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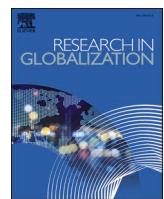
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Smart city development Models: A cross-cultural regional analysis from theory to practice

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ABSTRACT

Based on the multiple definitions and cultural interpretations of smart cities, this study systematically compiled the components, standards, and development modes of smart cities in various regions of the world and proposed a new integration of smart city dimensions and operational framework based on the development process, aiming to provide a theoretical basis and practical orientation for the transition of future development of smart cities and the formulation of planning policies. The conclusions of study are as follows: (1) In the process of building smart cities, countries' understanding of smart cities is guided by their indigenous cultures, presenting various perceptions of smart city definitions, components, and standards in different geographic regions; (2) Scholars have proposed various dimensions and combinations for the development of smart cities based on their regional cultural, technological conditions, and temporal contexts, aiming to explore how cities can become 'smart'. (3) With the accumulation of experience in the construction of smart cities, the individual-technology-culture (IndiTeCultural) dimension model, which is a combination of individuals, technology, and culture, demonstrates better alignment with the requirements of smart city development around the world. This establishes the foundation for the transition from theory to practice in crafting a future operational framework for smart cities. (4) On the basis of cross-cultural geographical analysis, drawing on the practical experiences of smart city initiatives in various countries and the rating levels of their progress, this study analyses the challenges and opportunities faced by smart city development and presents the problems that need to be solved urgently for more effective mechanisms for smart city development.

Introduction

Smart city development has become a crucial topic as cities face transformation and increased needs for higher-quality planning needs for higher quality decisions. With the pressure of growing urban populations and accelerating urbanisation (Frey & Zimmer, 2001), governments and city administrators urgently need to find innovative ways to improve the sustainability of their cities, provide higher quality public services, and meet the growing needs of their residents, as existing urban resources and potentials have been fully exploited. To help cities transcend the limits of development under existing technological conditions (Einstein & Kogan, 2016) and eliminate the negative impacts of economic development such as environmental pollution, unequal distribution of resources, and rising crime rates, the concept of smart cities has been introduced into the field of planning and has begun to be practiced under the impetus of technological development in tandem with the wave of modernist ideas (Batty, 2017). The reason why academics seldom explicitly mention the origin of the concept of smart

city and the process of construction and development is that many countries intervene in the goals and standards of smart city construction based on their regional cultures and practical needs (Yang, 2020), so there is an urgent need to systematically explore various types of smart cities from a cross-cultural and geographical perspective. Some scholars espouse the conception of the smart city, first originating from the concept of digital city (Halegoua, 2020). The digital city integrates the people and technology of the city into a society of information exchange (Coulcelis, 2004); technology brings convenience to people and enhances the desire for information exchange; the concept of the informative city began to emerge as an upgrade of digital cities (Hepworth, 1990). Compared with digital technology, informatisation has introduced a distinctive three-dimensional economic and social paradigm (Castells, 2020; Stock, 2011). However, it has also brought forth numerous new economic and social issues for cities (Hepworth, 1990), such as a reduction in job opportunities and the exacerbation of wealth inequality. To alleviate these problems, scholars and urban planners in different fields have proposed ideas such as smart cities (Komninos,

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2007) and sustainable cities (Jenks & Jones, 2009), which have eventually been harmonised into the widely used smart cities that were widely accepted and applied in social practice.

Another mainstream perspective considers environmental protection as an important force driving the origin of smart cities. First, the economic development of cities poses threats to the health of residents in inner urban environments, such as air pollution caused by transportation systems and factory production (Sancini et al., 2012). Second, pollution discharged from urban industries damages agricultural land (Behera & Reddy, 2002) and ecosystems (Yuan et al., 2020) in the external environment of the city, and the city spends a large amount of its annual budget on preventing and solving pollution problems (Shen, 1999; Hettige et al., 2000). To address the complex environmental pollution problems inside and outside the city, scholars have proposed the concept of the smart city with technical support (Ghoneim & Hamed, 2019). Compared with industrial cities and post-industrial cities (Bronstein, 2009), smart cities are more environmentally friendly in terms of air and water quality improvement (Chu et al., 2021).

The introduction of the concept of smart city development has had a profound impact on urban development and planning. First, smart cities represent a new urban development paradigm that encompasses various crucial objectives and key elements of past planning endeavours (Angelidou, 2014), the accumulation of concepts and objectives makes it difficult to develop a holistic approach to development. Second, previous conceptualisations of the city as post-industrial city, digital city or information city are based on the analysis and summary of the city's existing appearance; the current version of development proposed for the smart city is not intended for cities to acquire the 'smart' status, but to further stimulate the city's vertical potential; the existing city or urban agglomeration development efficacy is witnessing a sharp increase in the number of urban residents (Toli & Murtagh, 2020), leading to a mismatch between the demand and supply of urban resources and infrastructure. Therefore, endeavouring to further enhance the city's infrastructure and vertical potential has become the starting point of the concept of the smart city. "Vertical" refers to the fact that when cities cannot continue to expand horizontally to increase their urban area, they can only improve the quality and competitiveness of their economic and social development by tapping the potential of existing urban resources. Third, the core mission of smart cities is to make cities 'smarter' (Angelidou, 2015), providing them with their own thinking and cultural patterns, which is a new challenge for both the city's stakeholder groups and the city's own development. Therefore, systematically sorting out the concepts, dimensions and practice cases of smart cities at the present stage can help to summarize the experience of smart city exploration and establish the direction of future planning and construction.

Evolution of the smart city paradigm

The construction of a smart city is an exploratory process for formulating a grand vision of the city of the future. It is an exploratory process that involves changes at many levels, including infrastructure, information technology, urban governance, and social interaction. To scientifically explore this uncharted territory, governments, international organisations, and academics have begun to formulate a series of discussions on the concept of smart cities to provide a clearer research paradigm and development basis for subsequent research and development of smart cities.

Definition of smart cities

Presently, the definition of a smart city remains relatively ambiguous and polysemous (Hollands, 2008), lacking a universally agreed-upon definition. Diverse cultural regions and research domains exhibit distinct interpretations and perspectives of this concept. Although Europe was an early starter in the development of smart cities, the definition of a smart city has been difficult to harmonise among

countries with varied directions of urban development. To assist European countries in defining a smart city, the European Commission (EC), which plays a key role in coordinating and promoting the smart city initiative in the European region, proposed two definitions of smart cities which incorporate these diverse directions of development. One is to define a smart city or community as one that aims to improve the quality of life through the provision of digital services that enhance the well-being of residents, businesses, visitors, organisations, and managers to provide better services to residents and meet the goals of the European Green Deal (European Commission, 2023a); the second is the definition of a smart city as a place where traditional networks and services are made more efficient through the use of digital solutions for the benefit of residents and businesses, aligned with the development needs of the European Single Market (European Commission, 2023b). These two definitions meet the different smart city needs and goals of many European cities and extend to other implementable areas as much as possible.

The U.S. and Canada in North America exhibit deep cooperation between cities, and while the two countries have been able to unify many of their cities into more solid urban agglomerations through the North American Trade Agreement (NAFTA), there are differences in their understanding and conception of smart cities. The multicultural influenced Canadian government considers a city to be 'smart' in the sense that it collects and analyses data interactions and usage of public infrastructure to improve services and enhance the experience of culturally diverse users (Canadian Security Intelligence Service, 2022), while the U.S. government deconstructs smart city as a term for a model of a city's operational program, which generally refers to the integration of information technology (IT) with the management and operation of residential functions (Cybersecurity and Infrastructure Security Agency, 2020).

The diversity of international definitions of smart cities validates, to varying degrees that the smart city concept is still in its early stages of exploration. While different definitions can enhance discussion and competitiveness among smart cities, they also make it difficult for smart cities to develop rapidly owing to their diversity and complexity.

Analysis of smart city components and structure

Although countries have different understandings of the definition of a smart city, they all agree that smart city components are significantly diverse and mainly include six components: smart environment, smart economy, smart governance, smart people, smart living, and smart mobility (see Fig. 1), each of which can be further derived from a number of topic nodes. Scholars and enterprises have conducted research and project development on these six components.

Smart environments are ecosystems of communication objects, including both users and cities, with the goal of making cities zero-pollution and capable of sustainable development. Smart environments have the potential to allow users to interact seamlessly with their surroundings (Nugent et al., 2014; Bartolini et al., 2012) and for designing furniture in the home to become home assistants to help build green ecosystems (Tewell et al., 2019; Aliero et al., 2021). For cities, smart environments can use machine-to-machine (M2M) systems such as Radio Frequency Identification (RFID) and Wireless Sensor Networks to help cities keep track of energy data in real time and ensure that machines can distribute energy efficiently (Samal et al., 2022); smart economy is the use of elements such as technological innovation, resource efficiency, sustainability, and high social welfare as engines for economic success, with the goal of improving the quality of life for all citizens (Frank & Fernández-Montesinos, 2020); smart governance is the use of technology to set up online and offline platforms, so that more residents break through the physical limitations to participate in the system of administration, and its goal is to change the reliance on a single traditional administrative management to multi-dimensional management (Hambleton, 2002); smart people entails a requirement

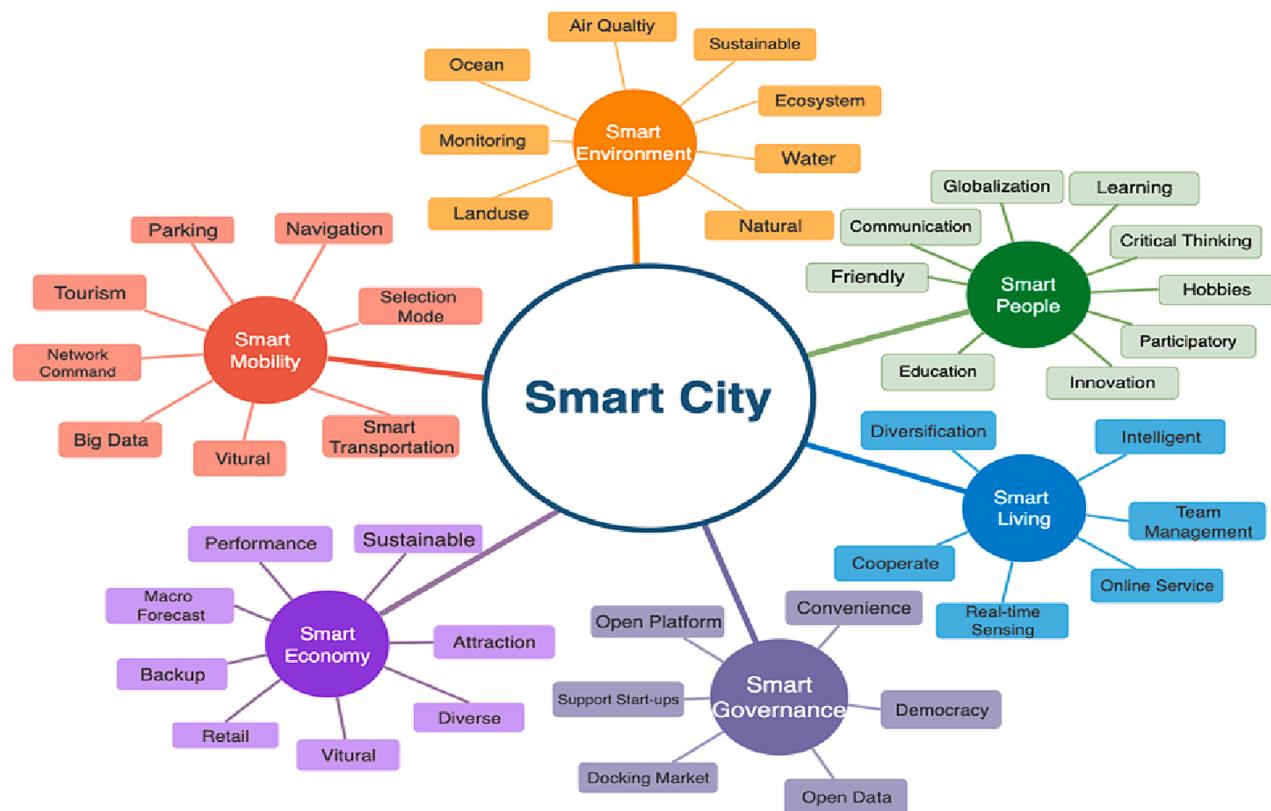


Fig. 1. Components of a smart city.

for cities to provide good education to equip the residents living in them with sufficient knowledge and skills (Nam & Pardo, 2011), so that they can form a habit of learning (Plumb et al., 2007), and the goal is for every individual in the city to be part of the city's information collection (Coe et al., 2001). Smart people require high ethical standards, an open mind, and a habit of participating in public affairs (Gupta et al., 2017), and cities can only be made smart if both residents and governments are involved (Rodríguez Bofvar, 2015a, 2015b); smart living involves making it easier for residents to use infrastructure and communication technologies, to integrate information technology with other technologies to create economic opportunities and improve the quality of life for residents (National Conference of State Legislatures, 2021); Smart mobility has always been a prioritised option for smart cities, including smart infrastructure, automation, connected and electric vehicles, combined mobility services, and new forms of sharing based on platform technologies (Docherty et al., 2018). At the governmental decision-making level, the goal is to utilise Information and Communication Technology (ICT) for real-time monitoring of traffic conditions, advanced control of traffic flow, and reduction in traffic accidents (Tomaszewska & Florea, 2018). At the population level, the goal is to provide seamless, affordable, and sustainable transportation networks for people to travel to and from their destinations (Biyik et al., 2021) to help them experience convenient, safe, active, balanced, and secure lifestyles (Ismagilova et al., 2019).

Exploration of evaluation standards and specifications for smart cities

Although definitions are still in disagreement, the current standards for smart cities play a vital role in urban planning and development. While standards can ensure that cities are moving towards smart city requirements in all aspects, the existence of standards also provides a common action framework for city managers, policymakers, and city residents to better plan, implement, and evaluate the smart city transformation process.

At the national level, the National Institute of Standards and Technology (NIST) conducts a series of research and development programs on smart cities to promote the formation of technical standards for smart cities. NIST first developed the Smart City Architecture or Consensus Framework (standard) (Framework, 2018) and the Smart Cities and Communities Framework (standard) (NIST, 2019a) with the goal of providing cities with a set of shared methodologies and reference models, covering key elements such as data, interoperability, privacy, and security, to assist cities in planning and implementing smart city projects. Under this framework (standards), NIST organises events such as the Global Cities Team Challenge (GCTC) and the Smart, Safe Cities, and Communities Challenge (NIST, 2019b) to allow cities to promote each other's technology and raise the standards cap.

The European Council considers setting smart city standards differently from the United States. In contrast to the United States, which relies on global city competition to drive smart city standards, the European Council focuses more on the development of European cities themselves, attempting to accomplish the goals of the European Green Deal in Europe by making local communities 'smart' and enabling their residents to live better lives (European Commission, 2023). The first standard involves the standard of living. The EU movement to Europeanise Smart Cities and Communities involves putting citizens at the centre and establishing standards for sharing data and operations; the second standard is the creation of local data platforms that allow digital technology systems to flow within and between cities to deliver smart services through synthetic data streams; the third standard is data security, where data are shared between smart communities with full assurance that the data are operated in a secure environment, and that local digital twins representing the region's physical assets, processes, and systems are established. These standards are intended to enhance the learning capabilities of AI, allowing it to create visualisation models for cities, and perform real-time urban management and long-term policy development.

International organisations are also actively involved in the

development of smart standards, such as the International Organisation for Standardisation (ISO), which has developed a series of standards related to smart cities that cover various aspects of urban sustainability and residents' quality of life. Indicators of urban sustainability and the quality of life of inhabitants (ISO 37120) (International Organization for Standardization, 2018) are used to measure the social, economic, environmental, and cultural dimensions of cities to better understand their overall performance and establish room for improvement.

Dimensions and operational architecture of smart cities

Based on the compilation of smart city components and standards, a multidimensional analysis of smart cities is required to provide all stakeholders with a comprehensive understanding of urban development and a better grasp of the diversity and complexity of cities, to construct an appropriate operational framework to guide urban planning, and to formulate urban development policies to provide a basis for decision-making. The operational framework is an important part of a smart city's transition from theory to real-world operability. Choosing the right dimensions ensures the feasibility of the framework's operation, while the right framework verifies whether the dimensions are accurate.

Dimensional development of smart cities

Academics have different understandings of the combination of dimensions of smart cities and continue to improve them, and each dimensional combination symbolizes a deeper understanding of the core essence of different cultures and regions and smart cities, which provides a more accurate and comprehensive theoretical system to adapt to the needs of different times, cultures, and regions.

The three dimensions of technology –human –institutional were the first mentioned combination of smart city dimensions (Nam & Pardo, 2011) and have also been considered as an important constituent dimension of the smart city framework (Sharifi, 2019). In the technological dimension, amidst the wave of the technological revolution, there has been a convergence of concepts such as the virtual city (enabling urban functions to be realised in cyberspace) (Boulton et al., 2011), the hybrid city (allowing cities to make their own choices across different modes) (Antoniadis & Apostol, 2014), and the ubiquitous city (U-city, ensuring the pervasive accessibility of urban infrastructure) (Anthopoulos & Fitsilis, 2010). In the human dimension, smart cities enhance the labour market and drive economic development through talented and creative individuals (Florida, 2002). To ensure sustained creativity, workers are required to rely on continuous learning to become smarter (Campbell, 2009). Simultaneously, cities encourage knowledge exchange among individuals, facilitating the acquisition of more knowledge and greater understanding of urban development. This transforms social networks into the social capital of the city (Edvinsson, 2006). In the institutional dimension, government agencies in a smart city need to help the city build a smart society and develop in a 'smart' manner (Urban Land Institute, 1998), while mitigating the uneven distribution of resources in the city and other problems (Ingram et al., 2009; Porter, 2002).

With changing times, the use of technology is gradually shifting from government institutions to the broader public. (Duan et al., 2019), in their article 'Smart city concepts and dimensions', have refined the previous dimension combination and proposed a new dimension combination of technology, people, and society. The key improvement in the refined dimension combination lies in the transformation of institutions into societies. This involves expanding the concept of institutions from a singular point in space to a societal plane, making institutions a part of—and engaging with—society rather than leading planning efforts (Karamizadeha et al., 2015). This can be achieved by incorporating technology users through smart forums (Bibri & Krogstie, 2021), fostering a platform for institutions, various communities, and streets to

engage in shared technological discussions.

With the increase in practical experience in smart city planning and the enhancement of smart technology, to further reflect the diversity and complexity of smart cities, scholars have also analysed the combination of smart city dimensions by dividing them into three latitudes: technology-human-space, whose goal is to make the city an intelligent organism (Zhen & Kong, 2021). This dimensional update is from the perspective of human-land relations and aims to address and promote the needs and synergies between people and space in the city through smart technologies (Zhen et al., 2019). In this update, the spatial dimension is viewed as an expansion of the social dimension, acting as its carrier. In the context of urban planning, space is defined as urban areas with different themes, such as administrative districts, business districts, and residential areas. The goal of a smart city is to not only provide services to the inhabitants of a society but also to help people break the limitations of spatial conceptual boundaries set by society while increasing the resilience of urban space. The role of technology in the dimensional combination is to help link spaces and people, and cutting-edge technologies such as the IoT, Artificial Intelligence (AI) chips, and Big Data analytics are not only transforming the way cities operate but also providing urban planners and decision makers with powerful tools for efficient, sustainable, and intelligent city management. With the maturity of technologies such as GPT, the difficulty for the average resident to master the operation of the technology will be further reduced in the future, and the public will be able to obtain information and convenience in space through this technology. In the development of smart cities in many regions, the human dimension is usually overlooked by the other two dimensions. The development of smart cities allows all members of society to adapt to the ever-changing iterations of technology, which has led to a rapid rise in the cost of technological equipment in urban planning; for example, the phenomenon of employee-free supermarkets is proof that technology is beginning to dominate people's lives. After the COVID-19 pandemic in 2020, major cities worldwide fell into a state of closure, and all countries introduced information technology in large numbers to help people look up information, while various companies developed virtual reality and *meta*-universes to help people adapt to living in isolation. However, this technological innovation did not win the general acceptance of the inhabitants, and the ensuing need for human interaction among people triggered the impetus for smart city planning.

Dimensional integration of smart cities: The Individual-Technology-Culture (IndiTeCultural) dimension

As smart cities develop on all continents of the world, the existing combination of dimensions and the manner in which they are constituted have been subject to some controversy and confusion. The first question is whether the dimensions are connected by coupling, which typically refers to the interrelationship or interdependence between two or more independent systems. Established dimensional analyses typically split these three dimensions separately for interpretation and focus on examining how to strengthen the intercoupling relationships between them. At the concrete level, smart city dimensions and components are intertwined, with each component including all three dimensions, and each dimension comprising all components. If each dimension is still considered autonomous and the architecture is in a segmented dimension relationship model, difficulties may arise in the smart city's self-operation. Therefore, the coupled dimension viewpoint needs to be gradually replaced by the integrated dimension viewpoint. In smart cities, integration typically refers to the integration of different dimensions, such as technology, people, society and space, to realise smart city management and operations. To integrate, past dimensional combinations have all been compartmentalised to varying degrees. In the first dimension, the role of science and technology is limited to assisting human activities through partial institutions, with limited breadth and culture inclusiveness of the dimensions; in the second

dimension, the social structure is subdivided into discrete geographic units by technological interventions, and science and technology are only able to establish interpersonal links between these discrete geographic units, but have not yet been able to realise the full integration of the social structure. The process from the first relatively closed communities to the modern connected society can be seen in the gradual segmentation of the structure of society and its unification through technology; however, there are yet some localised and incompletely integrated features requiring integration. The third dimensional combination emphasises—based on the first two combinations—the strengthening of the coupling between other dimensions in the spatial dimension to make it a system. However, it still ignores the uniqueness of individual behaviour and the influence of cultural pluralism, owing to which, the spatial dimension does not achieve true integration.

The second aspect under consideration is whether the existing dimensional combinations are suitable for the future smart city structure; the dimensional relationship determines the development framework of the smart city, and the accurate construction of the dimensional relationship helps reasonably construct the city system (Zhen et al., 2019). The reason why smart cities have started to become 'smart' compared to other types of cities depends largely on the depth of dimension integration. In response to the need for dimensional integration in smart cities and based on the history of the development of previous dimensions and the experience of regional development, this paper proposes a new combination of dimensions, of individual-technology-culture. Existing dimensional analyses have looked at the group of people as a whole, exploring the large amount of knowledge and culture that people are required to know with regard to the use of technology and how it can bring convenience to people in the space. However, the distinction between wisdom and intelligence lies in the ability to serve everyone as a whole. Under the smart city system, people and technology are not coupled but are integrated in the development process. The technology in the smart city must provide 'customised' information services to each individual in the city through a series of technologies such as algorithms. Each individual in the city is a unique space and database, technology in the smart city therefore, can accordingly create countless 'customised' spaces, resulting in the continuous integration of these spaces so that people are surrounded by technology but also enabled by it, to obtain greater freedom. Smart cities are influenced by "customized" spaces, both in terms of their conception and construction in different cultural regions, and these "customized" spaces form a multiculturalism in smart cities. At the same time, for individuals and technology to integrate more seamlessly, smart cities must understand their own culture, which permeates all types and sizes of space in human society, including the habits of its inhabitants, urban planning, resources, and tourist attractions. Only culturally-aware technology can empathise with an individual's behaviour and make the most 'humane' decisions, not just the most rational one.

Individual-technology-culture dimensions are highly integrated in Smart Cities, forming an IndiTeCultural framework. Under the framework of integrated dimensions, Smart Cities do not need to focus on sorting out the interrelationships among the dimensions when dealing with problems but rather have the ability to coordinate the relevant resources to solve problems in an all-rounded, immediate, and automatic manner. This allows the city itself to operate more like a "brain" with intelligence to think, rather than a static framework structure and passive implementation program. This integrated and self-coordinating quality enables cities to effectively respond to increasingly complex challenges, thereby improved sustainability of resources within the city and adaptability with citizens. Such an IndiTeCultural system connects the components and nodes to form a smart operational structure unique to smart cities, which helps improve the overall planning and resource allocation of the city, thus improving the quality of life of each individual with the needs of the cultural context and creating the most tacit balance between the individual and the whole.

Operational framework of smart cities

The Inditecultural theory of Smart Cities allows for the construction of a highly complex and sophisticated brain-like operational framework that provides the basis for moving from theory to practice. Operation framework (Inditecultural) by the individual – technology – cultural three-dimensional integrated formation, the core of the smart city operation framework with the nature of the existing city has undergone an essential metamorphosis, breaking the existing city operation framework in the hierarchy, coupling and other relationships in the cumbersome logic and unnecessary processes, constructed the core of the smart city, "wisdom" mechanism and become the brain stem of the smart city brain to control the life of the entire city. It constructs the core "wisdom" mechanism of the smart city and becomes the brain stem of the smart city brain, controlling the vitality of the whole city. At the same time, IndiTeCulture's external structure covers six key components, which together outline the peripheral framework of the smart city and become its brainstem, allowing for a balanced development of the smart city. These nodes serve as the cortex of the smart city brain and continuously receive new cognition. This allowed for the intertwining and gradual expansion of the two core components, dimensions, and components through intermediate nodes, ultimately giving rise to a highly intelligent operational framework for the city (Fig. 2). This framework integrates components that have been relatively dispersed or neglected in the coupling relationship and builds a huge and intricate urban network similar to the interconnection of countless neurons in the brain, which enables smart cities to quickly detect problems, collect diverse information, analyse data, and make rational and efficient decisions.

One of the distinctive features of a smart city is its self-evolving nature; that is, the number of nodes in the smart city gradually increase or decrease according to the characteristics of the city itself or the actual demand during the operation of the framework to better adapt to the city's needs and changes. The changes in node additions are intended to continually consolidate framework integration to better meet the evolving requirements of the city. The connecting lines in the operational block diagram do not simply represent static relationships between nodes, but are merely a figurative representation of the close integration and interactions between individual nodes.

This dynamism provides cities with great flexibility and a high degree of adaptability, so that both professional city planners and residents can coordinate with the smart city at any time according to changes in different cultural regions or individual needs and satisfy the expectations of every individual living in the city to maintain its effectiveness and adaptability. At the same time, maintaining the intelligence of the operational framework of the 'brain' of the smart city requires active multidisciplinary collaboration to understand the need for multiculturalism in order to achieve sustainable urban prosperity and to be able to respond to the challenges of a city that is constantly changing at the level of the realities of the world.

Cultural-regional models of smart city practices

In recent decades, an increasing number of countries have begun to attempt to establish smart cities that are deeply affected by the political, social, and cultural influences of their own regions, thus forming smart cities with different development directions. Based on current development results, analysing the different styles of smart cities in each cultural region can accelerate the transition of smart cities from theory to practice.

City-based smart cities

In the face of relatively mature and solid urban system, the development of smart cities in Europe in the reality of the level of difficult to reshape the existing urban system in all aspects, how to effectively and

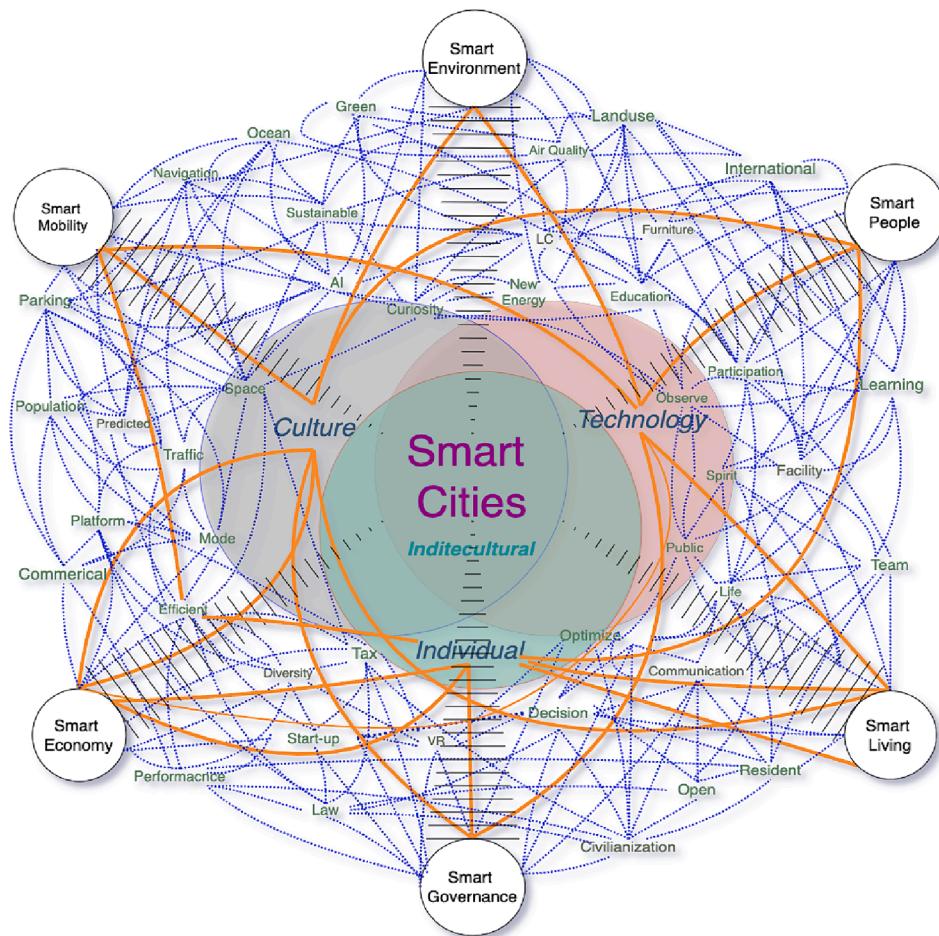


Fig. 2. Smart City Dimension Structure and Operational Framework.

“naturally” integrate technology into every corner of the city to make it start to “smart” is the focus of the EU’s exploration of this area. Smart environment and smart mobility are key breakthroughs in Europe, with cities choosing to start with nodes such as transportation, and meeting the standards of the relevant areas before building other dimensions.

Copenhagen has been one of Europe’s most distinctive examples of a smart city, where the city has combined two components, smart governance and smart people, to create a public-private partnership with information transparency. The government established the Copenhagen Solutions Lab in collaboration with companies such as Google. This collaboration involves integrating data from people’s mobile devices, GPS signals from public and private transportation, and sensors in public transport. This integration enables both the government and residents to monitor traffic conditions in real-time, preventing the emergence of traffic hotspots and mitigating congestion and environmental pollution. In recent years, the European Union has used smart city technologies to improve the efficiency of public transportation, based on a strong push for new energy vehicles. Stockholm is known for its smart transportation system, with 800,000 people choosing carbon-free and environmentally friendly travel options every day, and the city plans to have fossil fuel-free transportation by sea by 2030 (Smart City Sweden, 2023). European cities are increasingly using smart technologies to understand their “cultural” situation and reintegrate their cities and inhabitants into the natural system by achieving zero pollution.

Government-led smart cities

The transition to smart cities is not only characterised by serious

challenges at the operational level but also by the influence of local systemic culture. In the European Union, it took more than ten years for all governments to reach smart city standards in one or two areas. Consequently, new smart cities have become an actively explored and promoted goal for European governments and planners. In the East Asian region, because of the rapid transformation from an independent country to an economic powerhouse in a relatively short period of time, each country is facing the problem of overconcentration of resources in the core city, which often results in the government taking charge of the development of smart cities in the Asian region. Unlike the industrial and post-industrial city period when government investment was massively into infrastructure, government investment in the smart city building period was mainly in high-tech companies.

The South Korean government made an important decision to establish a new smart city, Songdo, in 2005 to ease the pressure on Seoul. The difference in Europe is that it does not cut from one node but builds six components holistically in three dimensions. Over time, Songdo’s construction schedule and investment increased, while the resident population remained at approximately 100,000 before the epidemic, which is a huge difference from the expectations of the international metropolis that the Korean government wants to create. The primary cause of this significant disparity is the substantial integration of cutting-edge technological systems in the construction process of Song Island. However, sustaining the operation of these extensive systems increases the cost of living. The working-class population, faced with high housing prices, prefers commuting for more than one hour rather than residing in apartments with exorbitant rents. Second, many smart-city functions rely heavily on automated systems, resulting in a minimal number of city personnel. For example, the entire city’s

cleaning system requires only seven individuals for management purposes. The scarcity of city management personnel, coupled with residents' reluctance to inhabit the area, renders the entire city unusually desolate. This discourages large corporate groups from establishing presences.

Market-oriented smart cities

The use of technology in smart cities requires market conditions, and the market conditions here are different from those in previous cities; instead of companies or businesses looking for a market based on the amount of demand from customers, technology companies are turning the entire city into their own experimental market to test their own products. Silicon Valley is at the forefront of IT industry development in the United States, where many information industry companies are clustered and neighbouring cities have become the first choice for the development of smart cities.

Since the U.S. is a market-government partnership to build new smart cities, the cities chosen are much smaller than those in South Korea; the city of Palo Alto had a population of merely over 50,000 when it launched its smart city program in 2016, which rendered it easy for it begin to 'smarten' up the city. As one of the more successful smart cities in its current phase of development, the city supports innovation and startups through the development of programs such as smart transportation, sustainable energy and green buildings, open data and digital services, and participatory planning for smart cities. A market-demand-oriented approach to building a smart city can avoid difficulties similar to those encountered when Songdo was built at too great a pace.

Although Palo Alto's smart city development is progressing

relatively well as of 2023, this case has limitations. A city with 70,000 people is not a case study in a country with a large population such as China, India, or Japan, and the city is too homogenous. The question of whether or not the city's development model can be replicated has also been discussed.

Cultural regional analysis of smart cities

According to the Smart Cities Expo 2023, more than 800 cities worldwide have shown interest in the development of smart cities, and nearly 100 have begun exploring them to varying degrees. As smart city exploration has gained experience, cities on all continents have discovered the most appropriate areas and suitable entry points for development (Table 1). This study selects 31 relatively typical cities as samples, based on five criteria: (1) the city has detailed plans for this field in its Smart City Development Report; (2) the city has ongoing implementations of Smart City projects; (3) the smart city development involves participation from both government and local businesses in the city; (4) the smart city projects have made some progress; and (5) feedback or monitoring from third-party organisations has been received for smart city projects. All 31 sample cities have public documents and results in the field of smart city development and serve as case studies for cities in other regions when they develop smart cities. The rest of the cities developing smart cities have too low a degree of design, making it difficult to form a systematic evaluation of them.

There are five levels of smart city development directions, 5 for core area development, 4 for important development, 3 for focused development, 2 for initial development, and 1 for planned development, and the ratings for each city in Table 1 depend on the degree of fulfilment of

Table 1
Names of smart cities and direction of development ratings.

Region	City	Smart Environment	Smart Economy	Smart People	Smart Governance	Smart Mobility	Smart Living
Asia	Singapore	5	5	5	5	5	5
	Songdo	5	5	5	5	5	5
	Hongkong	4	5	3	5	2	1
	Tokyo	3	5	2	2	4	1
	Beijing	3	5	1	1	5	1
	Seoul	3	3	3	1	5	1
	Shenzhen	2	5	1	1	1	1
	Shanghai	3	5	2	1	1	2
	Taipei	3	1	1	1	2	3
Middle East	Dubai	5	5	5	5	5	3
	Neom	3	5	1	1	5	4
Europe	London	5	5	2	2	4	4
	Barcelona	5	2	5	1	3	5
	Copenhagen	5	1	5	3	5	2
	Amsterdam	5	2	5	3	5	2
	Paris	5	2	2	3	4	4
	Stockholm	5	2	3	3	5	5
	Helsinki	5	1	3	1	5	1
	Berlin	5	2	5	3	5	1
	Madrid	5	2	2	3	2	1
	Olso	5	5	5	5	5	1
	Zurich	5	3	4	2	3	1
	Vienna	5	2	3	1	2	1
	Tallinn	5	2	1	1	1	2
	Milan	5	1	1	2	5	3
North America	Palo Alto	5	4	3	4	5	5
	Riverside	3	5	2	1	5	2
	Toronto	3	3	2	2	5	2
	Montreal	3	4	1	2	5	2
	New York	2	5	2	1	4	2
Others	Brisbane	5	3	2	2	4	2

*Note: 5 = core development; 4 = important development; 3 = focused development; 2 = preliminary development; 1 = planned development.

the criteria by the city. The cultures of the geographic regions listed in Table 1 influence the level of development in each smart city direction. Of the 31 mature smart cities worldwide, Eurasia accounts for 81 %, North America 16 %, and other regions 3 %. In the vast majority of cities, the core emphasis of development is on smart environment, smart economy, and smart mobility, these three can be quickly applied to the daily lives of residents or produce tangible benefits. Many cities ignore smart people, smart governance, and smart communities because they focus on training relevant government personnel and residents in humanistic literacy.

The development of smart cities is more common in countries and regions with more developed economies and relatively more modernised cities, which are more likely to afford the high cost and complexity of the challenges that smart city projects require. Currently, the concept of smart cities is driven by modern concepts and cutting-edge technologies, such as environmental protection and artificial intelligence, and is gradually gaining widespread acceptance worldwide. From a cultural regional perspective, North America has—in recent years—developed technologies such as drones, navigation technology, roadside sensing devices, and traffic management, all of which are pushing cities closer to smart mobility. Compared to smart mobility, North America has been behind Eurasia in research and development in areas such as smart environments. Asia, on the other hand, has focused on smart economy, with Southeast Asia focusing on how technology can be used to predict data, such as GDP, more accurately. The European region still focuses on smart environments, but it is worth noting that Europe has also invested considerable energy in the direction of smart people, taking into full consideration their importance in smart cities. Cities in the Middle East focus on economic sustainability, employing technology to develop a diversified economy and reduce dependency on energy resources. Although there are better developed areas of smart cities in each region, the weak components still exist. Weak components such as smart government and smart people have already begun to develop in many cities, as evidenced by the growth in the number of people obtaining advanced degrees in various cities. However, it is difficult to have corresponding data, documents, or standards to prove this trend. In the future, these weak components will rapidly improve and form a stable system driven by the strong components (Fig. 3).

Despite the rapid growth in the recognition of smart city concepts, the rate of implementation of these concepts and building smart cities has not increased at the same pace. The primary reason for this is that

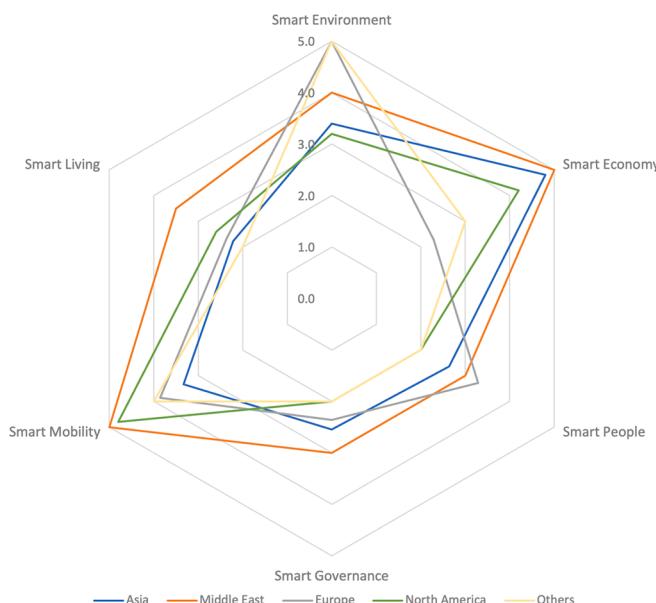


Fig. 3. Direction of smart city development in the world's continents.

developed countries tend to face slower progress in the development of smart cities, and they are usually only able to develop in depth in a particular area or aspect, which may be due to factors such as difficulties in coordination among various stakeholders, limited resources, or constraints in policies and regulations. Second, the development of smart cities is still accompanied by relatively high technology costs. While many developing countries are willing to adopt the smart city concept, the actual cost of construction may exceed what is needed and affordable.

Revelations and discussions

Smart cities across cultural regions have brought many unknown and unexpected surprises and challenges to the planning, geography, engineering, and information professions in the first 20 years of their development. By horizontally comparing the development trends of smart cities in different cultures and regions, this initial phase of exploration is not only an important inspiration for current research but also lays a solid foundation for future research in geography.

Dilemmas and opportunities

This study considers both cultural (macro) and individual (micro) perspectives to determine the future dilemmas and opportunities of smart cities. The cultural perspective considers the entire smart city ecosystem, including city size, government policies, and global trends, while the individual perspective focuses on specific people interacting with projects, technology, and society, allowing for a more nuanced understanding of localised issues and challenges. Fig. 4 shows the potential threats and opportunities for the future development of smart cities from two perspectives, with all the elements unfolding along the horizontal and vertical lines, and the city's strengths being utilised through different perspectives to compensate for its weaknesses to better promote the development of smart cities.

The future development of smart cities is accompanied by several challenges. First, issues of personal privacy and data security may raise concerns among some residents about living in a smart city. The operation of smart cities will rely on the collection and analysis of large-scale personal data, which will provide more convenient services for each resident, but will also cause some residents to question the system of how to manage and protect their privacy and data security. Second, in the process of building a smart city, the speed of technology iteration will be further accelerated, and in this process the digital divide phenomenon may increasingly appear in different population groups, resulting in some residents who do not have access to, or are unfamiliar with, the latest digital technology not being able to obtain equal or timely information resources, and gradually being excluded from the city's smart service system, aggravating the inequality of the society in terms of wealth and rights and interests. Simultaneously, smart cities face the challenge of isolation caused by the digital divide. Unique and complex urban systems make it more difficult for outside groups to gather information about their use, and the resulting cultural divide can lead to a lack of outside vitality in the city. Third, smart cities face high costs and investment needs. The construction and maintenance of cities require significant capital investment, which may put financial pressure on city governments. Finally, technology standards and interoperability issues need to be taken seriously. The various technologies used in smart cities often have different standards and interoperability issues, which have hindered the development of smart cities from their aims and purpose.

However, despite the many challenges to future development, smart city development is still worth imagining. First, smart cities can improve the quality of life for all its residents, and through the implementation of advanced technologies, city dwellers can enjoy a safer, more convenient, and healthier life. Second, smart cities are committed to sustainable development. Through smart city initiatives, cities can target audiences

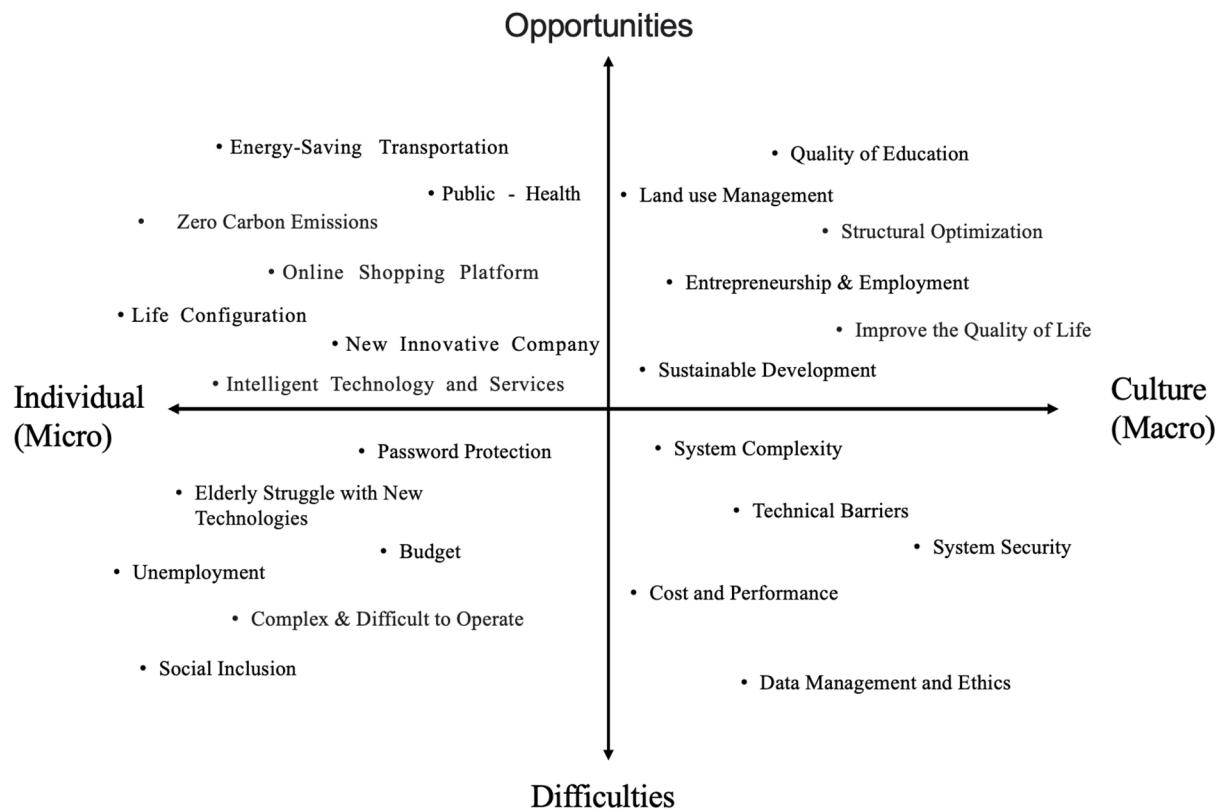


Fig. 4. Dilemmas and opportunities for smart city development from macro and micro perspectives.

to deal with issues such as waste, energy use, and water management more effectively, which helps improve the quality of the city's environment and achieve the goal of sustainable development. Third, the development of smart cities promotes innovation and entrepreneurship and creates new job opportunities in cities. The Internet of Things, artificial intelligence, and data analytics have attracted a large number of innovators and start-up entrepreneurs, which not only helps diversify the city's economy, but also provides more job opportunities for residents and promotes economic growth and innovation. Finally, smart cities offer new opportunities for community engagement and governance, with digital tools that can be used to gather the views of residents and help cities better measure between individuals and groups. Residents can participate in the city's decision-making processes, making urban governance more democratic and transparent.

Problems requiring solutions in the future of smart cities

Smart cities and their synonyms—digital city, information city, financial city, cultural city, and post-industrial city—are based on the existing city characteristics to crown the description, while received wisdom tends towards describing the characteristics of the people, using the term the city of 21st century urban planning. The development of smart cities in the coming times will still require human beings to build a large number of intelligent devices within the city to help gather personal data, in increasing number of cities to collect and centralise data, to make the city's newborn brain begin to think and become 'intelligent'. Along with major efforts to build a new generation of infrastructure, the research and development of communication devices, such as chips, quantum computers, and satellites, allow smart cities to think while reducing operating costs. Smart cities will become the development goal of most cities in the future, and even though some small and medium-sized cities do not need to popularize smart technology in all aspects, they will have smart city characteristics in some

areas.

From the perspective of cultural regions, there are yet three core issues to be discussed and resolved that will affect the development of smart cities in the future: (1) how to define the role of human beings within the city and whether human beings will hand over the control of the operation of the city entirely to the city itself; (2) whether smart cities are a type of urban development in developed regions or a trend of inevitable transformation for all cities in all regions; (3) when one or a group of cities in a cultural region reaches the stage of being a smart city in the future, how will they coexist with non-smart or quasi-smart cities in other regions, or in the process of popularising smart cities, will the first-formed smart cities export their cultures to later-formed cities in a one-way direction, leading to interregional inequality.

CRedit authorship contribution statement

Runlin Yang: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Feng Zhen:** Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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