Metaverse Technology for Public Services in Smart Cities: Opportunities and Challenges

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Abstract: This study investigates the viability of metaverse technology as a digital public service in smart cities and explores the prospects and challenges of implementing it in developed and developing countries. This study employs a conceptual exploration through a review of the contemporary literature concerning the deployment of metaverse technology, the construction of smart cities, and the revolutionization of public services. The analysis compares readiness factors of technology, infrastructure, and policy between developed and developing countries. Metaverse provides immense value to smart cities, including improved accessibility of public services, real-time interaction, and operational efficiency. However, key challenges in deploying such networks include limited infrastructure in the developing world, issues with data privacy, and high energy consumption in developed countries. Conceptual research needs further empirical studies focusing on implementing metaverse technology in smart cities. This research is beneficial for policymakers when designing smart-metaverse implementations.

1 INTRODUCTION

The smart city concept has evolved to address urbanization challenges by improving citizens' quality of life and public service efficiency, citizens' participation, and improving government and environmental communication sustainability (Din et al., 2020). Implementing innovative technology is one of the governance efforts in cities' development to ensure citizens' welfare. Citizens are the lifeblood of a city, where citizens' growing sustainability and welfare are things to be maintained. The sustainability of smart cities is defined by the elements of Emerging and advanced technology (Almeida et al., 2024). The use of technology is significant, especially in the government's application of public services in the context of smart cities. Public services are services that the government directly or indirectly provides to the community to fulfill citizens' basic needs and rights. The government has three roles in public service innovation: regulator, promoter, and user of technological innovation in public services. Governments commonly employ IoT, AI, Blockchain, Big Data Analytics, and Information and Information Communication Technology (ICT) to provide additional integrated, efficient and effective services. One of the new technologies that has yet to be studied by researchers is the metaverse.

Metaverse offers a new dimension in the transformation of digital public services. Metaverse enables a more interactive, immersive, and real-time virtual environment to provide a more transparent and inclusive public service experience (Senadheera et al., 2024). Metaverse can enhance digital public services in smart cities with many benefits, such as increased efficiency of public services, wider accessibility, transparency, and citizen engagement, and can reduce carbon footprint (Green ICT). It also supports the Green ICT agenda, contributing to the sustainability of innovative city initiatives (Chen et al., 2024). Metaverse supports public services more broadly (e.g., telemedicine as part of a city's health

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services or virtual classrooms as part of a smart city initiative).

However, there is a disparity between developed and developing countries adopting digital public service technologies. Developed countries have made significant progress in e-government, virtual services, and smart cities, while broader development challenges hinder the maturity of developing nations. Limited bandwidth further delays smart city adoption in these regions. This study offers three key contributions: (1) it compares metaverse adoption in public services between developed and developing countries based on technological readiness, infrastructure, and policy frameworks; (2) it integrates governance and public service perspectives with technology, highlighting opportunities and challenges in smart city development; and (3) it provides policy recommendations to support digital transformation through metaverse implementation, particularly for developing countries facing infrastructure and regulatory constraints. These insights enrich the literature and assist policymakers in advancing smart city initiatives through emerging technologies.

2 LITERATURE REVIEW

2.1 Smart Cities and Digital Public Service

In the digital era, technology plays a vital role in shaping smart cities that aim to improve urban services and the community's quality of life. Smart cities integrate various domains such as transportation, energy, and public services through a smart city environment. One of the key components of smart cities is digital public service, which refers to the use of digital technology to enhance the efficiency, accessibility, and inclusivity of public services. These services encompass e-government platforms, digital healthcare, smart transportation, and other essential public services designed to improve citizen engagement and service delivery. Despite offering many benefits, smart cities also face significant challenges, primarily related to the digital divide that most impacts people with disabilities (Sabri & Witte, 2023).

Smart cities utilize IoT-based digital technologies, artificial intelligence (AI), big data, and cloud computing to improve the efficiency of government services (e-government), healthcare, and response to community needs. AI and Big Data also play an important role in city planning, national service management, and improving the security and speed of public services. For instance, in the health sector, this technology supports preventive planning, predictive analysis, epidemiology, and pandemic management through surveillance, contact tracing, and remote consultation (Naik et al., 2022). However, the main challenges in implementing smart cities are data integration issues, privacy security, and differences in digital readiness in various countries. Research shows differences in the approach to smart cities between developed and developing countries. Developed countries focus more on sustainable production and supply chain emission reduction while developing countries focus more on education and human rights (Kvasničková Stanislavská et al., 2023).

The increased efficiency of government through digitalization is more pronounced in developed countries. However, both developed and developing countries face challenges in building smart cities. Developed countries also face challenges in implementing smart cities, primarily concerning data privacy, cybersecurity risks, and the ethical use of AI in public services. Meanwhile, developing countries experience problems such as low internet connectivity, inadequate infrastructure, and the digital divide. In addition, rapid urbanization often leads to institutional weaknesses and a lack of resources. Before moving to the stage of urban innovation, it is necessary to fulfill basic needs and increase community capacity (Fefta et al., 2023). The main obstacle to adopting Industry 4.0 in both countries is the lack of a clear digital strategy. Developed countries have formulated national strategies and policies to incentivize Industry 4.0 technologies, while developing countries have adopted Industry 4.0 technologies at the enterprise level, relying on individual enterprise initiatives rather than national and coordinated policies (Raj et al., 2020).

During the COVID-19 pandemic, digital technology has been invaluable in monitoring the outbreak's spread, predicting trends, and managing health institutions. As an example of digital technology adoption in smart cities, digital health services have played a crucial role in enhancing healthcare accessibility and efficiency. However, the gap remains, especially in developing countries. Limited infrastructure remain substantial obstacles to the equal distribution of digital health services across various regions (Naik et al., 2022).

Smart cities offer a sustainable solution for future city development. However, to ensure its success, a citizen-centric approach must be implemented. This

strategy must be aligned with the community's needs and preferences so that the presented innovations can benefit all city residents. In supporting digital public services, various advanced digital technologies have been integrated into smart cities. One emerging digital technology increasingly adopted in digital public services is the metaverse. This technology enables immersive virtual environments that facilitate citizen engagement, digital governance, and remote public service interactions. By leveraging extended reality (XR), AI, and blockchain, the metaverse has the potential to transform how public services are delivered, making them more interactive, accessible, and efficient (Yaqoob et al., 2023). Although challenges remain, some developing countries have successfully implemented innovative public service solutions to address existing constraints.

2.2 Digital Technologies for Developed versus Developing Countries

Significant differences in the adoption of digital technologies between developed and developing countries, as shown in Table 1, highlight structural and policy imbalances in implementing technologies. In advanced economies, mature digital infrastructure and connectivity (e.g., 5G) strengthen their digital transformation (Raj et al., 2020). On the other hand, development can meet significant constraints in terms of infrastructure and catch up with global technical development. It demonstrates how the global digital divide is not a question of access alone but a mirror of global economic and political inequalities that shape development priorities. Then, in the Smart city approach that leads to citizen focus, it is very important to gain insight into what services are most important from the citizen's perspective and which transaction channels are preferred (Wirtz et al., 2021).

Moreover, this highlights their generally stronger economic position by facilitating technology investments as opposed to developing nations that tend to rely on international grants or external support (Tukur et al., 2023). This condition implies that this dependency would drive an unequal and asymmetrical relationship that thwarts developing countries' independence in developing their technologies. Developed countries with structured data privacy policies reflect better preparedness in dealing with digital security risks through policies and data security (Tukur et al., 2023). On the other hand, policy inconsistencies in the developing world not only erode public trust but also affect all technologies introduced(Hadavi & Alizadehsalehi, 2024).

Table 1: Comparison of Digital Technologies.

Aspects	Developed Countries	Developing Countries
Infrastructure	Digital infrastructure is already established	Limited infrastructure and internet access
Implementation Cost	It is more straightforward to finance technology investments	Implementation costs are high and depend on international grants
Citizen Participation	High-tech literacy, active engagement	Low digital literacy and technology
Data Security	Well-established data privacy policy	Challenges in maintaining data privacy and security
Digital Policy	Data privacy regulations and technology policies are maturing	Policies are inconsistent and less integrated

Based on Table 1, developed countries have mature digital infrastructure, stable funding resources, and integrated regulatory policies between data security and technology regulation. In contrast, developing countries lack internet network infrastructure, have high implementation costs and dependency on external funding, and have a long-standing digital literacy gap that hinders increased public participation. Therefore, differences in digital policies and regulations, such as public services, make data protection and regulation less harmonious.

Table 2: Comparative Analysis of Digital Public Services in Smart Cities between Developed and Developing Countries.

Evaluation Criteria	Developed Countries	Developing Countries
Service Coverage	Comprehensive digital services	Basic services
Accessibility	24/7 access via multiple platforms (web, mobile apps)	Limited to office hours with in-person verification
Technology Utilization	Use of IoT, AI, blockchain, and digital twins	Basic web portals, SMS services
System Interoperability	Integrated systems across sectors (health, finance)	Fragmented systems with limited cross-sector

Table 2: Comparative Analysis of Digital Public Services in Smart Cities between Developed and Developing Countries (cont.).

Evaluation Criteria	Developed Countries	Developing Countries
Evaluation Criteria	Developed Countries	Developing Countries
Data Utilization	Big Data for Policymaking	Limited data usage in governance
Security and Privacy	Robust cybersecurity frameworks	Vulnerable to cyberattacks
Administrative Efficiency	Automation of administrative processes reduces service time and costs	Some processes are still manual

2.3 Metaverse in Digital Public Service

The metaverse concept has evolved significantly since its inception, with research interest increasing rapidly in recent years. 2021 is often considered the beginning of the "Metaverse Era," marked by a surge in scientific publications and technological advancements (Shen et al., 2023). The metaverse introduces a new paradigm in digital public services by offering immersive, real-time virtual interactions. The main components of the metaverse are hardware, software, and content. The two most common are VR and AR metaverse driving technologies (Yaqoob et al., 2023). Built upon technologies like virtual and augmented reality, AI, and blockchain, the metaverse has the potential to support various smart city initiatives. By enabling more interactive and engaging public services, it can enhance citizen participation, improve government transparency, and streamline digital transactions. The metaverse enables avatars, which allow users to interact in an immersive, synchronous, and continuous environment (Al-Ghaili et al., 2022). At the same time, it provides solutions for many sectors, including government administration, security, transportation, health, education, tourism, and social services. (Koohang et al., 2023). The metaverse is imagined to be the convergence of physical and digital worlds, defined by five features: digitally mediated, spatiality, immersion, and real-time operations.

However, scalability, interoperability, privacy, and ethical considerations remain. The metaverse provides the opportunity to revolutionize public services. A metaverse can benefit citizen service and engagement in government, especially for younger generations (Kshetri et al., 2024). However, challenges encompass privacy issues, possible abuse, and the disparate need for its careful implementation. The impact of the metaverse spans all kinds of industries, such as tourism and entertainment, providing fresh means for interaction and problem-solving (Koohang et al., 2023). Metaverse, an ethereal smart city representation, has the potential for environmental, economic, and social sustainability goals (Allam et al., 2022).

3 METHODOLOGY

This study employs a qualitative and exploratory approach to examine the potential of metaverse technology in enhancing digital public services within smart cities. Using a conceptual framework based on recent literature, it explores opportunities and challenges in developed and developing countries.Data collection involved document analysis of journals, conference proceedings, government papers, and policy documents on smart cities and digital transformation. Sources were retrieved from IEEE, Scopus, and Web of Science using keywords like *Metaverse in Smart Cities*, *Digital Public Services*, and *Metaverse Governance*. Government reports from organizations such as the OECD were also considered. Of the 96 papers initially found, 30 were selected based on relevance to public service applications. The inclusion criteria were: (1) peer-reviewed journal articles or conference proceedings, (2) studies on metaverse applications in digital public services within smart cities, (3) discussions on opportunities and challenges in government-related services, and (4) empirical studies or comparative analyses of developed and developing countries. Data analysis involved content and comparative analysis. Content analysis identified key themes, including benefits, challenges, and potential applications of the metaverse in public services. Comparative analysis examined differences in technological readiness, infrastructure, and policy frameworks between developed and developing countries.

4 FINDINGS

The findings are categorized into two main aspects: (1) *Opportunities of the Metaverse*, which highlights its potential in enhancing digital public services, and (2) *Challenges in the Metaverse*, which examines the barriers that must be addressed to maximize its benefits.

Table 3: Comparison of Opportunities and Challenges in Developed and Developing Countries.

Aspects	Develop Country	Developing Country
Opportunity	• Mature Infrastructure • Supportive Innovation Ecosystem • Cross-Sector Collaboration • Focus on Quality of Life • Leader in Technology	• Digital Transformation • Huge Market Potential • Focus on Local Solutions • Leap Frogging Effect • Development Support
Challenges	• Level of regulatory complexity • Ethics and Social Responsibility • Maintenance Cost • High User Expectations • Change Resistance	• Digital Divide • Inadequate Infrastructure • Low Technology Literacy • High Initial Cost • Reliance on International Aid

Table 3 compares the opportunities and challenges of metaverse deployment in developed and developing countries. Developed nations benefit from mature infrastructure, supportive innovation ecosystems, and well-established regulations but struggle with high costs and rising user expectations. Meanwhile, developing countries view the metaverse as a driver of digital transformation with vast market potential but face barriers such as the digital divide, inadequate infrastructure, and low technological literacy. Despite these differences, the metaverse presents opportunities for both to enhance public services and foster digital innovation.

4.1 Opportunities of Metaverse

The metaverse offers significant opportunities to enhance digital public services, particularly in accessibility and engagement. For example, *Metaverse Seoul* enables citizens to access administrative services virtually, eliminating the need for physical visits. In healthcare, Cleveland Clinic is utilizing metaverse-based training simulations to provide immersive learning experiences for medical professionals. In urban planning, Singapore's *3D Virtual City Model* enhances data visualization and decision-making processes, while the UAE is advancing its digital services through the *Dubai Metaverse Strategy*. Japan is also embracing this shift by developing *Metaverse Economic Zones*, a consortium aimed at creating virtual spaces for its citizens. Even smaller nations like Tuvalu recognize the metaverse's potential. Through the *Digital Nation Initiative*, Tuvalu is working to preserve its cultural heritage in a digital space, ensuring its identity remains intact despite the looming threats of climate change, natural disasters, and human activity (Naqvi, 2023). These real-world implementations highlight the transformative potential of metaverses in improving service delivery and citizen engagement. It can provide immersive simulations for government interaction and offer broader inclusion of disabled persons as a tool in content creation and art production (Radanliev et al., 2024). Metaverse can help create a learning environment for neurodivergent types, such as people with autism spectrum disorders (Hutson, 2022). In healthcare, metaverse wearables can also enhance patient care and wear; they can help reduce accessibility and improve medical education content (Kim et al., 2023).

The technology also has the potential to redefine urban planning and service delivery in cities. This change can open new doors for individuals with physical disabilities to partake in creative and social activities (Radanliev et al., 2024). At the same time, it can enhance introverts and Autism Spectrum Disorder (ASD) in academic and professional environments (Hutson, 2022). Metaverse can facilitate virtual meetings, which expand participation and diversity in conferences (Kim et al., 2023). In healthcare, the metaverse can transform medical practice, enhance diagnosis therapy and patient satisfaction for the hospitality and metaverse, co-create the future of the tourism industry, and create transformative experiences and value (Buhalis et al., 2023).

Metaverse offers significant potential to improve digital public services, particularly regarding accessibility and inclusivity. The metaverse enables remote governance, enhances service delivery, and increases transparency (Naqvi, 2023). However, not all services are as appropriate for the metaverse as for this space; Citizen empowerment and citizen development-focused services have the most promise. The metaverse can help promote the UN's Sustainable Development Goals, especially in developing countries. While it provides excellent potential for public services decision-making and the delivery of services, it is careful to be suitable for specific needs. As governments explore metaverse applications, they must navigate facilitators and

barriers, develop their presence, and consider the transformations required to benefit from these technologies entirely (Kshetri et al., 2024).

4.2 Challenges in Metaverse

The metaverse offers opportunities and challenges, which vary significantly between developed and developing countries. Infrastructure and connectivity gaps are essential hindrances in rural settings (Raj et al., 2020). Intermittent internet connections and improper infrastructure are significant barriers to metaverse adoption in developing countries (Raj et al., 2020; Tukur et al., 2024). 5G network limitations and high latency can hinder real-time interactions in virtual environments. Privacy and security concerns matter, of course, but we also need to know which apps, and how many, will continue to serve us and how they can please us with better features. To solve privacy and security challenges, we must prioritize digital literacy programs and infrastructure networks and discuss privacy and security concerns (Khalil & Jumani, 2024). Despite these obstacles, the metaverse offers potential benefits to developing economies, including opportunities for education and economic participation (Khalil & Jumani, 2024).

The Immersive and interactive metaverse individualized settings and learning experiences (Onu et al., 2024), yet it also inevitably raises concerns about digital privacy and security (Al-kfairy et al., 2024; Tukur et al., 2023). Libraries can design metaverses concerned with arts and cultural data meta literacy skills that librarians and users use. However, using metaverse technologies encounters hurdles like high cost, intricacy of implementation, incorporation of new technology, and ethical concerns (Tukur et al., 2024). Different governance systems use other architectures, making integration into a single metaverse difficult. To fully utilize the potential of the metaverse for digital education and information flow, independent research, and training challenges, insist on cooperation and appoint the agency of institutes for inclusive and ethical development (Al-kfairy et al., 2024; Onu et al., 2024).

Implementation challenges: High costs are mainly involved, and some notable challenges and technical complexity are present. Hardware and software are significant adoption barriers (Tukur et al., 2024). Metaverse requires servers with high computing power to handle real-time interactions, data storage, and graphics rendering. Furthermore, the complexity of implementation and the need for cutting-edge tech like VR, AR, AI, and blockchain present additional challenges. Privacy, management, security issues associated with data, and cybercrime threats are serious issues that must be addressed (Gupta et al., 2023; Tukur et al., 2023). Translation: Cultural aspects and ignorance regarding metaverse technologies also hold back large-scale acceptance. The merger of the physical and solving challenges in the digital world requires solving regulations, interoperability, and ethical considerations (Hadavi & Alizadehsalehi, 2024). This situation poses serious challenges in the metaverse (data privacy and cybersecurity). Key concerns include privacy threats, data management problems, and the requirement for strong security measures. Applying privacy computing approaches to tackle the abovementioned problems and using machine learning models to strengthen security in the metaverse. A decentralized general framework for Self-Sovereign Identity has been suggested to safeguard personally identifiable information (Fiaz et al., 2024). The future of these systems is being modeled using Zero-Trust Architecture for a potential solution (Gupta et al., 2023). Legal challenges around intellectual property, privacy, and jurisdiction in the metaverse need an interdisciplinary angle.

Significant potential also exists in the metaverse policy and governance challenges. Topics include privacy concerns, threats to national security, and data management. Ethics, including digital splintering, social regulation, and identity marshaling, require attention. Governments face obstacles in deploying metaverse technologies, demanding metamorphosis in their function (Kshetri et al., 2024; *OECD Digital Economy Outlook 2024*, 2024), which poses challenges to intellectual property protection and jurisdictional power over cyber borders. Governance based on technical standards is essential for aligning compatibility and security in various phases of tannic. The multifaceted, multi-dimensional nature of the metaverse requires an interdisciplinary approach to tackle these challenges better. Implementing a Zero-Trust Architecture model can enhance security (Gupta et al., 2023). Despite these challenges, the metaverse provides prospective advantages in education, commerce, and public sector services that demand ongoing research and development (Al-Ghaili et al., 2022).

5 CONCLUSION

This study explores the potential of metaverse technology in digital public services in smart cities by comparing its adoption in developed and developing countries. Metaverse can enhance citizen integration

and participation in interactive virtual public services. In developed countries, this technology supports service efficiency, government transparency, and the implementation of Green ICT. In developing countries, the metaverse has the potential to be an innovative strategy in public services that needs to be pursued immediately to improve the quality of services for its citizens. However, challenges remain, such as privacy and ethics issues, high energy consumption in developed countries, infrastructure limitations, high implementation costs, and technological literacy gaps in developing countries. To address these challenges, recommended policies include strengthening data privacy and security regulations, adopting green data centers, and piloting projects like virtual city halls. In developing countries, the focus should be increasing investment in digital infrastructure, technological literacy, and budget-friendly devices. International collaboration is also needed to support technology transfer, funding, and the implementation of best practices. Further research should focus on facilitating metaverse implementation in public services and smart cities. Efforts to improve accessibility and inclusivity also be considered so that the community can feel the benefits of the metaverse to support the sustainable digital transformation of smart cities.

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