



# Exploring the Role of Innovative Technologies in Smart Cities

Kagontle Selwe<sup>1</sup>  & Costa Hofisi<sup>1</sup> 

<sup>1</sup> North-West University, South Africa.

## ABSTRACT

Smart cities emerged as a solution to simplify the lives of urban citizens by integrating Information and Communication Technologies (ICTs) into daily operations and addressing the rapid urbanisation challenge. This article relied on an extensive literature review to explore the role of innovative technologies such as smart traffic management, smart buildings and smart healthcare in the development of smart cities. It further explored the policy, legal, and institutional frameworks that underpin the development and operation, including strategies for protecting and handling citizen data while also addressing both cybersecurity threats from cyberattacks and the privacy of citizens within these intelligent urban environments. The article identified the unique challenges posed by the very nature of smart city networks which include Cybersecurity Risks and Data Privacy Concerns. Despite the promising potential of smart city technologies to create a more efficient, sustainable, and citizen-focused urban environment, the challenges identified in this article should be addressed in order to unlock the full potential of innovative technologies for smart cities.

### Correspondence

Kagontle Selwe

Email:

[kago.selwe@gmail.com](mailto:kago.selwe@gmail.com)

### Publication History

Received: 5<sup>th</sup> October, 2024

Accepted: 13<sup>th</sup> December, 2024

Published online:

30<sup>th</sup> December, 2024

**Keywords:** *Innovative Technologies, Smart Cities, Information And Communication Technologies, Rapid Urbanization.*

## INTRODUCTION

The concept of "smart cities" emerged in the 1990s, coinciding with the rise of the information society, as highlighted by Albino, Berardi, and Dangelico.<sup>1</sup> This initial phase centered on the transformative potential of information and communication technologies (ICT) for both infrastructure and society.<sup>2</sup> Earlier discussions on smart cities revolved around how ICT could modernize urban systems and influence societal behaviour.<sup>3</sup> Currently, smart cities have evolved to be anchored on a collaborative vision, where technology empowers all stakeholders, citizens, administration, and industry to achieve shared goals, leading to overall city prosperity.<sup>4</sup> Roccotelli and Mangini argue that smart cities leverage advanced technologies to connect citizens, information, and infrastructure.<sup>5</sup> This

<sup>1</sup> Vito Albino, Umberto Berardi, and Rosa Maria Dangelico, "Smart Cities: Definitions, Dimensions, Performance, and Initiatives," *Journal of Urban Technology* 22, no. 1 (2015): 4.

<sup>2</sup> Albino, Berardi, and Dangelico, "Smart Cities: Definitions, Dimensions, Performance, and Initiatives." 4.

<sup>3</sup> Albino, Berardi, and Dangelico, "Smart Cities: Definitions, Dimensions, Performance, and Initiatives." 4.

<sup>4</sup> Chrysi K Metallidou, Kostas E Psannis, and Eugenia Alexandropoulou Egeyptidou, "Energy Efficiency in Smart Buildings: IoT Approaches," *IEEE Access* 8 (2020): 63679.

<sup>5</sup> Michele Roccotelli and Agostino Marcello Mangini, "Advances on Smart Cities and Smart Buildings," *Applied Sciences* (MDPI, 2022).1.

interconnectedness fosters a more sustainable and environmentally friendly city through smart grids and intelligent traffic management.<sup>6</sup> Furthermore, Batty, et.al., agree that the explosion of interconnected devices with varying processing power has transformed the vision of smart cities from science fiction to reality.<sup>7</sup> This paves the way for truly intelligent cities which are no longer confined to futuristic fantasies.<sup>8</sup>

Recent studies by Gracias, et.al., emphasize the transformative nature of the 21st century, where smart cities are transitioning from concepts to implemented realities.<sup>9</sup> These cities leverage advanced technologies and data analysis to achieve multiple goals, including enhancing citizen well-being, optimizing infrastructure and services, and driving sustainable economic growth.<sup>10</sup> Yin et.al., further highlights the significant impact of the digital revolution in cities, fundamentally reshaping both citizen experiences and city governance.<sup>11</sup>

Many cities around the world are transitioning towards becoming smart cities. Barcelona serves as a successful example of this trend. Bibri and Krogstie highlight that London boasts a superior Information and Communication Technology (ICT) infrastructure and access to data sources.<sup>12</sup> However, Barcelona excels in its data-oriented capabilities, featuring elements like shared information platforms, operational control centers, user-friendly dashboards, and robust training programs.<sup>13</sup> Additionally, Barcelona fosters innovation through dedicated labs and research centers, while also possessing a well-defined strategic planning office.<sup>14</sup> Barcelona is tackling several innovative projects, like their "superblock" program which transforms areas into pedestrian havens, and a unified digital platform that seamlessly integrates city services and data.<sup>15</sup> With a focus on leveraging technology and data, Barcelona's smart city strategy prioritizes enhancing liveability, sustainability, and innovation within the city.<sup>16</sup> This strategy centers on initiatives encompassing smart urban infrastructure, improved mobility solutions, energy efficiency, and a digital transformation across various sectors. Barcelona has already achieved success with various smart city projects, including a system for smart street lighting that minimizes energy use and a smart irrigation system that conserves water.<sup>17</sup>

While smart cities offer numerous advantages discovered above, researchers are focusing on addressing the potential drawbacks and hurdles associated with their development. For example, the rapid pace of urbanization presents a complex challenge for cities around the world.<sup>18</sup> As Siman, et.al., point out, this surge in urban populations coincides with a growing list of urban woes.<sup>19</sup> Smith elaborates on this point, highlighting how rapid urbanization strains existing infrastructure and resources, leading to a multitude of issues.<sup>20</sup> These concerns, as Shah emphasizes, extend to the economic sphere, with city growth placing significant demands on financial resources.<sup>21</sup>

<sup>6</sup> Roccotelli and Mangini, "Advances on Smart Cities and Smart Buildings."1.

<sup>7</sup> Michael Batty et al., "Smart Cities of the Future," *The European Physical Journal Special Topics* 214 (2012): 482.

<sup>8</sup> Batty et al., "Smart Cities of the Future."482.

<sup>9</sup> Jose Sanchez Gracias et al., "Smart Cities—a Structured Literature Review," *Smart Cities* 6, no. 4 (2023): 1719.

<sup>10</sup> Gracias et al., "Smart Cities—a Structured Literature Review."1719.

<sup>11</sup> ChuanTao Yin et al., "A Literature Survey on Smart Cities," *Science China. Information Sciences* 58, no. 10 (2015): 12.

<sup>12</sup> Simon Elias Bibri and John Krogstie, "The Emerging Data-Driven Smart City and Its Innovative Applied Solutions for Sustainability: The Cases of London and Barcelona," *Energy Informatics* 3, no. 1 (2020): 1.

<sup>13</sup> Bibri and Krogstie, "The Emerging Data-Driven Smart City and Its Innovative Applied Solutions for Sustainability: The Cases of London and Barcelona."1.

<sup>14</sup> Bibri and Krogstie, "The Emerging Data-Driven Smart City and Its Innovative Applied Solutions for Sustainability: The Cases of London and Barcelona." 1.

<sup>15</sup> M. Morningstar, "Barcelona," Barcelona Smart City - About Smart Cities®, 2021.

<sup>16</sup> Morningstar, "Barcelona."

<sup>17</sup> Morningstar, "Barcelona."

<sup>18</sup> Saba Latif, Hamra Afzaal, and Nazir Ahmad Zafar, "Intelligent Traffic Monitoring and Guidance System for Smart City," in *2018 International Conference on Computing, Mathematics and Engineering Technologies (ICoMET)* (IEEE, 2018), 1.

<sup>19</sup> E. Siman et al., "IoT-Driven Smart Cities: Enhancing Urban Sustainability and Quality of Life.," 2023.112.

<sup>20</sup> J. Smith, "Smart Cities and the Internet of Things: A Comparative Analysis of City A and City B," *Urban Studies Journal* 22, no. 1 (2019): 58–73.

<sup>21</sup> G. Shah, "The Economics of Urbanization: Challenges and Opportunities," 2023, the-economics-of-urbanization-challenges-and-opportunities.pdf (abacademies.org).

As such, innovative technologies and their role in building smart cities are attracting more scholarly attention.<sup>22</sup> Smart cities can leverage digital technologies to revolutionize how they deliver services to residents. By deploying these technologies, smart cities can make better decisions, reduce costs, improve the efficiency of city operations, and offer residents a more streamlined and user-friendly experience.<sup>23</sup>

The existing literature paints a clear picture of the challenges associated with urbanization hence the need for innovative technologies for smart cities. Frew and Breheny argue that the rapid influx of people to cities overwhelms existing infrastructure, causing traffic congestion, insufficient services, and environmental degradation.<sup>24</sup> Hsieh, et.al., further emphasize the strain on the job market, with rapid urbanization leading to increased unemployment, underemployment, and a rise in the informal economy.<sup>25</sup> Beyond these immediate concerns, Smith reiterates that effective resource management, environmental sustainability, and citizen well-being must also be considered.<sup>26</sup>

In response to these pressing challenges, the concept of smart cities has emerged as a potential solution. This transformative approach, as discussed by Jones, leverages advanced technologies to create a new urban paradigm.<sup>27</sup> Smart cities, according to Brown and Lee, utilize data-driven technologies, particularly the Internet of Things (IoT), to create intelligent environments that prioritize sustainability and improve the quality of life for citizens.<sup>28</sup> The rise of the IoT, as Smith explains, allows everyday objects to be connected and exchange data, forming the backbone of smart city initiatives.<sup>29</sup>

This article builds upon these existing works by exploring innovative technological solutions for the challenges faced by modern cities as smart cities hinge on using technology to enhance residents' lives, promoting both sustainability and overall cleverness.<sup>30</sup> While previous works have highlighted the need for smart solutions in areas like healthcare, building management, and transportation, this review delves deeper. The focus is on the future potential of these technologies and how advancements like the Internet of Things (IoT) are being harnessed to create smarter, more responsive cities. Ultimately, the success of smart cities hinges on their ability to deliver public value, ensuring residents reap the benefits of these advancements.<sup>31</sup>

## THEORETICAL FRAMEWORK

### Technology Acceptance Model (TAM)

Smart city initiatives hold immense promise for improving urban living through advanced infrastructure and technology.<sup>32</sup> However, the true value of these advancements lies in their citizen-centric approach, meaning residents must actively engage with them.<sup>33</sup> Understanding user behaviour and the factors influencing technology adoption becomes crucial in this context.<sup>34</sup>

<sup>22</sup> Costa Hofisi and Lewis Edwin Chigova, "Rethinking the Role of Local Government in Service Delivery in South Africa: Towards Digital Transformation," 2023.

<sup>23</sup> Hofisi and Chigova, "Rethinking the Role of Local Government in Service Delivery in South Africa: Towards Digital Transformation."

<sup>24</sup> Emma Frew and Katie Breheny, "Health Economics Methods for Public Health Resource Allocation: A Qualitative Interview Study of Decision Makers from an English Local Authority," *Health Economics, Policy and Law* 15, no. 1 (2020): 128–40.

<sup>25</sup> Ping-Hsuan Hsieh et al., "Economic Burden of Rheumatoid Arthritis: A Systematic Review of Literature in Biologic Era," *Annals of the Rheumatic Diseases* 79, no. 6 (2020): 771–77.

<sup>26</sup> Smith, "Smart Cities and the Internet of Things: A Comparative Analysis of City A and City B."

<sup>27</sup> K. Jones, "Internet of Things in Smart Cities: Advancements and Challenges," *Smart City Technology Journal* 18, no.2(2020):67–82.

<sup>28</sup> M. Brown and S. Lee, "Leveraging IoT for Sustainable Urban Development," *International Journal of Sustainable Cities* 8, no. 3 (2021): 201–18.

<sup>29</sup> J. Smith, "The Internet of Things: A Foundation for Smart Cities," *Journal of Urban Development* 25, no. 3 (2020): 214–31.

<sup>30</sup> Mohammed Sarrab, Supriya Pulparambil, and Medhat Awadalla, "Development of an IoT Based Real-Time Traffic Monitoring System for City Governance," *Global Transitions* 2 (2020): 230.

<sup>31</sup> Sarrab, Pulparambil, and Awadalla, "Development of an IoT Based Real-Time Traffic Monitoring System for City Governance."230.

<sup>32</sup> Ignasi Capdevila and Matías I Zarlenga, "Smart City or Smart Citizens? The Barcelona Case," *Journal of Strategy and Management* 8, no. 3 (2015): 266–82.

<sup>33</sup> Capdevila and Zarlenga, "Smart City or Smart Citizens? The Barcelona Case."

<sup>34</sup> Viswanath Venkatesh, James Y L Thong, and Xin Xu, "Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology," *MIS Quarterly*, 2012, 157–78.

Research has extensively explored how individuals adopt new technologies, drawing upon various social and psychological theories.<sup>35</sup> Given that smart city success hinges on citizen technology adoption,<sup>36</sup> a critical question emerges: do different smart city technologies have varying acceptance dynamics?<sup>37</sup> The TAM offers a well-established framework for investigating factors that influence user perception. Specifically, TAM focuses on how perceived usefulness and ease of use impact a user's acceptance of a particular technology.<sup>38</sup> Scholars frequently utilize the TAM framework developed by Davis (1986) to gain insights into user behaviour.<sup>39</sup> Dirsehan and van Zoonen highlight the foundational role of Davis's seminal work, "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology," which has garnered significant recognition within academia, exceeding 20,000 citations across computer science, business, and education fields according to Scopus and surpassing 55,000 on Google Scholar.<sup>40</sup>

Despite the valuable insights offered by TAM, achieving widespread public acceptance and user engagement in smart city technologies presents significant challenges. One such challenge lies in the potential power imbalance between governments and residents.<sup>41</sup> While citizen contributions provide valuable knowledge for developers, withholding this knowledge can leave citizens with less useful solutions.<sup>42</sup> As a result, smart city initiatives might fail to capture the diverse needs of different citizen groups, hindering their ability to deliver services and infrastructure that genuinely benefit the people.<sup>43</sup> This underscores the need for improved collaboration between public authorities and citizens. By fostering a space for experimentation and shared efforts, both parties can work together to unlock the full potential of smart city opportunities.<sup>44</sup>

### Key areas where innovative technologies are impacting smart cities

This section will examine the transformative impact of innovative technologies across key domains within smart cities.

#### a. Smart Traffic Management

Traffic congestion is a growing epidemic in cities worldwide, leading to economic stagnation, environmental degradation, and reduced quality of life.<sup>45</sup> With rapid urbanization, the need for innovative solutions to manage traffic flow effectively becomes increasingly critical. Smart transportation, a cornerstone of smart city initiatives, offers promising strategies to address this challenge.<sup>46</sup> A key theme is the utilization of real-time data for better traffic management.<sup>47</sup> Intelligent Transportation Systems (ITS) play a central role by collecting data from sensors on roads and highways.<sup>48</sup> This data is used to optimize traffic flow through adaptive traffic signals, freeway

<sup>35</sup> Venkatesh, Thong, and Xu, "Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology."

<sup>36</sup> Capdevila and Zarlenga, "Smart City or Smart Citizens? The Barcelona Case."

<sup>37</sup> Taşkın Dirsehan and Liesbet van Zoonen, "Smart City Technologies from the Perspective of Technology Acceptance," *IET Smart Cities* 4, no. 3 (2022): 197–210.

<sup>38</sup> Dirsehan and van Zoonen, "Smart City Technologies from the Perspective of Technology Acceptance."

<sup>39</sup> Dirsehan and van Zoonen, "Smart City Technologies from the Perspective of Technology Acceptance."

<sup>40</sup> Dirsehan and van Zoonen, "Smart City Technologies from the Perspective of Technology Acceptance."

<sup>41</sup> Nguyen, Marques, and Benneworth, "Living Labs: Challenging and Changing the Smart City Power Relations?"

<sup>42</sup> Nguyen, Marques, and Benneworth, "Living Labs: Challenging and Changing the Smart City Power Relations?"

<sup>43</sup> Nguyen, Marques, and Benneworth, "Living Labs: Challenging and Changing the Smart City Power Relations?"

<sup>44</sup> Bojana Suzic, Annette Ulmer, and Jens Schumacher, "Complementarities and Synergies of Quadruple Helix Innovation Design in Smart City Development," in *2020 Smart City Symposium Prague (SCSP)* (IEEE, 2020), 1–7.

<sup>45</sup> Fenghua Zhu et al., "Parallel Transportation Management and Control System and Its Applications in Building Smart Cities," *IEEE Transactions on Intelligent Transportation Systems* 17, no. 6 (2016): 1576.

<sup>46</sup> Prasanta Mandal, Punyasha Chatterjee, and Arpita Debnath, "An Intelligent Highway Traffic Management System for Smart City," in *Intelligent Computing: Proceedings of the 2019 Computing Conference, Volume 1* (Springer, 2019), 1; Sarrab, Pulparambil, and Awadalla, "Development of an IoT Based Real-Time Traffic Monitoring System for City Governance."230.

<sup>47</sup> Wei-Hsun Lee and Chi-Yi Chiu, "Design and Implementation of a Smart Traffic Signal Control System for Smart City Applications," *Sensors* 20, no. 2 (2020): 508.

<sup>48</sup> Lee and Chiu, "Design and Implementation of a Smart Traffic Signal Control System for Smart City Applications."

management systems, and other measures.<sup>49</sup> Studies by Mandal et al. and Sarrab et al. emphasize the importance of ITS in smart cities, ensuring traveller safety and comfort.<sup>50</sup>

Traffic monitoring technology extends beyond centralized systems. Popular navigation apps like Google Maps and Apple Maps leverage sensor data to provide real-time traffic updates to users.<sup>51</sup> This empowers drivers to make informed route choices, alleviating congestion.<sup>52</sup> Additionally, research by Shaygan, et.al., explores the potential of traffic prediction within navigation apps.<sup>53</sup> By developing more sophisticated prediction methods, these apps could provide even faster and more accurate traffic information, potentially preventing congestion altogether.<sup>54</sup>

Researchers propose Parallel Transportation Management and Control Systems (PTMS) as a potential next-generation solution for smart city transportation.<sup>55</sup> PTMS incorporates various elements, including social traffic data, cloud-based ITS services, and knowledge automation for transportation management.<sup>56</sup> It also utilizes agent-based traffic control for optimized flow. While this approach seems promising, further research is needed to evaluate its effectiveness in real-world scenarios.<sup>57</sup> The complexity of urban transportation systems necessitates innovative approaches.

## b. Smart Buildings

The origins of smart buildings can be traced back to the Energy Performance Building Directive.<sup>58</sup> This directive aimed to promote buildings with greater flexibility in energy use, the ability to generate renewable energy, and improved user interaction.<sup>59</sup> However, the concept itself has been evolving since the 1980s, fueled by continuous advancements in technology.<sup>60</sup>

Vijayan, et.al., delve into the concept of smart buildings, describing them as residences integrated with innovative technologies.<sup>61</sup> These technologies allow residents to interact with their homes through smart devices, fostering a more connected and automated living environment.<sup>62</sup> The functionalities offered by smart buildings are diverse, encompassing security surveillance, water management, energy management, smart lighting systems, and even elderly care support.<sup>63</sup> Additionally, Khatoun and Zeadally state that smart buildings offer a range of advantages that can lead to significant cost reductions. These benefits include real-time consumption monitoring, renewable energy integration, predictive energy management and automated building functions.<sup>64</sup> This emphasis on functionality aligns with the broader goals of smart city initiatives, which aim to improve various aspects of urban living.

<sup>49</sup> Moneeb Gohar, Muhammad Muzammal, and Arif Ur Rahman, "SMART TSS: Defining Transportation System Behavior Using Big Data Analytics in Smart Cities," *Sustainable Cities and Society* 41 (2018): 114–19.

<sup>50</sup> Mandal, Chatterjee, and Debnath, "An Intelligent Highway Traffic Management System for Smart City"; Sarrab, Pulparambil, and Awadalla, "Development of an IoT Based Real-Time Traffic Monitoring System for City Governance."230.

<sup>51</sup> B. Brindle, "How Does Google Maps Predict Traffic?," 2020, <https://electronics.howstuffworks.com/how-does-google-maps-predict-traffic.html>; Sarrab, Pulparambil, and Awadalla, "Development of an IoT Based Real-Time Traffic Monitoring System for City Governance."231.

<sup>52</sup> Sarrab, Pulparambil, and Awadalla, "Development of an IoT Based Real-Time Traffic Monitoring System for City Governance."231.

<sup>53</sup> Maryam Shaygan et al., "Traffic Prediction Using Artificial Intelligence: Review of Recent Advances and Emerging Opportunities," *Transportation Research Part C: Emerging Technologies* 145 (2022): 103921.

<sup>54</sup> Shaygan et al., "Traffic Prediction Using Artificial Intelligence: Review of Recent Advances and Emerging Opportunities."

<sup>55</sup> Zhu et al., "Parallel Transportation Management and Control System and Its Applications in Building Smart Cities."

<sup>56</sup> Latif, Afzaal, and Zafar, "Intelligent Traffic Monitoring and Guidance System for Smart City."1.

<sup>57</sup> Zhu et al., "Parallel Transportation Management and Control System and Its Applications in Building Smart Cities." 1577.

<sup>58</sup> Joud Al Dakheel et al., "Smart Buildings Features and Key Performance Indicators: A Review," *Sustainable Cities and Society* 61 (2020): 102328.

<sup>59</sup> Al Dakheel et al., "Smart Buildings Features and Key Performance Indicators: A Review."

<sup>60</sup> Mariangela Monteiro Froufe et al., "Smart Buildings: Systems and Drivers," *Buildings* 10, no. 9 (2020): 153.

<sup>61</sup> D S Vijayan et al., "Automation Systems in Smart Buildings: A Review," *Journal of Ambient Intelligence and Humanized Computing*, 2020, 1.

<sup>62</sup> Vijayan et al., "Automation Systems in Smart Buildings: A Review."1.

<sup>63</sup> Vijayan et al., "Automation Systems in Smart Buildings: A Review."1.

<sup>64</sup> Rida Khatoun and Sherali Zeadally, "Cybersecurity and Privacy Solutions in Smart Cities," *IEEE Communications Magazine* 55, no. 3 (2017): 51.

While smart buildings offer a glimpse into the future of residential living, the definition of a smart building remains somewhat elusive. Al Dakheel et al. highlight the lack of a universally agreed-upon definition, despite a multitude of proposed concepts within the research community.<sup>65</sup> However, the core principles seem to converge on the idea of buildings that leverage technology to improve efficiency, flexibility, and sustainability.<sup>66</sup> Information and Communication Technologies (ICT) play a critical role in smart buildings. Froufe et al. identify ICT as a key driver, enabling the connection of various building systems and infrastructure.<sup>67</sup> This connectivity offers several advantages service optimization, enhanced quality of life and public participation.

The need for energy conservation is a critical global concern, and smart buildings offer promising solutions. Vijayan et al. point out that conventional buildings are significant contributors to carbon emissions.<sup>68</sup> Metallidou et al., echo this concern, highlighting energy conservation as a major challenge for cities.<sup>69</sup> Smart buildings, equipped with advanced technologies like IoT, can address this challenge by optimizing energy use and promoting sustainable practices. For instance, Metallidou et al., advocate for integrating renewable energy sources like rooftop solar panels, which not only generate clean electricity but also reduce reliance on traditional grids.<sup>70</sup>

### c. Smart Healthcare

Studies by Al-Rawashdeh, et.al., and Masmali, Miah and Mathkooor, found surprisingly low adoption of internet-of-things (IoT) technology by healthcare end users.<sup>71</sup> They also identified healthcare professionals themselves as a major hurdle to implementing IoT for better care.<sup>72</sup> According to Tian, Yang, Le Grange, Wang, Huang and Ye, smart healthcare leverages cutting-edge information technologies to revamp the traditional medical system.<sup>73</sup> These technologies, like the Internet of Things, big data, and artificial intelligence, are transforming healthcare to be more efficient, convenient, and personalized.<sup>74</sup> A combination of patient monitoring and smart healthcare systems holds promise for preventing chronic diseases early.<sup>75</sup> Advancements in wireless technology and mobile apps have made patient monitoring more convenient and widespread, making early detection easier.<sup>76</sup> By using sensor systems for patient monitoring, for example, we can reduce unnecessary tests and appointments, ultimately lowering costs.<sup>77</sup> This technology also plays a crucial role in early disease detection and intervention, leading to better health outcomes.<sup>78</sup>

Healthcare professionals are under growing pressure from both the public and private sectors to address an increasing number of health issues.<sup>79</sup> This strain is compounded by rising medical costs, which negatively impact people's well-being.<sup>80</sup> A growing population and the development of new technologies are driving up healthcare costs.<sup>81</sup> One promising solution is the Internet of Things (IoT).

<sup>65</sup> Al Dakheel et al., "Smart Buildings Features and Key Performance Indicators: A Review."1.

<sup>66</sup> Froufe et al., "Smart Buildings: Systems and Drivers." 1.

<sup>67</sup> Froufe et al., "Smart Buildings: Systems and Drivers." 3.

<sup>68</sup> Vijayan et al., "Automation Systems in Smart Buildings: A Review."1.

<sup>69</sup> Metallidou, Psannis, and Egyptiadou, "Energy Efficiency in Smart Buildings: IoT Approaches."

<sup>70</sup> Metallidou, Psannis, and Egyptiadou, "Energy Efficiency in Smart Buildings: IoT Approaches."63686.

<sup>71</sup> Manal Al-Rawashdeh et al., "IoT Adoption and Application for Smart Healthcare: A Systematic Review," *Sensors* 22, no. 14 (2022): 5377; Feisal Hadi Masmali, Shah Jahan Miah, and Nada Yahya Mathkooor, "Internet of Things-Based Innovations in Saudi Healthcare Sector: A Methodological Approach for Investigating Adoption Issues," in *2020 IEEE Asia-Pacific Conference on Computer Science and Data Engineering (CSDE)* (IEEE, 2020), 1–5.

<sup>72</sup> Al-Rawashdeh et al., "IoT Adoption and Application for Smart Healthcare: A Systematic Review."

<sup>73</sup> Shuo Tian et al., "Smart Healthcare: Making Medical Care More Intelligent," *Global Health Journal* 3, no. 3 (2019): 62.

<sup>74</sup> Tian et al., "Smart Healthcare: Making Medical Care More Intelligent."62.

<sup>75</sup> Pantea Keikhosrokiani et al., "User Behavioral Intention toward Using Mobile Healthcare System," in *Consumer-Driven Technologies in Healthcare: Breakthroughs in Research and Practice* (IGI Global, 2019), 429–44.

<sup>76</sup> Keikhosrokiani et al., "User Behavioral Intention toward Using Mobile Healthcare System."

<sup>77</sup> Al-Rawashdeh et al., "IoT Adoption and Application for Smart Healthcare: A Systematic Review."2.

<sup>78</sup> Adem Karahoca, Dilek Karahoca, and Merve Aksöz, "Examining Intention to Adopt to Internet of Things in Healthcare Technology Products," *Kybernetes* 47, no. 4 (2018): 742–70.

<sup>79</sup> Al-Rawashdeh et al., "IoT Adoption and Application for Smart Healthcare: A Systematic Review."1.

<sup>80</sup> Al-Rawashdeh et al., "IoT Adoption and Application for Smart Healthcare: A Systematic Review."1.

<sup>81</sup> Fadi Al-Turjman, Muhammad Hassan Nawaz, and Umit Deniz Ulusar, "Intelligence in the Internet of Medical Things Era: A Systematic Review of Current and Future Trends," *Computer Communications* 150 (2020): 644–60.

By seamlessly integrating IoT technology into healthcare systems, we can address everyday challenges and improve overall efficiency.<sup>82</sup> Research shows that combining different technologies has the potential to significantly improve healthcare services and empower professionals to deliver better care.<sup>83</sup>

Al-Turjman et al. discuss the concept of the Internet of Medical Things (IoMT), which refers to an interconnected system of medical devices and individuals.<sup>84</sup> This network relies on wireless communication to share healthcare data. Al-Turjman et al. argue that integrating IoMT with healthcare has the potential to improve quality of life, enhance care delivery, and even lead to more cost-effective healthcare systems. A study by Al-Turjman et al. highlights that IoMT systems function best when biosensors, communication modules, and users work together seamlessly.<sup>85</sup> This collaboration allows for secure and efficient delivery of healthcare services. Furthermore, research by Abdullah, et.al., suggests that IoMT, particularly those using remote monitoring, empowers self-care and early diagnosis, significantly strengthening the healthcare ecosystem.<sup>86</sup> Despite evidence that the Internet of Medical Things (IoMT) and its supporting technologies can significantly improve healthcare by reducing medical errors, inefficiencies, and workflow issues, full integration of these systems within healthcare organizations remains a challenge.<sup>87</sup>

## Policy, Legal and Institutional Frameworks for Smart Cities

This section delves into the intricate web of policy, legal, and institutional frameworks that underpin the development and operation of smart cities.

### a. Sustainable Development Goals (SDGs)

Cities around the world are increasingly turning to data-driven approaches in their pursuit of becoming "smarter" and achieving sustainability goals.<sup>88</sup> This entails leveraging data to optimize urban operations, services, design, and policymaking, with the ultimate aim of enhancing both citizen well-being and environmental sustainability.<sup>89</sup> An OECD report underscores this trend, highlighting that most cities globally have implemented frameworks and policies targeting various sectors critical to the SDGs.<sup>90</sup> These sectors encompass water management, housing, land use, climate change mitigation and adaptation, transportation, and the economy.<sup>91</sup> Furthermore, researchers like Masuda, et.al., posit that cities, due to their inherent agility and innovation capacity, are better positioned than central governments to take significant actions towards achieving sustainability.<sup>92</sup>

However, despite the transformative impact of smart city initiatives on various aspects of urban life, a substantial body of research reveals a persistent challenge: the effective integration of

<sup>82</sup> Al-Rawashdeh et al., "IoT Adoption and Application for Smart Healthcare: A Systematic Review."2.

<sup>83</sup> Pantea Keikhosrokiani, Norlia Mustafa, and Nasriah Zakaria, "Success Factors in Developing iHeart as a Patient-Centric Healthcare System: A Multi-Group Analysis," *Telematics and Informatics* 35, no. 4 (2018): 753–75; Iuliana Chiuchisan, Hariton-Nicolae Costin, and Oana Geman, "Adopting the Internet of Things Technologies in Health Care Systems," in *2014 International Conference and Exposition on Electrical and Power Engineering (EPE)* (IEEE, 2014), 532–35.

<sup>84</sup> Al-Turjman, Nawaz, and Ulusar, "Intelligence in the Internet of Medical Things Era: A Systematic Review of Current and Future Trends."

<sup>85</sup> Al-Turjman, Nawaz, and Ulusar, "Intelligence in the Internet of Medical Things Era: A Systematic Review of Current and Future Trends."

<sup>86</sup> Amna Abdullah et al., "Real Time Wireless Health Monitoring Application Using Mobile Devices," *International Journal of Computer Networks & Communications (IJCNC)* 7, no. 3 (2015): 13–30.

<sup>87</sup> Riitta Mieronkoski et al., "The Internet of Things for Basic Nursing Care—A Scoping Review," *International Journal of Nursing Studies* 69 (2017): 78–90.

<sup>88</sup> Bibri and Krogstie, "The Emerging Data-Driven Smart City and Its Innovative Applied Solutions for Sustainability: The Cases of London and Barcelona." 3.

<sup>89</sup> Bibri and Krogstie, "The Emerging Data-Driven Smart City and Its Innovative Applied Solutions for Sustainability: The Cases of London and Barcelona." 3.

<sup>90</sup> OECD, "Achieving the SDGs in Cities and Regions. Promoting Local and Regional Development," 2022, <https://www.oecd.org/about/impact/achieving-sdgs-in-cities-and-regions.html>.

<sup>91</sup> OECD, "Achieving the SDGs in Cities and Regions. Promoting Local and Regional Development."

<sup>92</sup> Hiromi Masuda et al., "Exploring the Role of Local Governments as Intermediaries to Facilitate Partnerships for the Sustainable Development Goals," *Sustainable Cities and Society* 82 (2022): 103883.

sustainable development into smart city strategies.<sup>93</sup> Many current smart solutions deployed within these cities lack alignment with sustainability objectives.<sup>94</sup> This disconnect manifests in the gap between smart city targets and long-term sustainability goals.<sup>95</sup> This is particularly concerning given the well-documented potential of advanced ICTs, especially big data analytics and its applications, to propel smart cities toward a more sustainable future.<sup>96</sup>

Another layer of complexity arises when considering the implementation of SDGs at the city level. Sharifi, et.al., identify a fundamental challenge in this regard.<sup>97</sup> The SDGs were originally designed for adoption by national governments, and their direct application to city contexts presents difficulties.<sup>98</sup> Research by Berisha, Caprioli and Cotella and Koch and Krellenberg further emphasizes limitations in current indicators and targets for applying the SDGs, particularly SDG 11 (Sustainable Cities and Communities), to cities.<sup>99</sup> These studies propose frameworks specifically designed for measuring progress towards SDGs in urban environments, particularly focusing on SDG 11.<sup>100</sup>

Agenda 2030, with its framework of SDGs, embodies a global vision for sustainability, targeting both developed (Global North) and developing countries (Global South).<sup>101</sup> While countries like Germany have committed to the SDGs, successful implementation necessitates tailoring these goals to each nation's specific circumstances. For the SDGs to achieve their full potential as a truly global agenda, a crucial step involves adaptation by countries in both developed and developing contexts to their specific national and local situations. The broad goals outlined in Agenda 2030 provide a foundational framework but require further refinement and adjustments in indicators at the national and local levels. This process of "translation" is essential to ensure the SDGs are actionable and avoid becoming mere aspirational pronouncements.<sup>102</sup>

## b. General Data Protection Regulation (GDPR)

The burgeoning development of smart cities, while promising in its potential to enhance urban living, has raised concerns within the privacy and surveillance communities.<sup>103</sup> The European Union (EU) (2016) has addressed these concerns through the implementation of the GDPR, a robust legal framework safeguarding personal data.<sup>104</sup> In effect since 2018, the GDPR extends its reach beyond data storage within the EU, encompassing transfers of personal information for various purposes across

<sup>93</sup> Simon Elias Bibri and John Krogstie, "The Core Enabling Technologies of Big Data Analytics and Context-Aware Computing for Smart Sustainable Cities: A Review and Synthesis," *Journal of Big Data* 4 (2017): 1–50; Mattias Höjer and Josefin Wangel, "Smart Sustainable Cities: Definition and Challenges," in *ICT Innovations for Sustainability* (Springer, 2015), 333–49; Anna Kramers et al., "Smart Sustainable Cities—Exploring ICT Solutions for Reduced Energy Use in Cities," *Environmental Modelling & Software* 56 (2014): 52–62; Maria-Lluïsa Marsal-Llacuna, "City Indicators on Social Sustainability as Standardization Technologies for Smarter (Citizen-Centered) Governance of Cities," *Social Indicators Research* 128 (2016): 1193–1216.

<sup>94</sup> Hannele Ahvenniemi et al., "What Are the Differences between Sustainable and Smart Cities?," *Cities* 60 (2017): 234–45.

<sup>95</sup> Francesco Bifulco et al., "ICT and Sustainability in Smart Cities Management," *International Journal of Public Sector Management* 29, no. 2 (2016): 132–47.

<sup>96</sup> Eiman Al Nuaimi et al., "Applications of Big Data to Smart Cities," *Journal of Internet Services and Applications* 6, no. 1 (2015): 1–15; Margarita Angelidou et al., "Enhancing Sustainable Urban Development through Smart City Applications," *Journal of Science and Technology Policy Management* 9, no. 2 (2018): 146–69; Batty et al., "Smart Cities of the Future"; Simon Elias Bibri, *Smart Sustainable Cities of the Future* (Springer, 2018); Luís M A Bettencourt, "The Uses of Big Data in Cities," *Big Data* 2, no. 1 (2014): 12–22.

<sup>97</sup> Ayyoob Sharifi et al., "Smart Cities and Sustainable Development Goals (SDGs): A Systematic Literature Review of Co-Benefits and Trade-Offs," *Cities* 146 (2024): 104659.

<sup>98</sup> Sharifi et al., "Smart Cities and Sustainable Development Goals (SDGs): A Systematic Literature Review of Co-Benefits and Trade-Offs."

<sup>99</sup> Erblin Berisha, Caterina Caprioli, and Giancarlo Cotella, "Unpacking SDG Target 11. a: What Is It about and How to Measure Its Progress?," *City and Environment Interactions* 14 (2022): 100080; Florian Koch and Kerstin Krellenberg, "How to Contextualize SDG 11? Looking at Indicators for Sustainable Urban Development in Germany," *ISPRS International Journal of Geo-Information* 7, no. 12 (2018): 464.

<sup>100</sup> Berisha, Caprioli, and Cotella, "Unpacking SDG Target 11. a: What Is It about and How to Measure Its Progress?"; Koch and Krellenberg, "How to Contextualize SDG 11? Looking at Indicators for Sustainable Urban Development in Germany."

<sup>101</sup> Koch and Krellenberg, "How to Contextualize SDG 11? Looking at Indicators for Sustainable Urban Development in Germany."1.

<sup>102</sup> Koch and Krellenberg, "How to Contextualize SDG 11? Looking at Indicators for Sustainable Urban Development in Germany."5.

<sup>103</sup> Lilian Edwards, "Privacy, Security and Data Protection in Smart Cities: A Critical EU Law Perspective," *Eur. Data Prot. L. Rev.* 2 (2016): 28.

<sup>104</sup> G. Vojković and T. Katulić, "Data Protection and Smart Cities," in *Handbook of Smart Cities* (Cham: Springer International Publishing, 2021), 903–28.

borders.<sup>105</sup> This necessitates that Smart City initiatives in the EU grapple with how new technologies, such as the Internet of Things (IoT), video surveillance systems, and utility data collection, comply with the GDPR's regulations regarding the handling of vast amounts of personal data.<sup>106</sup>

The integration of the GDPR into smart city frameworks presents a two-pronged approach, addressing both cybersecurity threats from cyberattacks and the privacy of citizens within these intelligent urban environments.<sup>107</sup> Researchers have proposed various methods to ensure the security and GDPR compliance of Smart City (SC) systems.<sup>108</sup> One approach focuses on translating GDPR regulations into practical access control policies specifically designed for SC systems.<sup>109</sup> These policies can be derived directly from the GDPR itself,<sup>110</sup> or developed through intermediary frameworks.<sup>111</sup>

Further efforts to facilitate GDPR enforcement within smart city technologies (Smart ICT Systems) have yielded several proposals.<sup>112</sup> These proposals can be broadly categorized into three groups. The first category centers on utilizing access control mechanisms to safeguard personal data within the confines of Smart ICT Systems.<sup>113</sup> The second leverages a user's location information within the smart ICT system for both user authentication and data management purposes.<sup>114</sup> Finally, the third category aims to achieve GDPR compliance by exploiting specific security attributes inherent to the systems.<sup>115</sup> While all these proposals hold merit, they share a critical limitation: their inability to fully satisfy the demands of a privacy-centric and user-focused smart city architecture.<sup>116</sup>

## Challenges

The following section will explore the multifaceted challenges encountered during the implementation of innovative technologies within the evolving landscape of smart cities.

### a. Cybersecurity Risks and Data Privacy Concerns

Smart cities, with their promise of improved quality of life through enhanced services and infrastructure, are rapidly becoming a reality.<sup>117</sup> However, this progress comes with a significant caveat – security risks. One key concern highlighted by Khatoun and Zeadally is the integration of Information and Communication Technologies (ICT) into city infrastructure.<sup>118</sup> While ICT offers

<sup>105</sup> Vojković and Katulić, "Data Protection and Smart Cities."

<sup>106</sup> Vojković and Katulić, "Data Protection and Smart Cities."

<sup>107</sup> Said Daoudagh et al., "Data Protection by Design in the Context of Smart Cities: A Consent and Access Control Proposal," *Sensors* 21, no. 21 (2021): 7154.

<sup>108</sup> Daoudagh et al., "Data Protection by Design in the Context of Smart Cities: A Consent and Access Control Proposal."

<sup>109</sup> Daoudagh et al., "Data Protection by Design in the Context of Smart Cities: A Consent and Access Control Proposal."

<sup>110</sup> Cesare Bartolini et al., "Towards a Lawful Authorized Access: A Preliminary GDPR-Based Authorized Access.," *ICSOF 2019* (2019): 331–38; Farah Dernaika et al., "Accountability in the A Posteriori Access Control: A Requirement and a Mechanism," in *Quality of Information and Communications Technology: 13th International Conference, QUATIC 2020, Faro, Portugal, September 9–11, 2020, Proceedings 13* (Springer, 2020), 332–42.

<sup>111</sup> Bartolini et al., "Towards a Lawful Authorized Access: A Preliminary GDPR-Based Authorized Access.," Renato Carauta Ribeiro and Edna Dias Canedo, "Using Mcda for Selecting Criteria of Lgpd Compliant Personal Data Security," in *The 21st Annual International Conference on Digital Government Research*, 2020, 175–84.

<sup>112</sup> Al-Turjman, Nawaz, and Ulusar, "Intelligence in the Internet of Medical Things Era: A Systematic Review of Current and Future Trends"; Bharat Bhushan et al., "Blockchain for Smart Cities: A Review of Architectures, Integration Trends and Future Research Directions," *Sustainable Cities and Society* 61 (2020): 102360.

<sup>113</sup> Brian Greaves, Marijke Coetzee, and Wai Sze Leung, "Access Control Requirements for Physical Spaces Protected by Virtual Perimeters," in *Trust, Privacy and Security in Digital Business: 15th International Conference, TrustBus 2018, Regensburg, Germany, September 5–6, 2018, Proceedings 15* (Springer, 2018), 182–97.

<sup>114</sup> Jiang Haofeng and Gong Xiaorui, "Wi-Fi Secure Access Control System Based on Geo-Fence," in *2019 IEEE Symposium on Computers and Communications (ISCC)* (IEEE, 2019), 1–6.

<sup>115</sup> Christian Damsgaard Jensen, Kristine Geneser, and Ida C Willemoes-Wissing, "Sensor Enhanced Access Control: Extending Traditional Access Control Models with Context-Awareness," in *Trust Management VII: 7th IFIP WG 11.11 International Conference, IFIPTM 2013, Malaga, Spain, June 3-7, 2013, Proceedings 7* (Springer, 2013), 177–92; Maryam Davari and Elisa Bertino, "Access Control Model Extensions to Support Data Privacy Protection Based on GDPR," in *2019 IEEE International Conference on Big Data (Big Data)* (IEEE, 2019), 4017–24.

<sup>116</sup> Daoudagh et al., "Data Protection by Design in the Context of Smart Cities: A Consent and Access Control Proposal."

<sup>117</sup> Khatoun and Zeadally, "Cybersecurity and Privacy Solutions in Smart Cities."51.

<sup>118</sup> Khatoun and Zeadally, "Cybersecurity and Privacy Solutions in Smart Cities."

undeniable benefits, it also introduces potential security and privacy risks for both the city itself and its residents. This concern is echoed by Mylrea and Gourisetti who use the metaphor of a "double-edged sword" to describe smart buildings, a cornerstone of smart cities. While these buildings promise energy efficiency and economic advantages, their reliance on internet connectivity exposes them to cyberattacks.<sup>119</sup> This vulnerability stems from the interconnected nature of smart buildings, where automated systems and devices create multiple entry points for attackers. Such attacks can compromise critical building systems, posing a significant risk to public safety and well-being.<sup>120</sup>

Ma emphasizes the critical role of ICT in smart city infrastructure but also highlights its inherent vulnerability to cybersecurity threats.<sup>121</sup> These threats, ranging from data breaches to malicious attacks, can disrupt the normal operation of various smart city functions, potentially jeopardizing everything from traffic management to emergency response systems.<sup>122</sup>

Delving deeper, Zegzhda and Stepanova and Koliass, et.al., pinpoint the security weaknesses of Internet of Things (IoT) devices, a fundamental building block of smart cities.<sup>123</sup> These vulnerabilities allow attackers to exploit network infrastructure and communication channels for various malicious activities.<sup>124</sup> These activities include remotely accessing devices, intercepting data, launching denial-of-service attacks, and even building botnets of compromised devices to further amplify attacks.<sup>125</sup>

Adding another layer of complexity, Kalinin, Krundyshev, and Zegzhda identify the unique challenges posed by the very nature of smart city networks.<sup>126</sup> The vast number of devices from various manufacturers with different protocols creates a complex and ever-changing landscape.<sup>127</sup> This complexity makes it difficult to manage and secure the network effectively. Furthermore, Kalinin et al. highlight the challenge of keeping track of potential security risks as new devices are constantly added and removed from the network.<sup>128</sup> Effectively monitoring and securing such a dynamic system requires powerful computing resources and sophisticated software to handle the vast amount of data generated. The additional risk of outdated software with vulnerabilities further exacerbates the security challenges.<sup>129</sup>

## CONCLUSION

This article sought to explore the role of innovative technologies such as smart traffic management, smart buildings and smart healthcare in the development of smart cities. Innovative technologies have the potential to create a more efficient, sustainable, and citizen-focused urban environment. These technologies, like real-time traffic management and smart buildings, offer improved quality of life for residents. However, several key challenges must be addressed for smart cities to reach their full potential. These challenges include cybersecurity risks and data privacy concerns. These challenges may be addressed through the implementation of a robust legal framework safeguarding personal data.

While frameworks like the SDGs exist to integrate sustainability into smart city planning, more focus is needed to ensure these technologies are truly environmentally friendly. This could involve

<sup>119</sup> Michael Mylrea and Sri Nikhil Gupta Gourisetti, "Cybersecurity and Optimization in Smart 'Autonomous' Buildings," *Autonomy and Artificial Intelligence: A Threat or Savior?*, 2017, 263–94.

<sup>120</sup> Mylrea and Gourisetti, "Cybersecurity and Optimization in Smart 'Autonomous' Buildings."

<sup>121</sup> Chen Ma, "Smart City and Cyber-Security; Technologies Used, Leading Challenges and Future Recommendations," *Energy Reports* 7 (2021): 7999–8012.

<sup>122</sup> Ma, "Smart City and Cyber-Security; Technologies Used, Leading Challenges and Future Recommendations."

<sup>123</sup> Dmitry Zegzhda and Tatiana Stepanova, "Achieving Internet of Things Security via Providing Topological Sustainability," in *2015 Science and Information Conference (SAI)* (IEEE, 2015), 269–76; Constantinos Koliass et al., "DDoS in the IoT: Mirai and Other Botnets," *Computer* 50, no. 7 (2017): 80–84.

<sup>124</sup> Zegzhda and Stepanova, "Achieving Internet of Things Security via Providing Topological Sustainability"; Koliass et al., "DDoS in the IoT: Mirai and Other Botnets."

<sup>125</sup> Zegzhda and Stepanova, "Achieving Internet of Things Security via Providing Topological Sustainability"; Koliass et al., "DDoS in the IoT: Mirai and Other Botnets."

<sup>126</sup> Maxim Kalinin, Vasilii Krundyshev, and Peter Zegzhda, "Cybersecurity Risk Assessment in Smart City Infrastructures," *Machines* 9, no. 4 (2021): 78.

<sup>127</sup> Kalinin, Krundyshev, and Zegzhda, "Cybersecurity Risk Assessment in Smart City Infrastructures."

<sup>128</sup> Kalinin, Krundyshev, and Zegzhda, "Cybersecurity Risk Assessment in Smart City Infrastructures."

<sup>129</sup> Jesse Edwards, Ameer Kashani, and Gopalakrishnan Iyer, "Evaluation of Software Vulnerabilities in Vehicle Electronic Control Units," in *2017 IEEE Cybersecurity Development (SecDev)* (IEEE, 2017), 83–84.

prioritizing renewable energy use and resource efficiency in smart city development. It is of paramount importance to address these challenges, in order to unlock the true potential of smart cities and create a future where technology improves the lives of urban citizens while safeguarding their privacy and the environment.

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#### **ABOUT AUTHORS**

Kagontle Selwe is a Professor and Founding Research Director of the Afrocentric Governance of Public Affairs at North-West University.

Costa Hofisi is a Professor and Founding Research Director of the Afrocentric Governance of Public Affairs at North-West University.