This paper was presented at the 20th International Conference on Sustainable Development, Future Africa Campus, University of Pretoria, Pretoria, South Africa on December 3-4, 2024

Sustainable urban management through digital transformation and technologies in the South: Challenges and prospects

Taiwo Afinowi [1,2]
[1] Public Policy Hub, Department of Economics, University of Pretoria, Hatfield Campus, Pretoria, South Africa.
[2] Department of Architecture, University of Pretoria, Hatfield Campus, Pretoria, South Africa
[1] Corresponding author: taiwo.afinowi@up.ac.za

OIDA International Journal of Sustainable Development, Ontario International Development Agency, Canada.
ISSN 1923-6654 (print) ISSN 1923-6662 (online) www.oidaijsd.com
Also available at https://www.ssrn.com/index.cfm/en/oida-intl-journal-sustainable-dev/

Abstract: Traditional urban management plays a critical role in urban governance, addressing the increasing urban challenges relating to urban housing, land, infrastructure, services, and livelihood using policies, principles, specialised tools, and programmes. With increased urbanisation and population growth, the pursuit of sustainable development brings about complex challenges in planning and managing primary and secondary cities towards sustainability and efficiency. With urban centres and cities being a scramble point for shelter, employment, mobility, and access to quality health and education, urban managers are posed with a significant challenge in making predictions, planning, and managing cities timeously with updated information in real-time for better efficiency. These challenges have resulted in the development of various city concepts leaning on sustainability, innovation, information and communication technologies to better manage urban centres and cities. Despite developing various urban management approaches, smart city concepts and agendas, many Southern cities and even the North grapple with complex urban problems. The question thus arises: how can digital technologies and innovations be used in a sustainable way to improve traditional urban management in the cities of the South, considering their peculiar challenges? Following the broad paradigm of cognitive cities theory and smart governance theory, this paper explores the challenges and prospects of leveraging technological advancements in managing cities and improving urban management. While extensive structured and unstructured urban data are collected occasionally in silos by companies and municipalities, these data sets are not integrated to influence planning and management when they are processed. This article concludes that an integrated digital approach to urban management offers new sustainable pathways to address the planning, development, governing, monitoring and maintaining of cities using the Internet of Things, machine learning, remote sensing, drone technology, and other innovative practices.

Keywords: fourth industrial revolution, digital transformation in cities, digital twins, smart cities, sustainable urban management

Introduction to urban management and challenges in the South

Urban management is an essential aspect of human existence which constitutes planning and the implementation of those plans, policies, and strategies within an urban ecosystem to achieve continuous optimal living standards and conditions [1,2]. Karlenzig et al.assert that cities of the South are struggling on a daily basis to “meet daily operational needs while at the same time investing in the future – all with limited financial resources…(and are faced with) how to provide essential services–including housing, energy, water, sanitation, health and education--to meet the basic needs of an ever-growing population” [3: p. 1]. It is important to note that the world urban population has risen from “751 million in 1950 to 4.2 billion in 2018”, representing a leap from 30% to 55% respectively, and expected to reach about 5.2 billion in 2050 [4: p. 2]. The expected growth towards 2050 will be pioneered by China, India, and Nigeria, which comprise 35% of the urban populace (*ibid*.). Also, over “50% of the global population, expected to reach 9.7 billion by 2050”, will be concentrated in eight Southern countries, namely “the Democratic Republic of the Congo, Egypt, Ethiopia, India, Nigeria, Pakistan, the Philippines and the United Republic of Tanzania” [4: p. 2]. These figures imply that for cities of the South to remain efficient and sustainable in line with social and public service delivery, there is a need to optimise the urban infrastructure and management to accommodate human additions and other socioeconomic challenges [5]. While many Northern cities have managed their housing and infrastructure issues with increased data investment, the reverse is the case for many Southern countries with rapid urbanisation and problematic urban management [6]. The more cities become predominantly urban, the bulk of the pressure goes to the city officials and the built environment professionals to devise new strategies and innovations to combat the ills of urbanisation and meet the demands posed to the city or municipality [7]. The 2024 United Nations report stating that the member nations globally have only achieved about 17% of the 2030 Sustainable Development Goals is an indication of a crisis in achieving a sustainable world [8].

To manually and effectively manage urban issues requires practitioners to plan, organise, and ensure human capacity and resources to lead the various functions and lead and control the urban components and infrastructure [2]. According to McGill, urban management aims to "plan for, provide and maintain a city's infrastructure and services, and secondly, to make sure that the city's government is in a fit state, organisationally and financially, to ensure that provision and maintenance" [10: p. 463]. Devas and Rakodi state that urban management consists of municipal planning, town planning and economic development planning [11]. The significance of this statement is that urban management is closely related to planning in terms of the "design, growth and management of the physical environment, in accordance with predetermined and agreed policies, whereby balanced social and economic objectives may be achieved" [12: p. 42]. In their summation, they pointed out that while urban planning focuses on the preparation of projected land use and spatial urban development, urban management deals with the day-to-day running of public services across all sectors and ensuring law and order with the protection of life and properties[11]. Achieving urban management within the broad urban planning paradigm is done within the control of politicians (the executive), urban-city officials with different portfolios, and the confines of the legislature policies that govern urban centres and cities.

However, with rapid urbanisation and global challenges, there are limitations to what traditional urban Management (UM) tools and practices can achieve in cities, especially where there is an urgent need to act fast. For instance, there is a limit to what urban managers can do 'manually' and timeously when there are societal issues requiring urgent attention, climate induced disasters and other force majeures. The truth is that changes are happening very fast, and the nature of these changes does not always follow a predictable pattern, especially with the impact of climate change and all forms of migration [12,13]. The need for urban managers and politicians to respond to increasing urban demands and challenges has led to several UM practices and approaches. Also, there has been the optimisation of these practices through various smart city concepts and infusion of digital innovations and technologies. This study is grounded within the broad paradigm of cognitive cities theory and smart governance theory. Cognitive cities theory is founded on the principles of smart cities where there is reliance on advanced digital technologies and living city is optimised by a process of learning, adapting, and evolving based on the requirement of the city [14–16]. Through artificial intelligence and computer learning, it follows an adaptive learning process with focus on urban data to make informed decisions to serve the citizen [17]. Cognitive cities theory promotes interaction between human intellect and digital techniques to achieve efficient smart cities. Also, smart governance theory is based on the use of smart data-driven information to make decision to address the complex inter relationship between the various urban sectors and governance demands [18]. This article explores the influence of digital transformation on UM with digital tools towards achieving efficient, smart and digitalised cities. This article is structured in five parts: the first part explores the complexity of UM practices, and the second part looks at the historical and current UM approaches. The third part explores the technological and digital transformation journey and the various applications. The fourth part looks at the holistic application of digital transformation for UM and lastly, the implication of adopting digital transformation and technologies into urban management.

Cities and complexities around urban management practices in the South

According to the United Nations (UN), "cities have become a positive and potent force for addressing sustainable economic growth, development and prosperity, and for driving innovation, consumption and investment in both developed and developing countries" [19]. Similarly, Hardoy and Satterthwaite along with other scholars have emphasised that *"Cities have become centres where vast numbers of people compete for the most basic elements of life: for a room within reach of employment with an affordable rent, or vacant land on which a shelter can be why don without fear of eviction; for places in schools; for medical treatment for health problems or injuries, or a bed in a hospital; for access to clean drinking water; for a place on a bus or train; and for a corner on a pavement or square to sell some goods—quite apart from the enormous competition for jobs"*[21–22, 23: p. 301]. As a result of the city's many potentials, people migrate to urban centres and cities in search of juicy opportunities, better living conditions, and personal preferences. The continuous migration from rural and non-urban centres puts much pressure on the cities to accommodate the influx, thus requiring efficiency, sustainability and smart cities all over the globe. UM through city services and quality of life monitoring in urban centres are benchmarked against 19 sectors according to the International Organization for Standardization (ISO) 37120:2018 on sustainable cities and communities. These sectors are governance, urban planning, health, housing, urban/local agriculture and food security, safety, transportation, population and social conditions, economy, energy, education, environment and climate change, solid waste, waste, wastewater, recreation, finance, telecommunication, and sport and culture. The traditional UM forms an integral part of urban governance towards addressing daily increasing urban challenges relating to these sectors using policies, principles, specialised tools and programmes [23,24]. Kiani et al. (2013) emphasise that UM must deliver sustainable urban development goals for cities across various sectors and dimensions [26]. The failure or the success of cities in terms of liveability rests upon UM when cities are appraised as complex socioeconomic, environmental, and political systems. Cities within the built environment are complex systems likened to human metabolism, exhibiting the ability to breathe, respond to positive and negative stimuli, grow, develop, and produce waste [27]. The complexities require interactions at different levels of production and consumption with the systems, which include but are not limited to housing, transportation (road, rail, air, sea), biodiversity, environmental services (water, waste, sanitation), public services (healthcare, education) and public infrastructure (power, roads). One critical point of emphasis is that all these sectors and systems work together simultaneously and are interrelated. One way of addressing many sectoral and urban challenges is through integrated urban management (IUM); however, there are issues relating to time, governance, politics, and capacity for cities and municipalities [6,28–30].

Each system or sector within the city possesses peculiar management strengths and challenges depending on the city's scale, nature, size, available resources, and technical expertise on the part of the urban managers and public officials considering the population. Also, “while megacities have long dominated the urban conversation and will continue to play a prominent economic role, most of the future urban growth will occur in small, intermediate and secondary cities” [32: p. 116]. Thus, there is a need to pay attention to how smaller and growing cities are managed. Again, with upcoming small, intermediate and secondary cities worldwide, there will be a need for more capacities and resources, new expertise, new urban infrastructure and most importantly, the devising of clever ways of managing new challenges and devastating effects of climate change and other societal vices. Due to smaller capacities and space, the use of advanced technologies can be easily applied to smaller and upcoming cities to address issues around systems and sub-systems of the city’s socio-ecological systems at varying scales.

Another critical challenge with the UM is keeping up with social-economic, environmental and political changes as they occur in urban environments using the multi-sectorial governance approach of dealing with issues or sectors in isolation. At the barest minimum, UM involves day-to-day running and supply of physical infrastructure (water, sanitation, waste management, power supply and transportation, be it by road, rail, water or air); social infrastructure (education, healthcare services, social services/regulation such as recreational/sporting, court, security and law enforcement); entrepreneurial infrastructure (banking/financial services, legal services, private sector regulation/operations); environmental management, land use development, development planning, implementation and monitoring. UM in Southern cities becomes more complicated due to the unpredictable nature of frequent changes and service disruptions, which affect the effective functioning of systems [32,33]. Also, these cities lack adequate financial and human resources to address rising social and technical issues, such as housing, power supply and infrastructural maintenance.

In addition, these cities experience intra and inter-migrations comprising different racial and cultural values with political undertones [32]. Most cities and municipalities in the global South are underfunded and under-capacitated to address development challenges [34]. For instance, many South African and other African cities are defunded due to service delivery issues in human settlements [34]. While projects imbibing technological innovations in the global North develop “data platforms and sensor networks based on mature institutions and well-developed infrastructures, Southern cities such as Jakarta are characterised by rapid urbanisation, weaker institutions, a lack of resources, and poorer public services” [36: p. 1566]. Moreover, unlike their highly regulated Northern cities, cities in the global South are shaped predominantly by informal economies and improvisation practices that negatively impact local institutions. While there is nothing wrong with the informal economy driving urban development and management, the problem lies in the discrimination by the elite class [36,37]. Furthermore, a modern-day challenge in these cities is the lack of precise data to plan and manage urban issues. For instance, many African countries have porous borders, and most censuses carried out by their government are outdated [38,39]. Hence, it becomes extremely difficult to manage cities when the figures available are based on mere projections or estimates. It then becomes a significant problem to adequately plan for adequate housing, power supply, education, water supply and sanitation, healthcare facilities and other societal needs. Again, these recurrent challenges persist despite inadequate financial and human resources to meet the growing population.

In addition, many cities have adopted the United Nations 2015 Sustainable Development Goals and 2016 New Urban Agenda to achieve inclusive, resilient and sustainable cities, however, their management operations still follow old practices, and they are struggling to meet the targets [8]. Particularly for Sub-Saharan Africa and some parts of Asia, understanding of the urban environment, urbanisation and social indices remains a mirage with the same problems of the 20th century manifesting in different dimensions in the 21st century [40–43]. While these challenges seem prevalent in the South, the Northern counterparts are not exonerated from the wicked and complex problems with the need to optimise UM. Furthermore, the morphology of cities has changed considerably with the impact of local and international migrations, with more pressure on both primary and secondary cities [44–46]. As often observed and stated in the literature, the cities have become a scramble point for opportunities, which consequently significantly impact urban governance and management of people, services, and infrastructure across various sectors [47–49]. The next section looks at the historical UM approaches and policies.

Urban management approaches and policies in history

There has been a lot of local, national and global approaches, policies and 'good' practices proffered to urban managers to address effective and efficient urban planning, governance and management [28,48,50–54]. Despite extensive solutions and research into the relationship between urban growth and challenges within urban centres, no viable solution has been proffered to holistically address all the urban sectors in real-time. Similarly, there have been formulation and resolutions at the international level through the United Nations Human Settlements Programme (UN-Habitat) and allied organisations, however, the urban challenges and management issues persist [28,54,55]. As far back as the early 1990s, Mabogunje, stated that many cities in sub-Saharan Africa are very weak due to their inability to respond to changing city dynamics; instead, they cling to traditional practices and bureaucracy inherited from colonial legacy in city management [56]. For instance, as highlighted above, many African cities cannot provide or sustain timely essential service provision to their citizens, such as portable water, sanitation, and effective waste management. Unfortunately, despite rapid urbanisation, UM practices have not changed much in response to complex problems. He also noted that many municipalities or local governments suffer from institutional radicalisation to address growing urban issues facing the cities. Institutional radicalism refers to "changed processes which seek to preserve the obvious forms of existing institutions while radically transforming their substance; that is, to change processes which do not immediately abolish and replace forms of behaviour but circumvent them in a manner to make them more accommodating of new rules while still deriving advantages from the enforcement characteristics of the institutions" [58: p. 16]. So, despite many institutions having a modern facelift with borrowed planning and management ideas globally [58], they still hold on to traditional UM practices that do not acknowledge urban reality and socioeconomic status (*ibid*.).

Despite the increasing urban challenges, UM practices have undergone different phases across developing countries post-Second World War when there was a need to rebuild many places with the interventions of specific institutions. Some of these institutions are the World Bank, the UN Development Programme, the UN Housing, Building and Planning Committee, the UN Human Settlement Foundation Committee, and the UN Centre for Human Settlements, which later metamorphosed into the UN-Habitat [59–61].

Phases of urbanmanagement

The first phase of UM practices was dated pre-1972 when the World Bank focused on advancing development loans to finance various infrastructural projects in Africa and other developing countries. The second phase occurred between 1972 and 1982 when the focus shifted towards addressing urban challenges of poor human settlements with the popular scheme of 'site and services and slum upgrading' [43,62]. The next phase extends from 1982 to the early 1990s, where the approach was towards integrating projects across different sectors beyond focusing on the urban poor. The concept gained prominence in urban issues, governance and policy-making with the formal launch of the Urban Management Progroamme (UMP) by the World Bank and allied organisations in 1986. Remarkably, the UMP highlighted the importance of UM in human settlements and its contributions were directed towards social development, addressing poverty, economic growth and improved urban governance [63]. These periods saw the promotion of globalisation, neoliberal urban policies with heavy investment by the government of many countries in urban developments and the death of Keynesian state welfarsim in urban issues (*ibid*). UMP's direct pursuit and approach partially ended in late 2000 due to emerging issues in global development trends. While the World Bank promoted redevelopment policies and infrastructural developments through various financial products and loans advanced to developing countries, the UN-Habitat and United Nations Development Programme (UNDP) were promoting agendas addressing the ills of rapid urbanisation and underdevelopment beyond housing and human settlements.

Apart from different UM approaches, concurrent global urban development frameworks impacted housing and human settlements. For instance, there were the Healthy Cities Movement in the 1980s, the need for global sustainable development through the 1987-Our Common Future, and the notable vigintennial conferences (1976, 1996, 2016) by the UN-Habitat [64]. The World Bank and allied institutions promoted participatory budgeting, co-production at scale and bottom-up urban development in the 1990s. The 1992 Rio de Janeiro Conference, through the Agenda 21 birth goal setting, significantly impacted how urban areas are managed considering social, economic, environmental and political sectors [65,66]. As a result of many challenges at that period, the 'Global Campaign for Good Governance' was also promoted in 2001. By the early 2000s, there were the Millennium Development Goals, the 2015 Sustainable Development Goals and the Wider Agenda 2023 (*ibid*). While these goals and agendas were multisectoral, they also focus on specific sectors that impact UM in the cities. Pertinently, despite the changing nature of how the concept of UM was viewed or promoted, it remained an essential part of urban governance and human settlements towards ensuring the daily running of urban affairs to keep the society in equilibrium.

As a result of the enormous sectors and importance of UM towards maintaining ecosystem balance in cities and human settlements, many scholars and practitioners have advocated for an integrated urban management (IUM) approach [9,30,67–69]. IUM, through various principles and concepts, seek to build a more liveable, sustainable, and resilient urban environment that encourages citizens' well-being and economic growth and prosperity [69]. While IUM acknowledges that urban ecosystems are complex with interconnected sectors and tackling the issues necessitates a holistic approach, this approach becomes limited with urbanisation and the need to address challenges without waiting for governmental bureaucracies. For instance, Domingues et al. state that "the multilevel coordination (public-private, state-municipalities and parish-municipalities) configures still a fragility of the integrated public management, which should be addressed" [31: p. 67]. In the case of the Ethiopian Government, it was acknowledged that general urban managers cannot manage the "increasing complexity of urban problems [68]. This management issue shows that there is a need for specialised human capacity to address the complex problems related to UM due to the many sectors involved and the changing urban issues. Furthermore, while the IUM concept is promoted like other neoliberal urban policies by the likes of UN-Habitats and UNDP [9], Salari and Ahmadabadi lament that environmental, legal and decision-making challenges impede local governments' UM [9,70]. It goes to affirm that UM is a complex venture that requires decisive and modernised approaches with respect to challenges affecting cities. In all the challenges confronting UM, technology and digital transformation present an avenue to capture reality, make informed decisions, predict and manage physical and environmental issues. The next section explores technological applications in UM.

Journey into technological and digital transformations for urban management

Over the years, the world has transcended into different industrial revolutions to address the interphase between humans, labour, technology, and production to aid human existence. The transition started from using steam power to mechanise production lines in the first era to using electricity to fast-track the production of commodities and services in the second industrial revolution [71,72]. By the third era, there were computer programmes written to automate what humans will naturally do at a faster rate in a controlled environment. And now, in the age of the Fourth Industrial Revolution (4IR), the discussion centres around full automation, quantum computing, the internet of things (IoTs), machine learning, artificial intelligence and a lot more on the use of smart and innovative technologies to solve human and non-human challenges [71–73]. As it is currently known, the internet is undergoing significant transformation as we journey into the 4IR in an automatic response world as opposed to human control of issues in specific sectors [74]. The 4IR and the technologies available raise a concern around how practitioners in various fields, including the built environment, continue to do things normally in the analogue way when there are smarter machines and innovative systems that can deliver better, faster, and more efficient results. The use and adoption of digital transformation transcends many sectors, with every industry consistently outperforming itself towards greater efficiency, be it health, infrastructure or service provision. As shown in Figure 1, the world has transcended from the use of ancient mainframe large computers from the 1960s through the world-wide-web space and mobile devices to present-day intelligent technologies with the inert ability to read, respond, react, sense, store and transmit data remotely and in real-time [75,76].

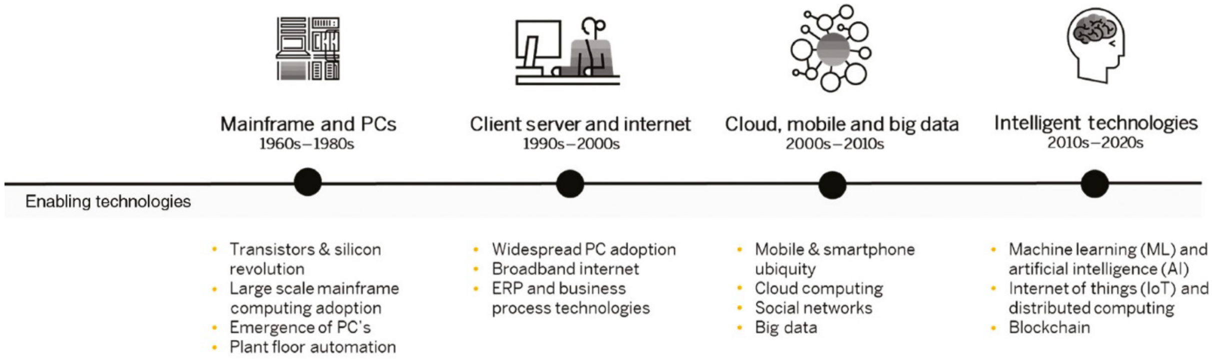

Figure 1: Evolution of Information Technologies (IT) from the digital era into the intelligence era [77].

Vial points out that digital transformation is a complex phenomenon where an entity is optimised through digital technology, considering its structure, culture, strategies, and processes to create a new value path [78]. It employs the infusion of digital technologies and strategies beyond disciplines to optimise an organisation's products, services and performance towards greater efficiency [78–80]. It entails fully exploiting innovative advancement in the industrial revolution to modify business operations, products, models and capacities to maximum benefit (*ibid*.). One critical element in the operations of digital transformation is to cause disruptions in the ways processes are carried out by infusing various digital technologies, which may be social in nature, mobile, analytics, cloud-based, and IoTs in line with the 4IR [81]. It substantially disrupts normal processes, giving rise to added values. This implies that it totally changes the business ontology to new forms of knowledge and sometimes unplanned better outcomes [78,82]. These changes are significant in the way technology innovations and strategies are used to revolutionise UM. For instance, the use of digital twin city (DTC) technology in the UM of cities such as Singapore, Wellington and Helsinki have shown that cities can be digitally replicated, managed, governed, and controlled in real-time [83–85]. With digital transformation, UM can be disrupted with better efficiency and management approaches, as evidenced by the digital twin city technologies.

Kraus et al. (2021) pointed out in their work that certain elements are responsible for these disruptions in modern digital transformation across concepts [87]. Firstly, the 4IR is highly enabled by the IoTs in terms of the interconnectedness of objects, systems and processes. Secondly, with artificial intelligence, cyber-physical systems are optimised with autonomous control, and they can function flawlessly with or without direct human involvement. This is a significant shift in management systems requiring hands-on monitoring and management. Lastly, these systems can handle big and multiple data irrespective of the structure, speed and size without crashing the entire system. Putting into consideration and combining the daily datasets coming from the environment, traffic, air quality, water, waste and other city sectors (tax and administrative data), this will go a long way in making an informed decision as well as good input for urban planning. This is because cyber-physical systems can be trained using machine learning, and the data can be identified, sorted, analysed and categorised to perform specific tasks. The importance and impact of digital transformation were invigorated with the COVID-19 pandemic across all fields and works of life with the disruption of traditional ways operations were performed. During the pandemic in 2020, despite the global advice on 'stay at home', UM was hampered in many regions. Still, planning and implementation of urban strategies were heightened with technological interventions [88]. Many physical activities relating to work and the academic environment were moved to cloud space with the introduction of new protocols.

While the global North is making remarkable progress with digital transformation, the global South and especially African countries, are lagging in leveraging digital technologies and innovation[89]. In the same way, the UN has acknowledged the urban divide regarding poverty and inequality, there is also a digital divide and inequality across the globe when it comes to adopting new technologies and innovations to address urban challenges [90]. While it may be expensive to digitalise many cities or municipalities, cities may adopt a phase-by-phase approach where digital transformation tools and applications can be introduced into the UM sectors, and these sectors can be optimised gradually. The next section presents the broader integrated frame of adopting these applications holistically beyond individual sectors, highlighting the challenges and human limitations affecting UM and the journey into digital transformation.

Digital transformation applications in urban management in cities

This section explores different approaches to addressing UM deficiencies beyond sectoral approaches with applying 4IR/ digital transformation concepts, tools and applications. According to the UN-Habitat, "many cities have struggled to appropriately plan, prepare for and manage the impacts of the (COVID-19) pandemic (which) is a clear indication of the inadequacy of current models and paradigms of urban planning and design that guide urban development in many parts of the world"[91: p. 181]. While many cities struggled with urban management practices, the pandemic further exasperated this struggle with the call for city and urban managers to rethink decision-making and deliver efficient and timely services based on accurate data. Table 1 shows endless possibilities of how digital transformation applications can be incorporated into urban management practices across the sectors. There are endless possibilities for artificial intelligence and machine learning to optimise operations and urban management. As part of a project where a digital twin city is explored in Hatfield Pretoria, physical evidence with sensors and other digital technologies, digital transformation offers limitless opportunities to manage the built environment. However, it requires heavy financial investment and capacity development.

Table 1: 4IR/ Digital transformation concepts, tools and applications

	ISO Urban management sector	**4IR/ Digital transformation concepts, tool and applications**	**Sources**
1	'Urban' Governance	Smart governance/e-governance Social, Mobile, Analytics, Radical openness, and Trust (SMART) components	[91–94]
2	Urban Planning	Smart cities, digital twin cities, virtual cities, Platform urbanism Urban informatics, Urban cybernetics Geographic Information Systems Decision Support Systems Planning support systems Expert Systems Early detection warning systems	[77,94–101]
3	Health	Biometrics Access to e-health Wearable technology Telemedicine/ virtual doctor visit Remote surgery/ telesurgery Electronic patient reported outcomes. Electronic health records Digital imaging E-prescription services Enterprise resource planning systems In patient monitoring Clinical Operation Connected imaging medication management. Digital laboratories	[96,102–104]
4	Housing	Airbnb Rental property technology Building information modelling (BIM) City Information Model (CIM) Facilities management Smart and efficient buildings Material passport & databanks Scan to BIM Building energy models Digital twinning Open BIM for building supervision	[98,105–109]

		3D printed technology Lean-agile integrated building construction Concrete technology Monitoring of greenhouse gases in buildings	
5	Urban/Local Agriculture and Food Security	Agricultural digitalisation Global positioning systems Unmanned aviation systems Agriculture Biosensors Farm robotic systems Electronic nose/ Digital disease control Improved food supply chain Robotics aquaculture Robotics farm harvesting Biosecurity Drone farm management Digital Farm Equipment Smart farming systems Virtual animal fence Smart dairy	[110–113]
6	Safety	Digital identity passport Facial recognition Building automation and control systems Home automation system or Building automation systems Fire protection systems Video surveillance Real-time visualisation Electronic evidence Device placement for intrusion detection Digital urban policing Urban digital twins Video digital twins for safety and security Smart alarm systems Natural disasters Smart warning systems Agile monitoring Digital access control systems Automated fire safety codes Building automation systems Fire protection systems, Natural disaster protection systems, Intrusion detection systems, Indoor air quality systems, Antiburglary systems Digital locks	[104,114–116]
7	Transportation	Smart mobility concept Intelligent transportation systems Smart grid initiative, E-hailing rides Autonomous vehicles Autonomous aircraft piloting Autonomous air taxis Google Map applications Smart parking solutions Connected vehicles Automatic detection of number-plate traffic infractions	[96,117–121]

		Electronic wayfinding and journey planning Intelligent transport systems Blockchain for transportation Electric and sustainable transportation	
8	Population and Social Conditions	Digital identity Digital economy Digital performance rating Smart city initiative for quality of life Social media revolution Care robots in public places Social welfare technology Shower robots Safety bracelets Online dating platforms	[104,122,123]
9	Economy and Finance	E-commerce and online marketing Online payment solutions Digital payments Mobile banking apps Blockchain and cryptocurrencies Fintech and digital banking Digital marketing Digital economy Digital finance Blockchain technology	[123]
10	Energy	Energy information management, Lighting control systems Energy management systems Renewable energy integration Energy smart metering Energy efficient buildings Smart grids Smart meters Urban energy dashboards Load shedding apps Predictive maintenance	[89,116]
11	Education	Gamification of education Learning management systems Online learning/virtual classrooms Artificial intelligence tutors Augmented and virtual reality learning Digital skills	[123–125]
12	Environment and Climate Change	Generative AI systems and sensors Carbon footing tracking Climate modelling and simulation Environmental monitoring Sensors	[96,126–128]
13	Solid Waste, Waste and Wastewater	Smart waste management Smart trash bins Mobile Automation Self-driving sweeping vehicles Digital waste tracking system Automatic sorting bins Waste robotics sorter	[126]

Source: Authors

From a non-exhaustive compilation of the digital transformation concepts, tools and applications, it is argued that a digitalised integrated urban management approach should be at the centre of urban policy to address multifaceted challenges affecting primary and secondary cities in the South. To meet these huge demand and expensive venture of managing cities, Brandt et al. state that "city governments and urban businesses are increasingly turning to information technology and systems as a way to make cities more efficient, sustainable, and resilient…(with) various initiatives seek to bring stakeholders together and leverage digital means for improving urban life" [130: p. 193]. The need to achieve efficient running of the cities, sustainable development and achieve all the objectives of smart sustainable urban management has historically led to the formation of various concepts and approaches [130–132]. Some of these concepts include smart cities, intelligent cities, digital cities, techno cities, hybrid cities and digital twin cities, which is the most advanced technological innovation to manage cities in real-time with multiple options. Pacione (2009) also highlights city concepts towards achieving sustainable development or high efficiency for future cities, emphasising ecologically friendly and 'tech' cities [133]. Notable among the concepts are the green or eco-city, close to the ecological or natural environment to achieve urban sustainability in line with climate change issues. Qin and Qi (2021) and Ringenson et al. (2018) alluded that the smart city concept came about as a solution to look for 'smarter' ways using information and communication technology (ICT) to address urban challenges, especially with demands related to urban and population growth [89,92].

As highlighted above, city officials and managers use many approaches to manage urban centres. With the introduction of some technological gadgets and innovations, there have been many misconstrued understandings of smart cities and other related concepts in recent years. For instance, the availability of digital images and navigation maps on digital applications does not necessarily make a city smart. For instance, because drivers can use Google Maps to navigate the city, commuters hail rides with Bolts or Uber, or a citizen can purchase an item online, it does not 'necessarily' imply that the city is smart. As rightly pointed out by Watson, we have many 'smart cities', 'eco-cities' and urban fantasies springing up, which use these concepts as a buzzword to 'imitate' world-class cities to connote greater city efficiency [134]. Many politicians and real estate actors have perfected the act and art of using smart or digital suffixes to the name of cities as a manifesto or promotional tool without these cities meeting the expected standards. For instance, how comparable are Wellington City or Singapore City in terms of smartness to cities such as Tatu City-Nairobi, Konza Techno-Nairobi, Eko Atlantic City-Lagos, or Waterfall City-Gauteng? The latter-mentioned cities are still in their developmental state and cannot boast of efficient urban management smartness to address the ISO urban management sectors mentioned above. These approaches to UM have not yielded the expected result because the conception and the political will to actualise 'smarter cities and digital cities' are fraughted. It has equally observed from literature where planning through development plans, strategic plans, national developments and even 'sustainable' urban development plans are used to manage city growth and services. Again, while these plans and approaches are great, they do not improve urban management and governance.

While there is no clear-cut definition for smart cities, different authors have tried to define smart cities regarding urban management, while others have used certain terminologies mentioned above. Hall *et al.* described a smart city one "that monitors and integrates conditions of all of its critical infrastructures, including road, rail/subways, airports, seaports, water, power, …buildings, (that) can better optimise its resources, plan its preventive maintenance activities, and monitor security aspects while maximising services to its citizens" [136: p. 1]. These descriptions in terms of ICT usage, technologies, monitoring and governance for the benefit of the citizens do not match urban fantasies in naming smart cities in southern cities. However, beyond the misconception of smartness in cities, it offers a great deal in addressing daily urban management concerns and challenges.

Implication of digital transformation and technologies for urban management in the South

In answering the key question above, Table 1 has proven to urban managers that there are endless opportunities to apply various technologies to address urban management challenges in contemporary primary and secondary cities. The question of whether cities can be transformed and managed by digital transformation has been answered by examples of cities like Wellington and Singapore [83,84]. These cities use digital platforms and dashboards to monitor the urban centres in real-time with data and information so that the authorities can make informed decisions. To achieve similar feats in the South, city and urban managers must accept and face the disruption digitalisation and digital transformation bring to urban management [78,136]. This requires changing old practices and approaches by embracing machine learning, artificial intelligence, and other innovative ways of urban management. As Mabogunje argued, urban and city managers should seek to avoid institutional radicalisation and explore best management planning and practices where these technologies have worked [57,137,138]. Particularly, practices and approaches that embrace IUM, urban sustainability, improved quality of life, less dependence on human resources and efficient urban management. Also, beyond the many benefits of digital transformation in cities, these technological advancements and innovations can be incorporated with indicators and used to monitor the implementation of the SDGs and the Wider Agenda 2030. The truth is that this urban transformation will come with its own huge cost, training and high investment in data and various technologies [139,140]. Also, there will be the need for urban planning and policy reforms with the support of politicians to see that it works and that there is continuity. The opportunity cost of transforming our cities with innovative and digital tools is in envisioning better planned, managed and efficient Southern cities.

The incorporation of digitisation in urban management practices for the cities of the South offers extensive pathways to sustainability and efficient cities [141]. While many countries in the South are lagging behind with census, the combination of remote sensing, data from telecommunication services providers and other government administrative data can aid development planning [38]. Firstly, urban planning, governance and management will be greatly enhanced through SMART components and e-governance, which will cover up all human deficiencies highlighted above. This will considerably reduce the pressure and weight of urban managers and city officials. Either through monitoring of dashboards or machine learning through artificial intelligence, city demand and supply for water, energy, and waste management can be efficiently managed[142,143]. Secondly, decision making will be faster and enhanced through accurate data [76]. Thirdly, adopting digital platforms to enhance urban management will aid sustainability and attainment of the United Nations SDGs with the targets and indicators. Particularly, city and country reporting of targets can be monitored in real-time [141,144]. Also, adverse effects of climate change and environmental disasters can be reduced significantly towards safety with the safety tools and technologies. With respect to climate change and greenhouse gases, safety and planning tools in Table 1 can help to monitor and reduce activities of humans towards Paris Agreement [145]. It is pertinent to note that incorporating digital transformation in urban planning and management becomes significant enabler of realising and monitoring the SDGs. Thirdly, imbibing digital transformation will also help to reduce the digital divide in the South, improve citizen participation and engagement in governing the city, and equally provide inclusive planning platforms [146–148]. In the case of Wellington digital twin, the citizens were co-planners with the government in developmental projects and they were able to give feedback on issues affecting the communities [84].

Digital twin cities (DTC) offer UM "a large-scale deployment of multifunctional information facilities and intelligent gateways that support various distance communication protocol standards" in real-time [77, 141: p. 129]. While smart cities use ICT and IoT-enabled devices to optimise the operational efficiency of city services for the benefit of the citizenry, DTC provides a real-time simulated holistic digital replica model of the city using building and city information modelling, connected through the IoTs with two-way feedback and feedforward loop for efficient management of city sectors and systems [27,129,140]. The benefits of DTCs transcend urban management, they address issues relating to sustainability, climate change and natural disasters with early warnings and predictions that can help urban managers. Apart from the many benefits, digital twinning in cities and buildings offers smart building and asset management features to cover up for limitations in terms of real-time monitoring, information management, asset predictions and optimisation of city infrastructural assets and services [27,129,149]. Hence, smart cities and DTCs can significantly optimise how urban centres and cities are managed towards more sustainable, efficient and smart future cities of the South, considering the rate of urbanisation and peculiar challenges experienced in the South.

Digital transformation and technology come with a huge cost in term of infrastructure and capacity building for urban managers. Also, it comes with concerns relating to cyber security, access control, and protection of private information [142,150,151]. Hence, it will require directed policies and legislation with a governance framework to incorporate digital tool on phase by phase based on what the cities can handle. It can help to reduce all the linking financial taps through e-financing and other digitalised financial systems where there are digital identities for everyone to monitor tax-based revenue for the government. Also, capital, and recurrent expenditures can be tracked digitally for all projects.

Conclusion and Recommendations for policymakers and urban managers

As highlighted above, urban management play a crucial role globally in the day-to-day running of cities and community. Apart from complex and wicked challenges experienced in many parts of the world, the pandemic has revealed deep urban management issues around urban population growth, nature of work, housing, public health, and the need to make impactful decisions in a short time. These deficiencies and challenges require a new holistic approach to sustainable urban management of cities beyond the TUM and IUM with the infusion of digital technologies. Particularly, the deficiency in managing and monitoring in real-time with the ability to make timely decisions with accurate data across multiple sectors requires digital and technological intervention. Incorporating innovative digital tools and artificial intelligent into urban governance creates a sustainable and inclusive approach in urban management beyond previously promoted practices and approaches. The 4IR with artificial intelligence offers new approaches and pathways to address the planning, development, governing, monitoring and maintenance of cities using IoTs, machine learning, remote sensing, and drone technology (as shown in Table 1). While there are multiple ways and techniques used with digital transformation in urban management sectors, evident from smart cities' concept and digital twin city technology should be deployed in cities to help urban managers with different daily tasks. There is a need for a digitalised, sustainable, integrated urban management approach through digital transformation, which offers a holistic approach to urban management beyond the selective adoption of tools to achieve effective, efficient, and sustainable management of cities.

Acknowledgement

I would like to acknowledge useful feedback and comments from Mr Lodie Venter, Dr Calayde Davey, Dr Olubunmi Afinowi, Prof Chrisna du Plessis, Prof Landman Karina and Prof Taibat Lawanson.

References

1. Al-Sehrawy, R., Kumar, B., & Watson, R. (2023). The pluralism of digital twins for urban management: Bridging theory and practice. *Journal of Urban Management*, *12*(1), 16–32. https://doi.org/10.1016/J.JUM.2023.01.002
2. Chakrabarty, B. K. (2001). Urban Management: Concepts, Principles, Techniques and Education. *Cities*, *18*(5), 331–345. https://doi.org/10.1016/S0264-2751(01)00026-9
3. Karlenzig, W., Peck, M., & Zhiqiang, W. (2010). Delivering Effective Urban Management. In M. Peck (Ed.), *Shanghai Manual-A Guide for Sustainable Urban Development in the 21 st Century* (1st ed., pp. 36–75). The Municipal Government of Shanghai, the Bureau International des Exhibitions and the United Nations. Chrome extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.un.org/esa/dsd/susdevtopics/sdt_pdfs/shanghaimanual/Chapter%202%20-%20Delivering%20effective%20urban%20management.pdf
4. United Nations, Department of Economic and Social Affairs, P. D. (2018). *World Urbanization Prospects: The 2018 Revision*.
5. Egolum, C. C. &, & Emoh, F. I. (2017). The Issues and Challenges of Urban Renewal in A Developing Economy. *International Journal of Development and Economic Sustainability*, *5*(1), 32–34. www.eajournals.org
6. Engin, Z., van Dijk, J., Lan, T., Longley, P. A., Treleaven, P., Batty, M., & Penn, A. (2020). Data-driven urban management: Mapping the landscape. *Journal of Urban Management*, *9*(2), 140–150. https://doi.org/10.1016/J.JUM.2019.12.001
7. Eremia, M., Toma, L., & Sanduleac, M. (2017). The Smart City Concept in the 21st Century. *Procedia Engineering*, *181*, 12–19. https://doi.org/10.1016/j.proeng.2017.02.357
8. UN-DESA (Department of Economic and Social Affairs). (2024). *Press Release | With less than one fifth of targets on track, world is failing to deliver on promise of the Sustainable Development Goals, warns new UN report - United Nations Sustainable Development*. The Sustainable Development Goals Report 2024.
9. McGill, R. (1998). Urban management in developing countries. *Cities*, *15*(6), 463–471. https://doi.org/10.1016/S0264-2751(98)00041-9
10. Devas, N., & Rakodi, C. (1993). Planning and managing urban development. In N. Devas & C. Rakodi (Eds.), *Managing fast growing cities : new approaches to urban planning and management in the developing world.* (pp. 41–62). Longman Scientific & Technical.
11. Devas, N., & Rakodi, C. (1993). Planning and managing urban development. In N. Devas & C. Rakodi (Eds.), *Managing fast growing cities : new approaches to urban planning and management in the developing world.* (pp. 41–62). Longman Scientific & Technical.
12. Kaczan, D. J., & Orgill-Meyer, J. (2020). The impact of climate change on migration: a synthesis of recent empirical insights. In *Climatic Change* (Vol. 158, Issues 3–4, pp. 281–300). Springer. https://doi.org/10.1007/s10584-019-02560-0
13. Balsari, S., Dresser, C., & Leaning, J. (2020). Climate Change, Migration, and Civil Strife. In *Current Environmental Health Reports* (Vol. 7, Issue 4, pp. 404–414). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/s40572-020-00291-4
14. Ayesh, A. (2019). Cognitive Systems Approach to Smart Cities. *RXiv Preprint ArXiv:1906*, 1–5. http://arxiv.org/abs/1906.11032
15. Carvalho, C., Cabral Pinto, F., Borges, I., Machado, G., & Oliveira, I. (2019). *Cognitive Cities an Architectural Framework for the Cities of the Future*. 173–182. https://doi.org/10.5121/csit.2019.91314

16. Machin, J., & Solanas, A. (2019). *Conceptual Description of Nature-Inspired Cognitive Cities: Properties and Challenges* (pp. 212–222). https://doi.org/10.1007/978-3-030-19651-6_21
17. Sobrino, A. (2019). *Cognitive Cities: An Approach from Citizens* (pp. 31–46). https://doi.org/10.1007/978-3-030-00317-3_2
18. Ranchod, R. (2020). The data-technology nexus in South African secondary cities: The challenges to smart governance. *Urban Studies*, *57*(16), 3281–3298. https://doi.org/10.1177/0042098019896974
19. UN-Habitat. (2016). *World Cities Report 2016: Urbanization and Development - Emerging Futures*.
20. Revi, A. (2017). Re-imagining the United Nations' Response to a Twenty-first-century Urban World. *Urbanisation*, *2*(2), 1–7. https://doi.org/10.1177/2455747117740438
21. Revi, A. (2014). *Sustainable Development Goals and other Global Processes: The floor Debate of the United Nations when a Debate Took Place Between Representatives of UN member Countries, the Global Campaign for an Urban SDG and UN Officials on 7 January 2014.* DGAcademyX SC001: Indian Institute for Human Settlements. https://learning.edx.org/course/course-v1:SDGAcademyX+SC001+1T2020/block-v1:SDGAcademyX+SC001+1T2020+type@sequential+block@7e1f1e886ccb44ac9750bff59b9b3fc2/block-v1:SDGAcademyX+SC001+1T2020+type@vertical+block@e6fb269f46e84f07b7f3092236a2c7e5
22. Hardoy, J., & Satterthwaite, D. (2014). *Squatter Citizen: Life in the Urban Third World*. Routledge. https://www.taylorfrancis.com/books/9781134157389
23. Dano, U. L., Balogun, A.-L., Abubakar, I. R., & Aina, Y. A. (2019). Transformative Urban Governance: Confronting Urbanization Challenges with Geospatial Technologies in Lagos, Nigeria. *GeoJournal*, *85*(4), 1039–1056. https://doi.org/10.1007/S10708-019-10009-1
24. Brandt, T., Ketter, W., Kolbe, L. M., Neumann, D., & Watson, R. T. (2018). Smart Cities and Digitized Urban Management. *Business and Information Systems Engineering*, *60*(3), 193–195. https://doi.org/10.1007/S12599-018-0537-1/METRICS
25. Kiani, A., Fazelniya, G., & Salari Sardari, F. (2013). Comparative Comparison Approach of Traditional and New Urban Management in Iran. *Journal of Urban Ecology Researches*, *4*(8), 81–100.
26. Kiani, A., Fazelniya, G., & Salari Sardari, F. (2013). Comparative Comparison Approach of Traditional and New Urban Management in Iran. *Journal of Urban Ecology Researches*, *4*(8), 81–100. https://grup.journals.pnu.ac.ir/article_1128_en.html
27. Ketzler, B., Naserentin, V., Latino, F., Zangelidis, C., Thuvander, L., & Logg, A. (2020). Digital Twins for Cities: A State of the Art Review. *Built Environment*, *46*(4), 547–573. https://doi.org/10.2148/BENV.46.4.547
28. Chakrabarty, B. K. (2001). Urban Management: Concepts, Principles, Techniques and Education. *Cities*, *18*(5), 331–345. https://doi.org/10.1016/S0264-2751(01)00026-9
29. Al-Sehrawy, R., Kumar, B., & Watson, R. (2023). The pluralism of digital twins for urban management: Bridging theory and practice. *Journal of Urban Management*, *12*(1), 16–32. https://doi.org/10.1016/j.jum.2023.01.002
30. Domingues, R. F., Seixas, P. C., & Dias, R. C. (2021). Difficulties of Integrated Urban Management: The Case of Parque das Nações From the Users' Perspective. *Revista Portuguesa de Estudos Regionais*, *58*, 67–81.
31. UN-Habitat. (2022). *World Urban Forum-11 Background Paper*.
32. Mbigi, L. (1994). The spirit of African management. In P. Christie, R. Lessem, & L. Mbigi (Eds.), *African Management: Philosophies, concepts and applications* (pp. 77–91). Randburg: Knowledge Resources.
33. da Cruz, N. F., Rode, P., & McQuarrie, M. (2018). New urban governance: A review of current themes and future priorities. *Https://Doi.Org/10.1080/07352166.2018.1499416*, *41*(1), 1–19. https://doi.org/10.1080/07352166.2018.1499416
34. Andrews, K., Gatti, R., Avitabile, C., Conner, R., & Chang, A. Y. (2021). *The quality of health and education systems across Africa: Evidence from a decade of service delivery indicators surveys*. World Bank Publications.
35. Offenhuber, D. (2019). The platform and the bricoleur-Improvisation and smart city initiatives in Indonesia. *Urban Analytics and City Science*, *46*(8), 1565–1580. https://doi.org/10.1177/2399808319865749
36. Fattah, K. N., & Walters, P. (2020). "A Good Place for the Poor!" Counternarratives to Territorial Stigmatisation from Two Informal Settlements in Dhaka. *Social Inclusion*, *8*(1), 55–65. https://doi.org/10.17645/si.v8i1.2318
37. Baye, F., Wegayehu, F., & Mulugeta, S. (2020). Drivers of informal settlements at the peri-urban areas of Woldia: Assessment on the demographic and socio-economic trigger factors. *Land Use Policy*, *95*, 104573. https://doi.org/10.1016/j.landusepol.2020.104573

38. Georganos, S., Hafner, S., Kuffer, M., Linard, C., & Ban, Y. (2022). A census from heaven: Unraveling the potential of deep learning and Earth Observation for intra-urban population mapping in data scarce environments. *International Journal of Applied Earth Observation and Geoinformation*, *114*. https://doi.org/10.1016/j.jag.2022.103013
39. Irekponor, V. E., Abdul-Rahman, M., Agunbiade, M., & Bustamente, A. J. (2022). A framework to determine micro-level population figures using spatially disaggregated population estimates. *ArXiv Preprint ArXiv:2212. Cornell University*, 1–18.
40. Mabogunje, A. L. (1990). Urban Planning and the Post-Colonial State in Africa: A Research Overview 1. *African Studies Review*, *33*(2), 121–203.
41. Watson, V. (2009). 'The Planned City Sweeps the Poor Away…': Urban planning and 21st Century Urbanisation. *Progress in Planning*, *72*(3), 151–193. https://doi.org/10.1016/J.PROGRESS.2009.06.002
42. Schindler, S. (2017). Towards a Paradigm of Southern Urbanism. *City*, *21*(1), 47–64. https://doi.org/10.1080/13604813.2016.1263494
43. Mabogunje, A. L. (1992). *Perspective on Urban Land and Urban Management Policies in Sub-Saharan Africa* (Papers 196; Technical Papers).
44. Erda, F. (2020). *Migration, Urbanisation and Conflict in Africa (MUCA)*.
45. WESTING, A. H. (1994). POPULATION, DESERTIFICATION, AND MIGRATION. *ENVIRONMENTAL CONSERVATION*, *21*(2), 109–114. https://doi.org/10.1017/S0376892900024528
46. Vearey, J. (2011). Challenging urban health: towards an improved local government response to migration, informal settlements, and HIV in Johannesburg, South Africa. *GLOBAL HEALTH ACTION*, *4*. https://doi.org/10.3402/gha.v4i0.5898
47. Hardoy, J. E., & Satterthwaite, D. (2014). *Squatter Citizen: Life in the Urban Third World*. Routledge. https://doi.org/10.4324/9781315070193
48. Awuah, B. L., Lamond, J., Lewis, E., Bloch, R., & Falade, B. J. (2015). *Urban Land, Planning and Governance Systems in Nigeria. Urbanisation Research Nigeria (URN) Research Report*.
49. Afinowi, T. (2019). Urban Regeneration and Renewal in African Cities in the Light of the Sustainable Development Goal for Cities: the Case of Lagos, Nigeria. *Sustainable Urbanisation: Sustainable Urbanisation through Research, Innovation and Partnership, South African Sweden University Forum 2019 Conference, Nelson Mandela University, May 6-8, 2019, Port Elizabeth, South Africa, 26-45, ISBN No. 978-1-928472-12*, 24–65.
50. Dano, U. L., Balogun, A.-L., Abubakar, I. R., & Aina, Y. A. (2019). Transformative Urban Governance: Confronting Urbanization Challenges with Geospatial Technologies in Lagos, Nigeria. *GeoJournal*, *85*(4), 1039–1056. https://doi.org/10.1007/S10708-019-10009-1
51. da Cruz, N. F., Rode, P., & McQuarrie, M. (2018). New urban governance: A review of current themes and future priorities. *Https://Doi.Org/10.1080/07352166.2018.1499416*, *41*(1), 1–19. https://doi.org/10.1080/07352166.2018.1499416
52. Alem, G. (2021). Urban Plans and Conflicting Interests in Sustainable Cross-Boundary Land Governance, the Case of National Urban and Regional Plans in Ethiopia. *SUSTAINABILITY*, *13*(6). https://doi.org/10.3390/su13063081
53. Simonneau, C. (2016). Understanding the weak performance of technology in urban management: Insights from the urban land registry in Benin. In *International Business: Concepts, Methodologies, Tools, and Applications*. https://doi.org/10.4018/978-1-4666-9814-7.ch044
54. Bustos-Peñafiel, M. A. (2022). Integrated approach as a new challenge for urban planning and management: Review of perspectives, approaches and tools for territorial intervention. *Ciudad y Territorio Estudios Territoriales*, *53*(211), 161–180. https://doi.org/10.37230/CyTET.2022.211.9
55. Sun, J., Hu, Y., Li, Y., Weng, L., Bai, H., Meng, F., Wang, T., Du, H., Xu, D., & Lu, S. (2023). A temporospatial assessment of environmental quality in urbanizing Ethiopia. *Journal of Environmental Management*, *332*. https://doi.org/10.1016/j.jenvman.2023.117431
56. Mabogunje, A. L. (1990). Urban Planning and the Post-Colonial State in Africa: A Research Overview 1. *African Studies Review*, *33*(2), 121–203. https://www.cambridge.org/core/journals/african-studies-review/article/urban-planning-and-the-post-colonial-state-in-africa-a-research-overview1/D36553C687C744BFE5F77DC70023AA53
57. Mabogunje, A. L. (1992). *Perspective on Urban Land and Urban Management Policies in Sub-Saharan Africa* (Papers 196; Technical Papers).

58. Friedmann, J. (2010). Crossing Borders: Do Planning Ideas Travel? In *Crossing Borders: International Exchange and Planning Practices* (pp. 313–328). Routledge. https://www.taylorfrancis.com/books/e/9780203857083/chapters/10.4324/9780203857083-23
59. Birch, E. L. (2016). Journal of the American Planning Association A Midterm Report: Will Habitat III Make a Difference to the World's Urban Development? *Journal of the American Planning Association*, *82*(4), 398–411. https://doi.org/10.1080/01944363.2016.1216326
60. UN-Habitat. (2015). *Transforming Our World, the 2030 Agenda for Sustainable Development*.
61. Afinowi, T. A. (2022). *The intersections between global urban agendas and practice at local levels in housing and human settlements, a case of Lagos. Thesis for the Doctor of Philosophy*. School of Architecture and Planning, University of Witwatersrand.
62. Huchzermeyer, M. (2012). World Bank. In *Entry in the Encyclopedia of Housing* (pp. 783–787). Sage, London.
63. Obeng-Odoom, F. (2012). On the origin, meaning, and evaluation of urban governance. *Norwegian Journal of Geography*, *66*(4), 204–212. https://doi.org/10.1080/00291951.2012.707989
64. Afinowi, T. A. (2022). *The intersections between global urban agendas and practice at local levels in housing and human settlements, a case of Lagos. Thesis for the Doctor of Philosophy*. School of Architecture and Planning, University of Witwatersrand.
65. United Nations Division for Sustainable Development. (1992). *Agenda 21 - United Nations Conference on Environment & Development*.
66. Hall, P., Pfeiffer, U., & Germany. Bundesministerium für Verkehr, B. Wohnungswesen. (2000). *Urban future 21 : A Global Agenda for Twenty-first Century Cities*. E & FN Spon.
67. Atghaei, H., & Pilevar, A. A. (2017). Designing Integrated Urban Management Pattern for Metropolises, Case Study: Mashhad. *Armanshahr Architecture & Urban Development*, *9*(17), 285–301.
68. Van Dijk, M. P., Pennink, C., & Ruisink, S. (2013). Capacity development for urban development: The evolution of the integrated urban management Masters course at the Ethiopian Civil Service University. *Water Policy*, *15*(SUPPL.2), 121–136. https://doi.org/10.2166/wp.2013.216
69. Chakrabarty, B. K. (1998). Urban management and optimizing urban development models. *Habitat International*, *22*(4), 503–522. https://doi.org/10.1016/S0197-3975(98)00029-0
70. Salari, M., & Ahmadabadi, M. N. (2016). Ranking the Obstacles of the Establishment of Integrated Urban Management in Tehran Municipality Using MCDM Technique. *Modern Applied Science*, *10*(8), 48–55. https://doi.org/10.5539/mas.v10n8p48
71. Kim, K. B., Kim, G. C., & Cho, H. J. (2018). Status and Prospect of Smart City in the Fourth Industrial Revolution Era. *Journal of the Korea Convergence Society*, *9*(9), 191–197. http://www.koreascience.or.kr/article/JAKO201830540461919.page
72. Xu, M., David, J. M., & Kim, S. H. (2018). The fourth industrial revolution: Opportunities and challenges. *International Journal of Financial Research*, *9*(2), 90–95. https://doi.org/10.5430/ijfr.v9n2p90
73. Johannessen, J. A. (2018). *Automation, Innovation and Economic Crisis: Surviving the Fourth Industrial Revolution*. Routledge. https://www.taylorfrancis.com/books/9781351039857
74. Ticker, A. (2022, July 9). *From NASA to Web 3.0 - The Insane Story of Digital Twins - YouTube* [Video recording]. Ticker Symbol: YOU.
75. Paper, O., Gopal, G., Suter-crazzolara, C., Toldo, L., & Eberhardt, W. (2019). Digital transformation in healthcare – architectures of present and future information technologies. *Clinical Chemistry and Laboratory Medicine*, *57*(3), 328–335.
76. Engin, Z., van Dijk, J., Lan, T., Longley, P. A., Treleaven, P., Batty, M., & Penn, A. (2020). Data-driven urban management: Mapping the landscape. *Journal of Urban Management*, *9*(2), 140–150. https://doi.org/10.1016/j.jum.2019.12.001
77. Paper, O., Gopal, G., Suter-crazzolara, C., Toldo, L., & Eberhardt, W. (2019). Digital transformation in healthcare – architectures of present and future information technologies. *Clinical Chemistry and Laboratory Medicine*, *57*(3), 328–335.
78. Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, *28*(2), 118–144. https://doi.org/10.1016/J.JSIS.2019.01.003
79. Haktanır, E., Kahraman, C., Onar, S. Ç., Öztayşi, B., & Çebi, S. (2023). A State of the Art Literature Review on Digital Transformation. In E. Haktanır & C. Kahraman (Eds.), *Intelligent Systems in Digital Transformation: Theory and Applications* (Vol. 549, pp. 3–31). Springer. https://doi.org/10.1007/978-3-031-16598-6_1
80. Marques, I. C. P., & Ferreira, J. J. M. (2020). Digital transformation in the area of health : systematic review of 45 years of evolution. *Health and Technology*, *10*, 575–586. https://doi.org/https://doi.org/10.1007/s12553-019-00402-8

81. Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, *28*(2), 118–144. https://doi.org/10.1016/J.JSIS.2019.01.003
82. Lioutas, E. D., Charatsari, C., & De Rosa, M. (2021). Digitalization of agriculture: A way to solve the food problem or a trolley dilemma? *Technology in Society*, *67*(September), 101744(1-8). https://doi.org/10.1016/j.techsoc.2021.101744
83. National Research Foundation (Singapore Government). (2018). *Virtual Singapore*. Virtual Singapore. https://www.nrf.gov.sg/programmes/virtual-singapore
84. Buildmedia. (2021). *Wellington Digital Twin* . https://buildmedia.com/work/wellington-digital-twin
85. Hämäläinen, M. (2021). Urban development with dynamic digital twins in Helsinki city. *IET Smart Cities*, *3*(4), 201–210. https://doi.org/10.1049/smc2.12015
86. Kraus, S., Schiavone, F., Pluzhnikova, A., & Chiara, A. (2021). Digital transformation in healthcare : Analyzing the current. *Journal of Business Research*, *123*, 557–567. https://doi.org/10.1016/j.jbusres.2020.10.030
87. Kraus, S., Schiavone, F., Pluzhnikova, A., & Chiara, A. (2021). Digital transformation in healthcare : Analyzing the current. *Journal of Business Research*, *123*, 557–567. https://doi.org/10.1016/j.jbusres.2020.10.030
88. World Health Organisation. (2020). *WHO Director-General's Opening Remarks at the Media Briefing on COVID-19 - 11 March 2020*. https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020
89. Ringenson, T., Höjer, M., Kramers, A., & Viggedal, A. (2018). Digitalization and environmental aims in municipalities. *Sustainability (Switzerland)*, *10*(4), 1278(1-16). https://doi.org/10.3390/su10041278
90. UN-Habitat. (2022). *World Cities Report 2022: Envisaging the Future of Cities*. https://unhabitat.org/sites/default/files/2022/06/wcr_2022.pdf
91. Sarker, M. N. I., Wu, M., & Hossin, M. A. (2018). Smart governance through bigdata: Digital transformation of public agencies. *2018 International Conference on Artificial Intelligence and Big Data, ICAIBD 2018*, 62–70. https://doi.org/10.1109/ICAIBD.2018.8396168
92. Qin, B., & Qi, S. (2021). Digital transformation of urban governance in China: The emergence and evolution of smart cities. *Digital Law Journal*, *2*(1), 29–47. https://doi.org/10.38044/2686-9136-2021-2-1-29-47
93. Sucupira Furtado, L., da Silva, T. L. C., Ferreira, M. G. F., de Macedo, J. A. F., & de Melo Lima Cavalcanti Moreira, J. K. (2023). A framework for Digital Transformation towards Smart Governance: using big data tools to target SDGs in Ceará, Brazil. *Journal of Urban Management*, *12*(1), 74–87. https://doi.org/10.1016/j.jum.2023.01.003
94. Hämäläinen, M. (2020). A framework for a smart city design: digital transformation in the Helsinki smart city. In V. Ratten (Ed.), *Entrepreneurship and the Community. Contributions to Management Science* (pp. 63–86). Springer, Cham.
95. Pacione, M. (2009). *Urban Geography: A Global Perspective* (3rd ed.). Routledge.
96. Yigitcanlar, T., Kankanamge, N., Regona, M., Maldonado, A. R., Rowan, B., Ryu, A., Desouza, K. C., Corchado, J. M., Mehmood, R., & Li, R. Y. M. (2020). Artificial intelligence technologies and related urban planning and development concepts: How are they perceived and utilized in Australia? *Journal of Open Innovation: Technology, Market, and Complexity*, *6*(4), 1–21. https://doi.org/10.3390/joitmc6040187
97. Sanchez, T. W., Shumway, H., Gordner, T., & Lim, T. (2023). The prospects of artificial intelligence in urban planning. *International Journal of Urban Sciences*, *27*(2), 179–194. https://doi.org/10.1080/12265934.2022.2102538
98. Batty, M. (2021). The digital transformation of planning. *Environment and Planning B: Urban Analytics and City Science*, *48*(4), 593–597. https://doi.org/10.1177/23998083211016122
99. Shah, H. (2023). Beyond Smart: How ICT Is Enabling Sustainable Cities of the Future. *Sustainability (Switzerland)*, *15*(16). https://doi.org/10.3390/su151612381
100. Hämäläinen, M. (2021). Urban development with dynamic digital twins in Helsinki city. *IET Smart Cities*, *3*(4), 201–210. https://doi.org/10.1049/smc2.12015
101. Anthony Jnr, B. (2021). Managing digital transformation of smart cities through enterprise architecture–a review and research agenda. In *Enterprise Information Systems* (Vol. 15, Issue 3, pp. 299–331). https://doi.org/10.1080/17517575.2020.1812006
102. Haggerty, E. (2017). Healthcare and digital transformation. *Network Security*, *2017*(8), 7–11. https://doi.org/10.1016/S1353-4858(17)30081-8
103. Marques, I. C. P., & Ferreira, J. J. M. (2020). Digital transformation in the area of health : systematic review of 45 years of evolution. *Health and Technology*, *10*, 575–586. https://doi.org/https://doi.org/10.1007/s12553-019-00402-8

104. Frennert, S. (2021). Hitting a moving target: digital transformation and welfare technology in Swedish municipal eldercare. *Disability and Rehabilitation: Assistive Technology*, *16*(1), 103–111. https://doi.org/10.1080/17483107.2019.1642393
105. Murawiowa, N., Mudrova, E., & Degtereva, V. (2021). Smart Housing and Utilities: A Causal Diagram. *ACM International Conference Proceeding Series*, 245–252. https://doi.org/10.1145/3527049.3527134
106. Çetin, S., De Wolf, C., & Bocken, N. (2021). Circular digital built environment: An emerging framework. *Sustainability (Switzerland)*, *13*(11). https://doi.org/10.3390/su13116348
107. Gamil, Y., & Cwirzen, A. (2022). Digital Transformation of Concrete Technology—A Review. *Frontiers in Built Environment*, *8*(March), 1–14. https://doi.org/10.3389/fbuil.2022.835236
108. Shen, Q., Hua, Y., Huang, Y., Ebstein, R., Yu, X., & Wu, Z. (2022). Knowledge management and modern digital transformation of the property management industry in China. *Journal of Knowledge Management*, *26*(8), 2133–2144. https://doi.org/10.1108/JKM-04-2021-0320
109. Prasetya, C. S., & Arief, R. (2022). Digital Transformation in the Property Management Industry : A Systematic Literature Review. *Proceedings of the 7th North American International Conference on Industrial Engineering and Operations Management, Orlando, Florida, USA, June 12-14, 2022*, *Bogataj 2020*, 1922–1932.
110. Lioutas, E. D., Charatsari, C., & De Rosa, M. (2021). Digitalization of agriculture: A way to solve the food problem or a trolley dilemma? *Technology in Society*, *67*(September), 101744(1-8). https://doi.org/10.1016/j.techsoc.2021.101744
111. Ali, A., Mansol, A. S., Khan, A. A., Muthoosamy, K., & Siddiqui, Y. (2023). Electronic nose as a tool for early detection of diseases and quality monitoring in fresh postharvest produce: A comprehensive review. *Comprehensive Reviews in Food Science and Food Safety*, *22*(3), 2408–2432. https://doi.org/10.1111/1541-4337.13151
112. Gebresenbet, G., Bosona, T., Patterson, D., Persson, H., Fischer, B., Mandaluniz, N., Chirici, G., Zacepins, A., Komasilovs, V., Pitulac, T., & Nasirahmadi, A. (2023). A concept for application of integrated digital technologies to enhance future smart agricultural systems. *Smart Agricultural Technology*, *5*(March), 100255. https://doi.org/10.1016/j.atech.2023.100255
113. Vuppalapati, J. S., Kedari, S., Ilapakurthy, A., Ilapakurti, A., & Vuppalapati, C. (2017). Smart dairies-enablement of smart city at gross root level. *Proceedings - 3rd IEEE International Conference on Big Data Computing Service and Applications, BigDataService 2017*, 118–123. https://doi.org/10.1109/BigDataService.2017.35
114. National Research Foundation (Singapore Government). (2018). *Virtual Singapore*. Virtual Singapore. https://www.nrf.gov.sg/programmes/virtual-singapore
115. Erol, T., Mendi, A. F., & Dogan, D. (2020). Digital Transformation Revolution with Digital Twin Technology. *4th International Symposium on Multidisciplinary Studies and Innovative Technologies, ISMSIT 2020 - Proceedings*. https://doi.org/10.1109/ISMSIT50672.2020.9254288
116. Khajavi, S. H., Tetik, M., Liu, Z., Korhonen, P., & Holmstrom, J. (2023). Digital Twin for Safety and Security: Perspectives on Building Lifecycle. *IEEE Access*, *11*(June), 52339–52356. https://doi.org/10.1109/ACCESS.2023.3278267
117. Ivanov, D., Pelipenko, E., Ershova, A., & Tick, A. (2021). Artificial Intelligence in Aviation Industry. In *Lecture Notes on Data Engineering and Communications Technologies* (Vol. 157, pp. 233–245). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-031-24434-6_22
118. Valencia, J. F., Ramírez-Guerrero, T., Castãeda, L. F., & Toro, M. (2020). Automatic detection of number-plate and traffic infractions of motorcyclists by Intelligent Transportation Systems. *IOP Conference Series: Materials Science and Engineering*, *844*(1), 012035 (1-15). https://doi.org/10.1088/1757-899X/844/1/012035
119. Klopp, J., Williams, S., Waiganjo, P., Orwa, D., & White, A. (2015). Leveraging cellphones for wayfinding and journey planning in semi-formal bus systems: Lessons from digital matatus in Nairobi. *Planning Support Systems and Smart Cities*, *213*, 227–241. https://doi.org/10.1007/978-3-319-18368-8_12
120. Tijan, E., Jović, M., Aksentijević, S., & Pucihar, A. (2021). Digital transformation in the maritime transport sector. *Technological Forecasting and Social Change*, *170*, 120879(1-15). https://doi.org/10.1016/j.techfore.2021.120879
121. Kadłubek, M., Thalassinos, E., Domagała, J., Grabowska, S., & Saniuk, S. (2022). Intelligent Transportation System Applications and Logistics Resources for Logistics Customer Service in Road Freight Transport Enterprises. *Energies*, *15*(13), 4668(1-27). https://doi.org/10.3390/en15134668

122. Greve, B. (2019). Welfare states and digitalization. In *The Digital Transformation of Labor (Open Access): Automation, the Gig Economy and Welfare* (1st Editio, pp. 163–173). Routledge. https://doi.org/10.4324/9780429317866-9
123. Savirimuthu, J. (2017). Research Handbook on Digital Transformations. *SCRIPTed*, *14*(1), 145–151. https://doi.org/10.2966/scrip.140117.145
124. Aditya, B. R., Ferdiana, R., & Kusumawardani, S. S. (2021). Categories for barriers to digital transformation in higher education: An analysis based on literature. *International Journal of Information and Education Technology*, *11*(12), 658–664. https://doi.org/10.18178/IJIET.2021.11.12.1578
125. Abad-Segura, E., González-Zamar, M. D., Infante-Moro, J. C., & García, G. R. (2020). Sustainable management of digital transformation in higher education: Global research trends. *Sustainability (Switzerland)*, *12*(5), 2107 (1-24). https://doi.org/10.3390/su12052107
126. Maiurova, A., Agustiono, T., Kustikova, M., Bykovskaia, E., Hafiz, M., Othman, D., Singh, D., & Hwang, H. (2022). Promoting digital transformation in waste collection service and waste recycling in Moscow (Russia): Applying a circular economy paradigm to mitigate climate change impacts on the environment. *Journal of Cleaner Production*, *354*(April), 131604 (1-15). https://doi.org/10.1016/j.jclepro.2022.131604
127. Feroz, A. K., Zo, H., & Chiravuri, A. (2021). Digital Transformation and Environmental Sustainability: A Review and Research Agenda. *Sustainability*, *13*(3), 1530 (1-20).
128. Feroz, A. K., Zo, H., & Chiravuri, A. (2021). Digital transformation and environmental sustainability: A review and research agenda. *Sustainability (Switzerland)*, *13*(3), 1530(1-20). https://doi.org/10.3390/su13031530
129. Brandt, T., Ketter, W., Kolbe, L. M., Neumann, D., & Watson, R. T. (2018). Smart Cities and Digitized Urban Management. *Business and Information Systems Engineering*, *60*(3), 193–195. https://doi.org/10.1007/S12599-018-0537-1/METRICS
130. Zheng, C., Yuan, J., Zhu, L., Zhang, Y., & Shao, Q. (2020). From digital to sustainable: A scientometric review of smart city literature between 1990 and 2019. *Journal of Cleaner Production*, *258*, 120689 (1-24). https://doi.org/10.1016/J.JCLEPRO.2020.120689
131. Zubizarreta, I., Seravalli, A., & Arrizabalaga, S. (2016). Smart City Concept: What It Is and What It Should Be. *Journal of Urban Planning and Development*, *142*(1), 04015005. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000282
132. Ferré-Bigorra, J., Casals, M., & Gangolells, M. (2022). The adoption of urban digital twins. *Cities*, *131*, 103905. https://doi.org/10.1016/j.cities.2022.103905
133. Pacione, M. (2009). *Urban Geography: A Global Perspective* (3rd ed.). Routledge.
134. Watson, V. (2014). African urban fantasies: Dreams or nightmares? *Environment and Urbanization*, *26*(1), 215–231. https://doi.org/10.1177/0956247813513705
135. Hall, R. E., Bowerman, B., Braverman, J., Taylor, J., & Todosow, H. (2000). The vision of a smart city. *2nd International Life Extension Technology Workshop, Paris, France. (BNL-67902; 04042)*, *28*, 1–7. https://www.osti.gov/biblio/773961
136. Cominola, A., Monks, I., & Stewart, R. A. (2020). Smart Water Metering and AI for Utility Operations and Customer Engagement : Disruption or Incremental Innovation? *HydroLink: Journal of IAHR International Association for Hydro-Environment Engineering and Research*, *4*, 114–119.
137. Bianchi, I., & Schmidt, L. (2023). The Smart City Revolution: Design Principles and Best Practices for Urban Transformation. *Eigenpub Review of Science and Technology*, *7*(1), 55–70. https://studies.eigenpub.com/index.php/erstEigenpubReviewofScienceandTechnologyhttps://studies.eigenpub.com/index.php/ersthttps://studies.eigenpub.com/index.php/erst
138. McCormick, K., Anderberg, S., Coenen, L., & Neij, L. (2013). Advancing sustainable urban transformation. *Journal of Cleaner Production*, *50*, 1–11. https://doi.org/10.1016/j.jclepro.2013.01.003
139. Botín-Sanabria, D. M., Mihaita, S., Peimbert-García, R. E., Ramírez-Moreno, M. A., Ramírez-Mendoza, R. A., & Lozoya-Santos, J. de J. (2022). Digital Twin Technology Challenges and Applications: A Comprehensive Review. In *Remote Sensing* (Vol. 14, Issue 6, p. 1335). https://doi.org/10.3390/rs14061335
140. Deng, T., Zhang, K., & Shen, Z. J. (Max). (2021). A systematic review of a digital twin city: A new pattern of urban governance toward smart cities. *Journal of Management Science and Engineering*, *6*(2), 125–134. https://doi.org/10.1016/j.jmse.2021.03.003
141. Hamamurad, Q. H., Jusoh, N. M., & Ujang, U. (2022). Modern City Issues, Management and the Critical Role of Information and Communication Technology. *International Journal of Advanced Computer Science and Applications*, *13*(4).

142. Baud, I., Scott, D., Pfeffer, K., Sydenstricker-Neto, J., & Denis, E. (2014). Digital and spatial knowledge management in urban governance: Emerging issues in India, Brazil, South Africa, and Peru. *Habitat International*, *44*, 501–509. https://doi.org/10.1016/J.HABITATINT.2014.09.009
143. Qin, B., & Qi, S. (2021). Digital transformation of urban governance in China: The emergence and evolution of smart cities. *Digital Law Journal*, *2*(1), 29–47. https://doi.org/10.38044/2686-9136-2021-2-1-29-47
144. Gupta, S., & Degbelo, A. (2022). An empirical analysis of AI contributions to sustainable cities (SDG11). In F. Mazzi & L. Floridi (Eds.), *The Ethics of Artificial Intelligence for the Sustainable Development Goals*.
145. UNFCCC. (2015). *Paris Agreement* .
146. Rensburg, N. J. V, Matheri, A. N., & Meyer, J. (2019). *Bridging the digital divide in an African smart city*. 518–526. https://doi.org/10.1109/ISC246665.2019.9071771
147. Vassilakopoulou, P., & Hustad, E. (2023). Bridging Digital Divides: a Literature Review and Research Agenda for Information Systems Research. *Information Systems Frontiers*, *25*(3), 955–969. https://doi.org/10.1007/s10796-020-10096-3
148. Xi, J. (2024). Digital blueprints for the urban future: a study on the transformation of urban planning with examples from China and Singapore. In *Highlights in Science, Engineering and Technology CEAT* (Vol. 2024).
149. Lu, Q., Xie, X., Kumar, A., Phd, P., Schooling, J. M., & Konstantinou, E. (2022). Moving from building information models to digital twins for operation and maintenance. *Proceedings of the Institution of Civil Engineers - Smart Infrastructure and Construction*, *174*(2), 46–56. https://doi.org/10.1680/JSMIC.19.00011
150. Sarker, M. N. I., Wu, M., & Hossin, M. A. (2018). Smart governance through bigdata: Digital transformation of public agencies. *2018 International Conference on Artificial Intelligence and Big Data, ICAIBD 2018*, 62–70. https://doi.org/10.1109/ICAIBD.2018.8396168
151. Sucupira Furtado, L., da Silva, T. L. C., Ferreira, M. G. F., de Macedo, J. A. F., & de Melo Lima Cavalcanti Moreira, J. K. (2023). A framework for Digital Transformation towards Smart Governance: using big data tools to target SDGs in Ceará, Brazil. *Journal of Urban Management*, *12*(1), 74–87. https://doi.org/10.1016/j.jum.2023.01.003