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Sustainable Urbanism in the Digital Age: The Smart City Approach

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Abstract: ***The word "smart" represents something modern and handled quickly; in the case of a smart city, it refers to a sector that is very modern, prosperous in every facility, and well-functioning for people. That is the reason for growing up in urbanisation and vice versa. As smart cities possess multifunctional qualities, urban growth occurs rapidly, which presents major problems for people from an environmental perspective. As the population has grown, concrete buildings and other structural developments have been constructed for people's comfort, like the increase of web-based networks to make cities more modern and digital, along with smart cities, which affect the ecosystem and environment and have some return gifts to the earth's people. These days, people swiftly apply technology to enhance their ability to navigate the digital world. But people should consider their activities and the development of society as sustainable, instinctively extending from the present into the future. There are significant challenges for planners in making a city smart through the application of modern technologies. These two words have a very impactful and impressive effect on the urban people and the growth of urbanisation. So, the growth of a smart urbanisation should be made with the concern of both words in a single term, i.e., smart-sustainable city.***
Keywords: Smart City; Sustainability; Technology; Urban Development.

I. INTRODUCTION

The development of urban areas is known as the stages of Urbanisation as well as smart cities. Urbanisation is the process by which a habitat is developed along multidimensional axes such as population, area, socio-economic status, skills, technology, and the promotion of complex lifestyles and relations among different sectors of society. Then, people's civic amenities and a regular high standard of living make them more intelligent. People have become accustomed to easy accessibility in their daily lives. In short, urbanisation may be termed as a positive quantitative development and qualitative upliftment of society step by step. There is a relationship between urbanisation and smart cities. Though there is no scientific definition of smart cities, they have some criteria, which vary in different cities (Sikora-Fernandez & Stawasz, 2016). Urbanisation is very common in the world nowadays, but the rapid population growth and uncontrolled urbanisation (77% in developed regions & 46% in developing regions) impact the environment of India negatively (Surawar & Kotharkar, 2012). Along with the environment, it impacts local administration by providing facilities in urban areas. A large number of people come to the nearby urban center, in addition to the existing residents, which creates a critical challenge in meeting the high skill and technical requirements of the dwellers, particularly in terms of digital challenges (Sikora-Fernandez & Stawasz, 2016).

Drastic changes in population and their needs affect the land-use system, which in turn impacts the terrain, environment, and ultimately humans. So, development should continue, and sustainable urbanisation is required to proceed with smart cities (Surawar & Kotharkar, 2012).

A smart city refers to the leveraging of advanced digital infrastructural accommodations, ICT, and digital transformations to solve cities' problems with sustainable development (Stawasz, 2019). Smart cities aim to increase sustainability and develop urban people's livelihood with more functionality (Seymen & Arabacioglu, 2024).

The smart city is needed to reduce socio-economic disparities and make people smarter in the globalisation era. Though it was started to modify people's lifestyles since the industrial revolution, the technological skill is improving regularly, so the developmental processes are running and shifting, which are the solution of urban infrastructure with balance, but "smart city" was used as "smart growth" in the late 90s and has a relationship with the term "internet" and "digitization" (Gere, 2018).

In this paper, the concept of a smart city, its relation with urbanisation and the importance of sustainability have been discussed through a literature review and a comprehensive analytical process. The smart city concept is based on specific approaches and criteria, has developed various models, and adheres to several multidimensional pillars.

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II. CONCEPTUAL INFORMATION

A. Definition of a smart city:

When a city invests in its people for their development, social capital, and transport-communication system; uses sustainable fuel; and leads economic growth and high-quality life with sustainable resource management and participatory governance, it has the characteristics of an ideal smart city (Caragliu et al., 2011; Gere, 2018; Seymen & Arabacıoğlu, 2024). According to the International Telecommunication Union, an innovative city that uses ICT and related communication systems to improve city life and efficiency in urban operational systems and services that can fulfill the needs of the city dwellers, from economy to culture, in all aspects, is called a "smart city" (Azambuja et al., 2020).

Giffinger et al. (2008) said about the six main pillars of a smart city (Smart Economy, Smart People, Smart Governance, Smart Mobility, Smart Environment, and Smart Living, etc.) (Seymen & Arabacıoğlu, 2024; Gere, 2018; Bhagat et al., 2014). According to Komninos (2008), a smart city is a region with high learning quality, innovation and creative power, and digital infrastructure (Seymen & Arabacıoğlu, 2024).

Moreover, Nma and Pardo (2011) said that it has the three-dimensional features, namely technology, people, and institutions, which is called a "smart city" (Pourahmad et al., 2018; Miah & Amin, 2020)

B. Sustainability:

According to the report of the World Commission on Environment and Development (1987), that is called "sustainability" when we conserve the resources for future generations without hampering the needs of the present generation (Azambuja et al., 2020; Jasrotia, 2018).

In the case of urban sustainability, there is less visible short-term development in a city where long-term development is most prominent for human well-being, the environment, the economy, and society (Finco & Nijkamp, 2001; Tampouridou & Pozoukidou, 2018).

C. Evolution to Wise City:

The concept of a wise city emerged from critical evaluation and the paradigm of a smart city. The spatial and temporal entity makes a three-dimensional form, and that generates wisdom and transforms a smart city into a wise one. "Smartness" refers to a specific quality of an individual, and "wisdom" is related to the knowledge of anyone else, as well as experience, process, and social and collective formats. Smartness is connected to data, whereas wisdom is related to knowledge (Seymen & Arabacıoğlu, 2024).

D. 3D features of a smart city:

As a city has a specific area and can be marked on a map, it has a specific shape, and for that, the concepts of spatial and non-spatial or synthetic concepts come with respect to geographic information systems. In this criterion, the area is covered by lines, points, and polygons, and an area is limited to a two-dimensional feature; that means a horizontal approach is applicable in the urban planning system.

But the historical environment has required a multilayered structure or 3D features; that is the main contradiction here (Seymen & Arabacıoğlu, 2024).

III. SIX-DIMENSIONAL FRAMEWORK (AFTER GIFFINGER MODEL)

Seymen & Arabacioglu (2024) said that the smart city follows different models, but Cohen's Smart Cities Wheel (SCW) model is the most popular, and many researchers follow it. This method was accepted by the European Commission and reinterpreted. According to Sikora-Fernandez & Stawasz (2016), scientists state that economy, people, governance, environment, living, and mobility are considered the dimensions or components of a city, and all of these must be smart (Stawasz, 2019). There are three sub-factors under every six components of the wheel. Here, we discuss the six renowned components. Cohen (2014) divides the components into six categories (Fig 1; Table 1).

The main purpose of the development of these six smart pillars and their proper application to transform an analogue urban environment to a smart city, i.e., can fulfil the needs of modern society and economy, which are the principles and principles of sustainable development of urbanisation (Ilic et al., 2020).

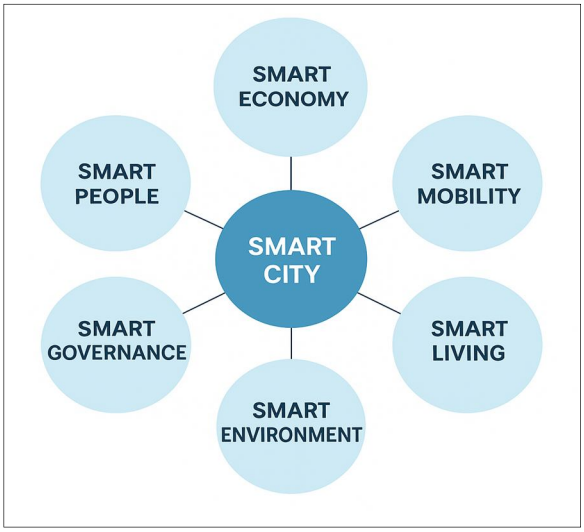

Fig 1. Six Pillars of Smart City, after the Giffinger Model, prepared by the author (Dhole, 2026). Source: Giffinger *et al*., 2010; Sikora-Fernandez and Stawasz, 2016

Table 1. Six Pillars of a Smart City

Components	Description
Smart Economy	● High productivity with skill and knowledge, ● Innovation and flexibility in adaptation, ● Business and Technology,
Smart People	● Higher education and multi-skilling, ● Human capital development and awareness, ● Improve creativity, capabilities, and innovation.
Smart Governance	● Adoption of efficient and successful communication, openness in decision-making, and accessibility to digital services E-governance and entrepreneurship development. ● Stakeholders' participation, ● Healthy and safe life of the city's people,
Smart Environment	● Increase the use of renewable energy or green fuels. ● Energy consumption and resource optimisation, resource and waste management ● Planning for development and policymaking for sustainable development
Smart Living	● Improvement of quality of life with high awareness and lifetime education achievement for a secure and friendly lifestyle ● Technical and socio-cultural infrastructure and wide access to public services,
Smart Mobility	● Zero pollution emissions, or "green urban transport," and advanced transport communication technologies, ● Integral ICT in a traffic management system with a highly developed network,

Source: Seymen & Arabacioglu, 2024; Ilic et al., 2020; Sikora-Fernandez & Stawasz, 2016; Stawasz, 2019

Caragliu (2009) focused on the six major pillars of a smart city: high technology, social inclusion, business focus, network infrastructure, creative industries, social capital, and sustainability for the direct relationship between urban people's property and their professional forces in a smart city (Pourahmad et al., 2018). Technology is used as a tool for innovation, organisation is used to

manage it, and policy is for creating an empowering environment and peripheral conditions. These dimensions, as outlined by Nam and Parodo (2011) and Pourahmad et al. (2018), represent the goals of urban sustainability for a smart city.

IV. SUSTAINABILITY EMBEDDED IN SMARTNESS

According to Seymen & Arabacioglu (2024), "smartness" refers to some special characteristics and the availability of all benefits and instant solutions of a problem, whereas "sustainability" refers to balanced but long-term development. Several factors and a multidimensional index are suggested by several scientists and researchers. Azambuja et al. (2020) said a smart sustainable city has the innovation capacity that can easily be applied to Information and Communication Technologies (ICTs) for people's improvement.

So, sustainability automatically includes smartness. Some authors are considered 'sustainability' as an important pillar of a smart city, but they have not used the same components for it.

A specific smart city integrates the three pillars (environmental sustainability, social development, and economic development) of sustainability, along with equality (Table 2; Fig 2 and 3) (Caltabiano, 2014-2015; Rudewicz, 2023).

Source:

Table 2. Three pillars for the sustainable smart city

Environmental	Renewable energy, green spaces, eco-design
Social	Equity, education, inclusion, quality of life.
Economic	Job creation, competitiveness, and innovation hubs.

Caltabiano, (2014-2015); Rudewicz, (2023)

Since the digital revolution, some digital tools, like ICT services, etc., have enriched ecological health, economic prosperity, and social integration in a city, and all three pillars of sustainable urbanism have transformed a city into a smart eco-city or smart sustainable city (Gere, 2018). Miah & Amin (2020) posited in their paper that a good intercommunication between technology and people creates a smart city. These three pillars play a crucial role in turning a city into a smart, sustainable one. Mukhametov (2019) said the most important components that create a smart city are human capital, inclusive institutions, and the business community, with the city administration. Bokhad et al. (2024) focused on balanced economic growth, environmental sustainability, and social well-being of a sustainable smart city.

Most researchers have said that the three common pillars of making a smart city are sustainable integration. The most important dimensions are environmental, economic, and social (Toli & Murtagh, 2020).

V. SMART URBAN INFRASTRUCTURE

To grow and develop its features, every city requires specific foundational digital and physical infrastructures, which we will discuss here.

A. Smart Grids, Renewable Integration, and Smart Buildings:

Azambuja et al. (2020) cited the statement of Guedes et al. (2018) and said about a smart city that the technology is the main controller of sustainable smart city development. So, identify the grid energy, buildings, and technology smartly. The primary attributes of a smart city involve reduced dependency on non-renewable energy and expanded use of renewable energy sources (such as solar, wind, and biofuel) facilitated by technology and smart grid functionalities that allow for monitoring, self-assessment, and sensing capabilities. (Hashemi, 2022).

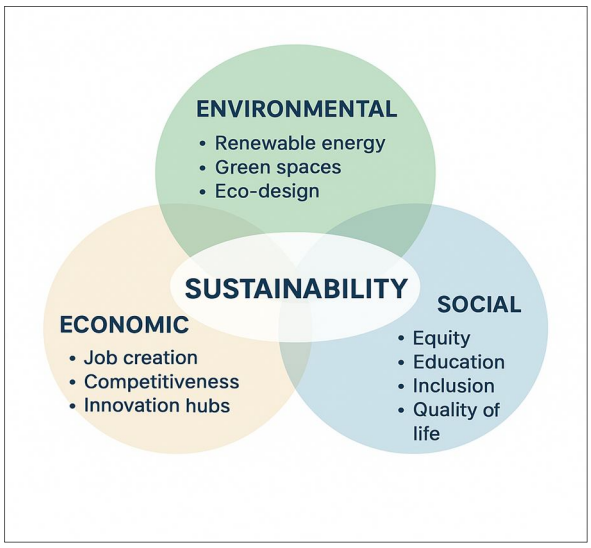

Fig 2. Three Pillars of Sustainability, prepared by the author (Dhole, 2026).

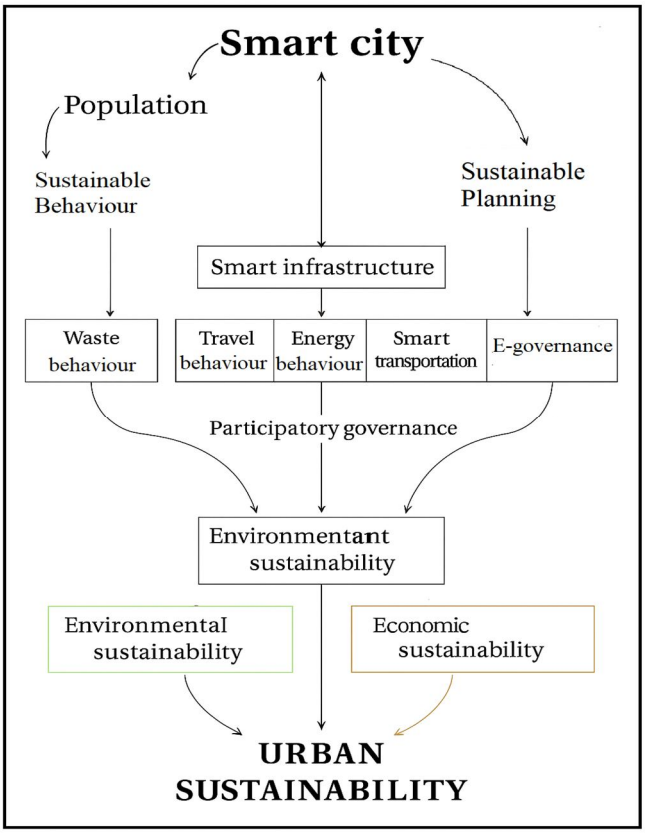

Fig 3. System of urban sustainability, prepared by the author (Dhole, 2026); Source: (Khansari et al., 2014)

B. Broadband Connectivity, Sensor Networks, Edge/Cloud Computing

Azambuja et al. (2020), cited Bibri (2018), said about all necessary components of digital wireless infrastructure, that are data collecting and storage, coordinating, integrating, processing, analysing and synthesising data; managing and exchanging; and sharing in urban areas. Azambuja et al. (2020) mentioned some more infrastructural components like a wireless network for communication and a telecommunication system with internet, cloud, and fog computing structure; middleware architecture, database systems, computers and terminals, sensors, and smartphones. Hashemi (2022) described a sensor that functions as an operating device. Automatically, it collects data, analyses and classifies it, and then it makes decisions as intelligent experts. Ilic et al. (2020) said about another application, IoT, that it is a global network of interconnected devices, digital machines, and objects. Furthermore, it can act like a human who can communicate in positive ways.

C. Resilient Systems for Climate Adaptation, Healthcare, and Mobility:

Toli & Murtagh (2020) stated that smart cities, like the European Innovation Partnership on Smart Cities and Communities, the smart cities behave like humans and can utilise the flows of energy, resilience, high-quality life, and capital to achieve sustainable economic development (European Commission, 2019). Telecare and telemedicine system services to the patients regardless of physical presence (Miah and Amin, 2020). A smart transport system has included sustainability in the transportation systems in all sectors (Rudewicz, 2023).

VI. ROLE OF TECHNOLOGY AND INFRASTRUCTURE

A. Use of IoT, AI, GIS, and Big Data for Urban Management

The smart city model can help the urban centres to transform into sustainable urban area development in the future as a smart integral basis (Ilic et al. 2020), and GIS (Geographic Information System) is a tool that is applied to collect spatial and non-spatial data, processing and presenting the system (Seymen and Arabacıoğlu, 2024). AI (Artificial Intelligence) functions to collect and analyse large data sets and is also used for planning and decision-making systems (Hashemi, 2022).

B. Real-Time Monitoring of Air Quality, Energy Use, Traffic, etc.

Real-time data means the data is collected hourly or every time data is collected, and that can be collected through sensors, social media, and road cameras, and decisions are made through analysing it. The real-time data helps improve the traffic network system and a sustainable and secure traffic system (Miah and Amin, 2020). In this accommodation application, ICT plays a crucial role. ICT-enabled cities also facilitate easy monitoring and wide-ranging improvement (Azambuja et al. 2020). In fact, a monitoring system applies to environmental conservation, i.e., environmental monitoring, because the real-time data explain the environmental pollutants' existence and their range. Therefore, it warns people about their activities and the necessity of management in the city (Tampouridou & Pozoukidou, 2018).

C. Data-Driven Governance and Service Delivery

For a governance system that operates the technology, data is crucial, and it improves the decision-making process that generates smart governance, also known as data-driven governance. Ultimately, it has improved the services of the smart city (Alawadhi and Scholl, 2016; Azambuja et al., 2020), and the smart governance has reduced the city's operating cost for urban people (Stawasz, 2019).

D. Digital Twins and Simulation Models for Planning

Ilic et al. (2020) suggested that smart cities must collect and apply real-time data for their future development and use AI for processing the large data with the digital twin concept. Seymen and Arabacıoğlu (2024) proposed to use the City GML, a three-dimensional geographic information system model, and the methodology model refers to a software, namely, City Engine. Mukhametov (2021) said that the enablement of this approach will create the study of behaviour over time, generate a structure of system elements, and make an interaction between them depending on this.

VII. GOVERNANCE AND CITIZEN PARTICIPATION

A. Governance Maturity Models

Urban structure serves as the foundation of sustainable smart cities, with governance at the top of a conceptual framework. This structure is the framework of a developed sustainable smart city (Azambuja et al. 2020). According to Meijer and Bolívar (2016), with the collaboration of ICTs, human beings could obtain a better governance system (Azambuja et al., 2020). To make a smart city and solve the non-technical problems of an urban centre, the policy was emphasised by Nam and Pardo (2011) (Azambuja et al., 2020).

B. Co-creation, Participatory Planning, and E-Services

Technology-driven development, technology-enabled city-led developments, and citizen co-creation are the three pillars that develop a new generation smart city (Cohen, 2015). Enhancing stakeholder participation relations and encouraging citizens to participate in the city's decision-making program can enhance the city's progress (UNCTAD, 2016; Gere, 2018). Digital components and online services are the key components for this system (Stawasz, 2019).

C. Dashboards for real-time performance and open data platforms

Mukhametov (2021) cited Kitchin et al. (2012) and stated that real-time dashboards, urban benchmarking, and other tools are used to monitor and explore cities. Seymen and Arabacıoğlu (2024) stated that All city stakeholders are required under the Smart Cities Wheel methodology to have thorough knowledge and data about the smart city, which calls for a completely transparent system with safe data-sharing features. Subsequently, the database evidence and information-sharing system are required for smooth governance, and the process is required to inform people about the high quality of city life (Pereira et al., 2018; Azambuja et al., 2020).

VIII. OPPORTUNITIES FOR TRANSFORMATION

A. Better Resource Efficiency

Caragliu et al. (2011), as cited by Gere (2018), stated that smart cities acquire and manage natural resources through participatory governance. A case study revealed that energy consumption was reduced by almost 70% through the use of LED lights in the street (Bokhad et al., 2023), and the smart water network system has reduced water consumption, while a water recycling system has been initiated (Hashemi, 2022).

B. Enhanced Citizen Engagement

To improve the sustainable smart city, its environment and society, there should be emphasised the potential empower and involve the citizen in the governance system (Martin et al., 2019; Azambuja et al., 2020). Citizens' political thought should be changed in case of participatory governance (Khansari et al., 2014; Tampouridou & Pozoukidou, 2018)

C. Use of urban analytics for prediction and planning

Some new technologies are used as a three-level model to monitor the cities: sensors, machine learning algorithms, actuators, etc., which can be regulated without human activity (Mukhametov, 2021).

D. Creation of Innovation Ecosystems

A smart city is a high-learning and innovation capacity-based region where people have creativity and skill-based knowledge with digital institutional infrastructure (Komninos, 2009; Tampouridou & Pozoukidou, 2018).

IX. RISKS AND CRITIQUES

A. Digital Divide and Unequal Access to Smart Services

The primary issue with a smart city is that its government is mostly controlled by a well-educated, middle-class populace, making it inaccessible to other inhabitants (Gere, 2018). According to Pourahmad et al. (2018), It is challenging to efficiently handle massive volumes of data since not everyone has equal access to the internet. For a smart city to be developed successfully, smart residents are essential (UNCTAD, 2016; Gere, 2018).

B. Privacy and Surveillance Risks

Numerous studies have addressed some of the problems with smart cities, such as Rudewicz (2023), who cited Greenfield (2013) and acknowledged the possibility of technopolitical social orders, citizen control, and monitoring. The three most significant issues are citizen supervision, privacy, and the security of personal information (Pourahmad et al., 2018). Mukhametov (2021) stated that wireless sensors, data collection tools, and analysis cannot manage all processes every time, but they can control the population.

C. Corporate Control of Urban Systems

Gere (2018) used the quotation of Hollands (2008) and asked about the possibilities of the rebirth of a high-tech smart city in the 21st century. The author identified that communal and urban architecture, as well as market interest, are less essential to larger companies in the business-driven approach.

D. High Costs and Risk of Greenwashing

Innovation projects and small-scale development are not assured of improvement at all levels of the city (Pourahmad et al., 2018). Though smart growth has potential for progress, there are some limitations in the disciplines of cities and populations, and it reduces sustainability in technical sectors. Another limitation is the difference between the official and original vision and the project's environmental impact (Caltabiano, 2015).

X. SOME CASE STUDIES IN GLOBAL PRACTICES

1) Here, some case studies of the top smart cities in the world are highlighted, and an attempt has been made to show their scenarios and activities as smart cities. For example, Barcelona is an open data platform, and the participatory tools are very praiseworthy. According to Cohen (2015), a smart city must possess three qualities: the ability to adopt technology, integrate it into people's daily lives to enhance overall livelihood, and address any issues faced by the city and its residents. Barcelona, as a smart city, has all the qualities of a smart city. This city is a combination of sustainability, technology, and quality of life (Bakici et al. 2010). The addition of smart parking, streetlights, irrigation, and renewable energy (Bokhad et al., 2024) has made it a sustainable smart town (Toli and Murtagh, 2020). There have been more case studies, for example, like Singapore, Masdar city of the United States of America (USA), London, Berlin, etc.
2) Singapore improves its quality of life through smart digital systems in health, transportation systems, and the IoT (Internet of Things) sector (Bokhad, 2024). Since 1997, the education system in schools has integrated IT (information technology) to develop children's creativity (Mahizhnan, 1999; Petre and Suciu, 2020). This smart island began its journey in 1992 and gradually achieved many milestones, including a top ranking from Forbes in 2009 and becoming a part of the World Bank in

2011–2012 for its business (Hashemi, 2022). They use "digital twins," for their digital development, and the e-governance system is well-developed. The island has enabled to enhance its water energy system, for the benefit of its small size and proximity to the South China Sea.

3) Masdar City, USA, uses renewable energy as a model here. They have been actively developing greenfield technologies, demonstrating their cutting-edge, eco-friendly, and sustainable characteristics. According to Sassen (2012), this system functions as a real-time laboratory rather than a natural urban settlement, as it allows for real-life experiences that are only possible with advanced technologies. This model emphasises organic matter, resulting in high costs and selective resident base areas within the model area. People are aware of their responsibility to the city, and people act like that (Gere, 2018).

4) London is very developed in IT like New York and Tokyo (example of global cities in the world). They can use IT for their own needs (Gargiulo & Galderisi, 1995; Papa et al., 2013). A smart city board was established in London in 2013, whose aim was to apply technology to lead a better life there (Kunzmann, 2014). They developed and applied ICT to transport, health, and business sectors and improved sensor systems (Azkuna, 2012; Bélissent, 2010; Cohen, 2010; Batty et al., 2012). Like other big cities, Berlin began using technologies in various sectors, and due to its small area, it quickly succeeded in becoming a smart city. Over the last century, collaboration among the mayor, builders, and planners completely transformed the urban sector (Kunzmann, 2014).

XI. FRAMEWORK PROPOSAL

1) *The Wise City Model***:** A wise city is like a proposed model where smartness, wisdom, and analysis are insufficient. The concept of this model has been defined as an architectural project and a historical environment of urban planning. It is suggested to locate the trace within the city and subsequently transfer the trace and associated knowledge to the three-dimensional inventory (Seymen & Arabacıoğlu, 2024).

2) *Integration of Smart and Sustainable Dimensions:* A sustainable smart city uses ICTs, has improved quality of life and effective urban services, and meets the needs of present and future generations. A smart city has five main dimensions, and the position of a smart city is the governance at the top and urban infrastructure at the base (Azambuja et al., 2020). Smartability is the unified form of the terms "smart" and "sustainability" (Tampouridou & Pozoukidou, 2018).

3) *Contextual Dimension: Historical and Cultural Specificity:* Urban identity is shaped by the historical environment produced through cultural aggregation, and it evolves by adapting to change. The author posited that variations in urban structure may exist across nations, thereby characterising a comprehensive approach to spatial analysis of development (Seymen & Arabacıoğlu, 2024).

4) *Suggested Indicators and Performance Metrics:* According to Pourahmad, Giffinger et al. (2008) found 33 sub-sections of a smart city that perform for it (Pourahmad et al., 2018). According to the ITU 2013 report, a smart sustainable city carries some special components like air quality, water quality, waste management, emission of greenhouse gases, green space, ecological footprint, vulnerability, and urban productivity (Azambuja et al., 2020). The indicators of the social dimension are active citizen participation, education, public health, equity (accessibility), and social services (Tampouridou and Pozoukidou, 2018).

XII. RECOMMENDATIONS AND CONCLUSION

1) Summary of the paper: The overall view from this paper is that although there have many opportunities and gainful offers in every smart city, there are some limitations related to corporate control, digital exclusion, and privacy-related issues (Gere, 2018; Pourahmad et al., 2018; Rudewicz, 2023). The wise city concept highlights the limitations of the conventional smart city by incorporating spatial and temporal dimensions, creating a three-dimensional framework that transforms the city from smart to wise (Seymen & Arabacıoğlu, 2024). A sustainable smart city authority always focused on the needs of city people, i.e., called city-driven, uses ICT for better communication and uses collaborative behaviour with engaging stakeholders' participation (Azambuja et al., 2020).

2) Future research approaches: Ahvenniemi et al. (2017) said that the concept of a sustainable smart city needs more analytical discussion of the standardised indicators and their application (Azambuja et al., 2020). There is a need for participatory governance, and citizens should be involved in decision-making sectors that will make smart citizens (UNCTAD, 2016; Gere, 2018). Bokhad et al. (2023) suggested investigating the impact of the technological tools on governance and democracy, which are used in smart cities, and exploring the citizens' engagement with these tools and the abuse of power in urban localities. Citing Martin et al. (2019) and Azambuja et al. (2020), it was noted that, to develop and transfer a city to a sustainable smart city, it is essential to find out the power and include the citizens in the city's governance.

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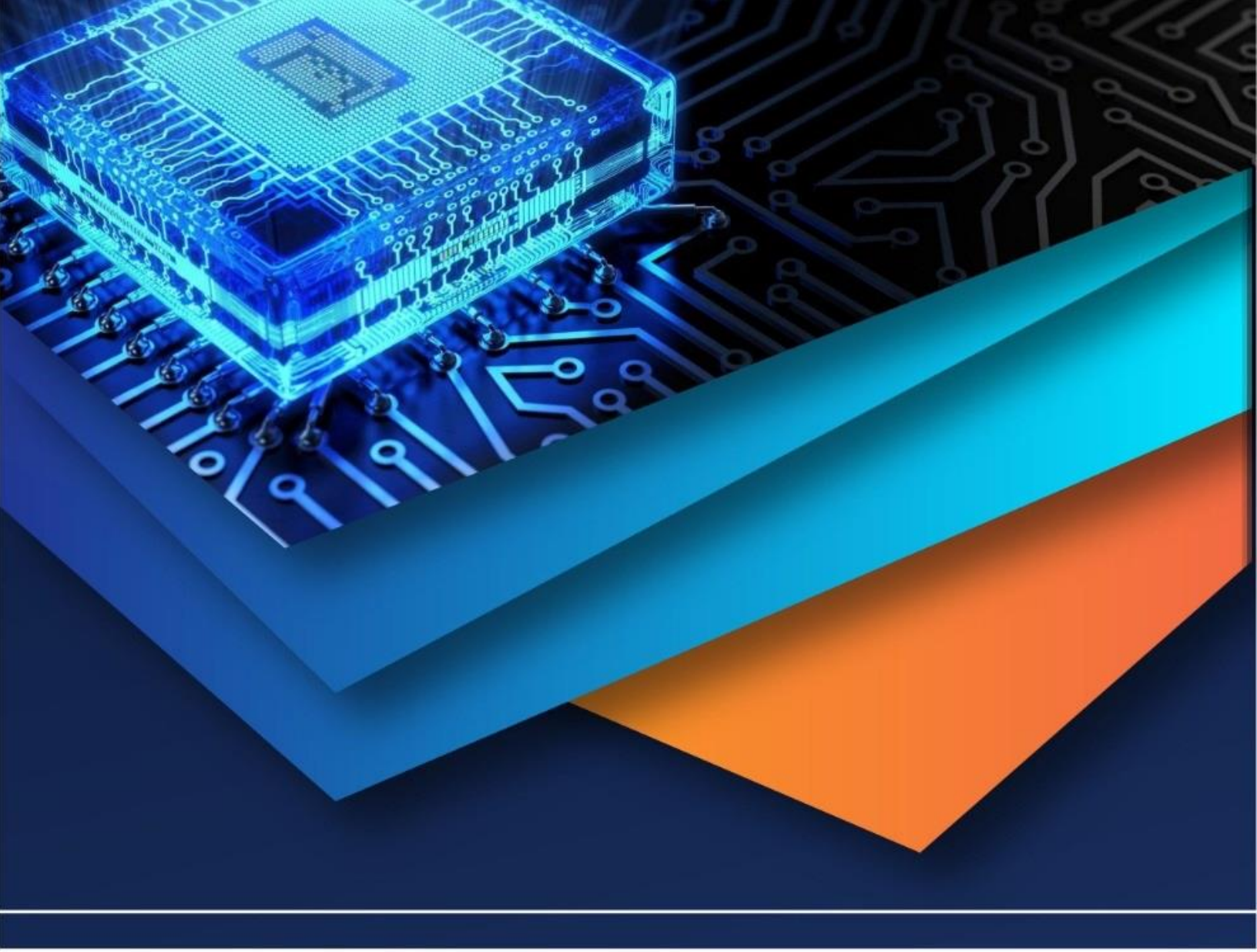

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