smart energy.

3.3 Synergistic Effects

The interaction between the smart technologies listed above creates a synergistic effect, enhancing their individual impact. For example, IoT appliances collect data on energy usage, which is then analysed using advanced artificial intelligence and predictive machine learning techniques to optimise energy allocation and manage demand. Renewable energy powers smart grids, enabling a more sustainable and flexible energy system.

The technological developments discussed in this chapter are fundamentally reshaping smart cities and smart energy. These technologies offer opportunities to create both sustainable, resilient and equitable urban environments, however require addressing related challenges. Realising the full promise of these technologies thus ensure a smooth shift to a smarter, more sustainable tomorrow will require further research and development.

3.4 The Cornerstones of Smart Cities: Key Concepts

Smart cities-urban centers employing state-of-the-art technologies and novel approaches-are a crucial response to the challenges arising from rapid global metropolitanisation and a growing demand for more durable, efficient

and liveable environments. As mentioned above, smart cities offer smarter solutions than traditional methods in such areas as traffic management and reducing energy consumption and waste management, thanks to data collection and analysis processes. The smart transformation is founded on five key pillars: smart transport, smart energy management, smart buildings, smart healthcare, and smart governance.

3.5 Intelligent transport systems

In a smart city, the transportation system is designed to be efficient, sustainable and adapted to users' needs. Improved traffic flow, enhanced road safety, and reduced environmental impact are achieved through Intelligent Transport Systems (ITS), which utilize information and communication technologies namely sensors and Big Data analysis. Intelligent transport systems are based on real-time monitoring of traffic and the integration of technologies such as public transport, car sharing and electric vehicle infrastructure. By optimising the management of people and goods, intelligent transport reduces congestion, cuts emissions and improves the overall mobility of urban populations.

The subsequent discussion delineates several components integral to intelligent transportation systems:

* Real-time traffic management: data collection from sensors and cameras enable instant detection of traffic density and accidents.

* Intelligent traffic signals: Traffic lights optimize traffic flow based on real-time data analysis.

* Autonomous vehicles: Driverless vehicles are integrated into intelligent transport systems to improve traffic efficiency and reduce accidents.

* Optimizing public transport: Intelligent ticketing systems and real-time tracking make public transport services more efficient.

3.6 Intelligent energy management

The seamless combination of renewable energy sources, advanced energy storage solutions and sophisticated energy management systems characterises the energy environment of a smart city. The sophisticated energy management framework allows the city's energy consumption to be controlled and optimised. Through the deployment of smart grids, smart meters and new technology for energy efficiency, smart cities can reduce their carbon footprint, cut energy costs and provide more reliable and flexible power to their residents. This holistic approach to energy management

not only benefits the environment, but also empowers citizens to take an active role in their energy consumption. Smart cities aim to increase energy efficiency and sustainability through intelligent energy solutions. Presented below are several illustrative instances of applications:

* City of Songdo, South Korea: energy consumption is optimized thanks to smart networks and renewable energy systems.

* Freiburg, Germany: An example of sustainable urban planning thanks to solar energy and ecological building practices.

* City of Amsterdam, Netherlands: Reducing carbon emissions through smart metering and energy management solutions.

3.7 Intelligent buildings

Intelligent buildings are an important component of the smart city ecosystem. These structures are equipped with advanced sensors, automatic controls and energy management systems that optimize energy use, regulate temperature and adapt to the needs of building occupants. By integrating technologies such as building automation, energy-efficient appliances and smart home devices, smart buildings can significantly reduce energy consumption, cut operating costs, enhance safety and offer a more comfortable, sustainable living experience for their occupants.

3.8 Intelligent healthcare services

In a smart city, the healthcare system is designed to be more accessible, more efficient and more personalized. Through the integration of telemedicine, remote monitoring and data-driven decision-making, smart healthcare initiatives can improve the delivery of medical services, enhance disease prevention and offer more tailored treatment options for urban residents. In addition, the use of smart technologies in hospitals and clinics can improve patient satisfaction, streamline administrative processes and optimize the allocation of healthcare resources.

3.9 Intelligent governance

A well-coordinated and transparency of governance is the core of a smart city. Smart governance strengthens decision-making, improves public service delivery and fosters a more inclusive and participatory urban environment through the use of digital technologies, open data and citizen engagement. This can include the use of online platforms for civic engagement, the implementation of e-government services, and the adoption of data-driven policies that prioritise the demands and concerns of the local community.

Citizen engagement in smart cities is essential to improve the performance of city governance and to better meet the needs of citizens. The following are some of the ways in which citizen engagement can be promoted:

* E-participation platforms: Citizens can submit feedback and contribute to decision-making processes via digital platforms provided by the municipalities.

* Mobile applications: Mobile applications giving access to municipal services and enabling citizens to report problems are being developed.

* Community workshops: Citizens can play an active role in urban planning and projects through physical meetings and workshops.

* Social media and digital surveys: Citizens' opinions and suggestions are collected via social media platforms and digital surveys.

By integrating these five pillars - smart transportation, smart energy management, smart buildings, smart healthcare and smart governance - smart cities can create a more sustainable, efficient and liveable urban environment. However, successful implementation of these concepts requires a collaborative approach, with governments, businesses and citizens working together to meet the unique challenges and potential of their local contexts.

As the world continues to evolve, the vision of smart cities promises a future where technology and innovation are used to improve the experience of life for all city dwellers, leading the way to a more prosperous and equitable future.

3.10 A framework for sustainable and resilient urban environments

Achieving sustainable and resilient urban environments requires a holistic approach that integrates smart city initiatives and smart energy strategies:

* Participatory planning: Involving citizens in the planning and execution processes is essential to ensure widespread acceptance and ownership.

* Data-driven decision-making: Leveraging data analysis to inform policy decisions and optimize resource allocation is essential.

* Public-private partnerships: Collaboration between government agencies, private sector companies and research institutions is essential to stimulate innovation and support investment.

* Investment in infrastructure: Significant investment is needed to upgrade existing infrastructure and deploy new smart technologies.

* Capacity building: Investment in education and training programmes to improve digital and technical skills is essential.

4. Smart Cities and Smart Energy: Economic Impacts

The paucity of evaluation tools has made assessing the economics of smart city projects a challenging task. To meet this challenge, an exploratory research approach was employed to identify the economic benefits of smart cities (Wirsbinna and Grega, 2021). The authors have summarised the opinions of 12 experts in Table 1 below and classified the economic benefits of smart cities into 10 categories.

A summary of the principal economic benefits of the Smart City approach is presented in the Table 1.

4.1 Cost Savings

Indeed, the potential for cost savings is inextricably linked to the performance potential of smart city projects. By reducing costs, such projects have a chance to increase business and revenue. It is important to acknowledge that the realisation of smart infrastructure is a long-term investment. A comprehensive set of policy strategies exists to cut costs, such as implementation of efficient transportation systems, reliable water and energy supplies, and the optimisation of public facility maintenance.

Table 1: Smart city initiatives' economic benefits illustrated by themes and categories

Theme	Categories	Codes
Economic benefits of smart city initiatives	Productivity	Greater mobility and easier access to services
	Security	Peak-time traffic control, emergency response services, mobilizing citizens in pandemic situations
	Attractiveness of the city	Enhancing the urban landscape, panoramic views
	Reducing Costs	Service and maintain system costs to a minimum
	Durability	Ensure a balance between preservation and use of amenities in a strategic perspective, creating mutual interest for all stakeholders.
	Intelligent transport	Priority to public transport, integration of urban transport facilities, increased number of shared transport stations
	Intelligent building	Minimisation of the environmental burden caused by the use of water and energy
	Financing	Allocation of public funds, promotion of an intelligent energy strategy
	Measurability	Smart city application monitoring, including evaluation of the impact of smart city initiatives

4.2 Efficiency

Efficiency is evident in processes such as manufacturing, power consumption and urban agriculture that can be enabled by smart city technologies. Efficiency is linked to digitalisation. More connected systems, thanks to information technologies, will speed up services and connect stakeholders. The ability to compare, measure and evaluate all of the information in smart cities should improve the performance of service distribution. Consequently, services will be restructured and consolidated to improve citizen satisfaction and efficiency.

4.3 Safety

Control centers in large cities are necessary to ensure people's safety. These control centres feed data about traffic and pedestrians, as well as sensors such as water levels in areas at risk of flooding. Safety is approached from many angles, such as emergency response preparedness, peak-time traffic management, disaster or pandemic mobilization. Risk and damage prevention are top priorities. Smart city initiatives can contribute to and

address this, particularly during periods of pandemic when a rapid response is required.

4.4 Attractiveness of Cities

Smart people want to live in smart cities. Indeed, talented human recources are attracted to desirable cities, and major employers are keen to relocate when they perceive strong demand. Smart city initiatives can ease the process of urban integration by reducing many administrative requirements. Improving the standard of living for residents is the aim of smart city initiatives. Better living conditions are more valuable than advanced technology. In turn, the city offers more tax and other revenues, an abundance of skilled labour and a better image. A high speed network can make a city or province more desirable and economically attractive, for home-businesses. In this case, regions with a fast Internet infrastructure will become more attractive for pandemic-type processes.

4.5 Connectivity

Connectivity is essential to the success of smart city projects. A lot has been said about the significance of Internet of Things (IoT) applications. These include LoRaWan technology (Long Range Wide Area Network, a protocol that allows IoT devices to interact with each other and with the cloud), open interfaces and bulk data processing. Making data available to city inhabitants or creating business opportunities has become the main element of smart city projects. It is rather novel approach from the municipal point of view. The explicit aim is avoiding handing private public data over to commercial providers, while ensuring that it is still accessible to those who need it. However, there are often no specific ideas about how this data would be used. The level of networking between cities is seen as an economic advantage.

4.6 Intelligent transport

With regard to smart city initiatives in the field of intelligent transport, the public sector is intensively evaluating autonomous driving to cut both costs and crowding. Transportation should receive preferential treatment in order to reduce costs. City dwellers will only take it, when it is as convenient or pleasant than private transport. Intelligent app-based systems optimise traffic patterns.

4.7 Economic Development

Cities generate around 90 per cent of total US national output and provide 85 per cent of US national employment; in other words, cities are the focus of economic vitality (Florida, 2017). When talking about economic impact on a global scale, it would be more accurate to target cities rather than nations. The goal of stimulating economic development is to increase incomes and employment, and reduce indigence, and thus contribute to a reduction in crime rates, which can lead to a stronger economy and an increase in people's quality of life and prosperity. Smart cities represent departure from inflexable, scripted approaches to managing urban resources. High crime levels dissuade both foreign and domestic investment and redistribute assets, leading a lack of both certainty and efficiency. In contrast, smart city model open ways to major economic potential and public security. As we can see, achieving smart city goals also means achieving economic development goals (Musa, 2017).

As cities develop smart technologies, job opportunities increase; besides smart cities create new, green workplaces. GIS (Geographic Information Systems) are applied to reducing crime through the geographical location of high crime areas and the identification of particular crime patterns. High crime rates have a negative influence on economic activity, creating insecurity as well as inefficiency. Smart city tools, including GIS, can help reduce crime, improve productivity, save costs, make communities safer and improve people's quality of life (Musa, 2017).

Based on the literature review and discussions, we propose a classification of the positive (in Table 2) and negative (in Table 3) economic impacts of smart cities as below (Radchenko, 2023).

Table 2: The positive economic impact of the smart city (selected by stakeholders)

The positive economic impact of the smart city
Investment growth
Strengthening of economic growth
Facilitating joint public-private partnerships
Qualitative development of workforce resources
Evolution from a low-skilled to a high-skilled workforce
Increased productivity
Improving the competitiveness of local authorities
Advanced data system management, analytical insight to trigger cost-effective solutions
Wage increases
Encouraging small-scale approaches

Table 3: The most significant economic impacts of smart cities (selected by stakeholders)

The most significant economic impacts of smart cities
Corruption
Lacking funding for non-Smart City projects
Economic risks associated with cybercrime
Deepening socio-economic gap
The financial inaccessibility of smart transformation for poor communities without additional resources
Focus on smart metropolitan infrastructure to address urban-rural divide
Dependence on exclusive technologies; obligation to renew licenses when existing systems are replaced or become obsolete
Incompatibility between system and hardware
Increased poverty for those without technological expertise
Shifting resources from traditional sectors and services to smart urban planning, limiting access to traditional industry resources.

Traffic congestion also has a detrimental effect on income and employment growth. Road accidents also result in job losses and have a negative impact on economic development. Road traffic crashes are estimated to cost most countries around 3% of their GDP (WHO, 2024). Around 1.19 million people worldwide die each year as a consequence of road traffic crashes, and road traffic crash injuries are the leading cause of mortality of children and young adults between the ages of 5 and 29. Despite owning around 60% of the world's vehicles, 92% of the world's road deaths occur in lower-

and middle-income countries. Traffic problems can be alleviated through sensors and intelligent solutions. The data from sensors allows the number of traffic lights to be increased or footpaths to be widened where necessary. GIS solutions help transport planners determine the best possible place for new traffic signals or a new viaduct. The speed of drivers who run red lights is reported by intelligent traffic cameras. The results of using surveillance technology in the transport system have brought increased revenue to many cities, reduced traffic accidents and changed the behaviour of reckless drivers.

Popescu points out that smart city projects' economic impact will be the creation of businesses and jobs, the development of human resources and increased efficiency (Popescu 2015). Shelton et al. argue that the expansion of intelligence can have a positive role in the regional economic order by providing a tool for restructuring the local economy. A smart city has opportunity to improve information processing, increase capacity and help restructure the local economy. Smart cities can help unleash local talent and localize economic gravitational forces. They can also improve operational performance by making smart zones more attractive to investors. Intelligence has great potential, especially in times of austerity (Shelton, Zook and Wiig, 2015). Masera et al. mentioned the cybersecurity issues associated with smart energy (Masera, Bompard, Profumo and Hadjsaid, 2018). By definition, the smart city model allows for more collaboration and participation from stakeholders, leading to a co-creation and user-driven economy (Radchenko, 2021). A greater capacity for economic performance is vital to a smart city approach that uses both scientific and engineering solutions to overcome economic recession. Tangible examples of improved macro-economic metrics in advanced cities through the use of a smart framework exist (Radchenko, 2022).

Simultaneously, smart cities risk widening the rich-poor gap, leaving behind under-resourced communities and stealing funds from other sectors (Visvizi and Lytras, 2019). The negative economic impacts of smart cities, selected by stakeholders, are presented in Table 3 above. The most classic of these are threats to critical installations and state resources, like financial systems, and threats to personal privacy. They also include spying on individuals, institutions and organisations, the use of cyber warfare, competition for control of cyberspace, and the disruption of e-business and major economic sectors of the city (Khalifa, 2019).

5. Challenges and Obstacles

Despite their many benefits, several challenges stand in the way of widespread adoption of smart cities and smart energy:

* High upfront costs to invest: Deploying smart technologies takes a significant initial financial commitment. However, these costs can be financed in the long term through resources provided by the public, and social benefits can be increased.

* Data protection and privacy: Data security and privacy concerns arise from the large amounts of data that are collected and analysed.

* Interoperability issues: Ensuring seamless communication and data exchange between different systems and platforms remains a challenge.

* Digital divide: unequal access to technology and digital culture can exacerbate existing urban inequalities.

* Regulatory frameworks: Clear and effective regulations are still needed to govern the use of smart technologies and ensure their responsible deployment.

6. Method

This study uses a combination of qualitative and quantitative research methods to examine the socio-economic impacts of smart cities and smart energy systems. The research is based on literature review and open source data analysis. Firstly, the existing literature on smart cities and smart energy is reviewed and previous studies in this field are analysed. The literature review focused on the definition of smart cities, their objectives and technological developments.

In the second stage of the research, open source data were analysed to assess the economic and social impacts of smart city applications. These analyses aimed to reveal the impacts of smart cities in areas such as energy efficiency, job opportunities, infrastructure investments and citizen engagement. In addition, the challenges and obstacles faced by smart cities were also addressed within the scope of these analyses.

In the data collection process, reports of international organisations, academic articles and official documents related to smart city projects were used. The analyses were conducted with a comparative approach to understand the impacts of smart cities on economic growth, environmental sustainability and social inequalities.

7. Findings

The findings of the study reveal both positive and negative impacts of smart cities and smart energy systems. Firstly, smart cities have been found to make significant contributions in areas such as energy efficiency, reduction of carbon emissions and use of renewable energy sources. In particular, smart grids and energy storage systems have been observed to optimise energy consumption and reduce energy costs.

In economic terms, it has been determined that smart cities create new job opportunities and increase infrastructure investments. In particular, projects such as smart transport systems and smart buildings have been observed to revitalise local economies and increase employment. However, the high costs and financing problems of smart city projects stand out as an important factor preventing the expansion of these projects.

In terms of social impacts, smart cities have been found to increase citizen participation and improve quality of life. However, the digital divide and inequalities in access to technology cause some social groups not to benefit from smart city projects sufficiently. In addition, data security and privacy concerns have been identified as one of the important obstacles to the widespread use of smart cities.

8. Discussion

This study reveals that smart cities and smart energy systems play an important role in shaping the living spaces of the future. Smart cities offer significant opportunities in areas such as energy efficiency, economic growth and citizen engagement. However, some challenges need to be overcome in order to fully utilise these opportunities.

Firstly, the high costs of smart city projects make it difficult to implement these projects, especially in developing countries. Therefore, public-private partnerships and international financing mechanisms are critical for the expansion of smart city projects. In addition, to ensure the sustainability of smart cities, local governments need to involve citizens in decision-making processes and develop policies to reduce social inequalities.

Data security and privacy concerns are one of the most important challenges of smart cities. IoT devices and data collection systems used in smart cities may be vulnerable to cyber-attacks. Therefore, it is of great importance to take strong cyber security measures in smart city projects and protect citizens' data privacy.

In conclusion, smart cities and smart energy systems have a great potential to build sustainable and liveable cities of the future. However, in order to fully realise this potential, technological, economic and social challenges need to be overcome. In this context, future studies should focus on how smart cities can be implemented in different geographies and socio-economic conditions.

9. Conclusion

Smart cities and smart energy are intrinsically linked and profoundly shape the future of urban habitats. By overcoming the challenges and embracing the opportunities offered by technological advancements, smart cities can create sustainable, resilient and equitable urban environments that enhance the quality of all citizens' lives.

First, economic and social perceptions of smart cities were framed and a definition of a smart city was created. The common definition obtained through this study is as follows: "A smart city is an area that harnesses the potential of technology, data and innovation to improve the standards of living of its residents and the efficiency of city operations, creating a more sustainable and liveable environment". Second, in societal terms, the most frequently cited benefits are sustainability, quality living, the green agenda, increased connectedness and networking between people, and the potential, but not automatic, basis for facilitating inclusion and equality. On the negative side, the main criticisms of smart cities are seen as marginalisation, privacy concerns and data monopolisation.

Third, it unlocks smart cities' economic potential through encouraging micro-scale solutions and community innovation, fostering skills and knowledge, developing local talent, and making communities more competitive. In particular, cybersecurity risks and the exacerbation of divisions (rich-poor, urban-rural, etc.) are cited in the literature as negative aspects. Ultimately, despite the plethora of possible smart technologies and innovations, a consistent approach will be needed to reap their advantages or manage their impacts. Not only an overall strategy, but also concrete efforts at different levels are needed to address negative impacts while maximising positive outcomes. Otherwise, the potential benefits of the smart city could be diminished while the challenges get out of hand. This study has revealed that there is a strong relationship linking the smart city and sustainability; further research is necessary to explore the transformative and synergistic potential of smart cities to meet the challenges identified. Furthermore, the potential impacts of smart cities, the exploration of effective and balanced

definitions and the inclusion of the voice of citizens and stakeholders are among the things that remain to be done when it comes to smart cities.

The most important conclusions that can be drawn from the present paper are as follows:

1) The safety, security and well-being of the citizens is the common goal of both economic progress and smart metropolis initiatives. Economic development is about building communities and job creation for prosperity, while smart city initiatives are about technology for community safety and prosperity.

2) Smart City projects contribute both directly and peripherally to helping cities grow economically. Direct investment in infrastructure, resulting in less time spent on traffic, fewer accidents, and more local trade; better use of energy, including smart lighting and air conditioners; improved social infrastructure, including hospital, school, and library facilities; and effective regulation of new technologies, including self-driving electric vehicles and IoT. An important contribution can be made indirectly through (a) protecting lives against environmental hazards as well as crime, (b) promoting quality of life, (c) inhabitants being least dissatisfied and more motivated, (d) inhabitants having a sense of civic belonging, finally (e) building relationships across the private sector.

3) Urban smart applications are implemented through concentration on four key areas: economic growth, improved public safety, the climate changing, and finally traffic.

4) Autonomous electric vehicles, sensor-enabled traffic lights, sensor-enabled street lights, water leak detection sensors, GIS, high-speed internet connection, e-payments and e-licensing services are among the key smart solutions implemented by smart cities.

5) Smart technologies can connect infrastructure, but building a resilient, smart society takes more than technology. In order to achieve an inteligent society, citizen participation is an essential element. Local authorities are be encouraged to involve their inhabitants in the process of policy development, particularly on planning and policy issues.

Despite the apparent importance of the subject, there is still no comprehensive research on this issue, particularly with regard to the various stakeholders involved. It is therefore necessary to systematize existing results and broaden the theoretical debate in this direction.

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