A Systematic Literature Review Approach on the Role of Digitalization in Construction Infrastructure and Sustainable City Development in Developing Countries

Saheed Yusuf [1,*], Musa-Adamu Musa [2], Ikechukwu Diugwu [3], Chinedu Adindu [4] and Badmus Afeez [5]

[1234]Department of Project Management Technology, Federal University of Technology, Minna, Niger State, Nigeria; so.yusuf@futminna.edu.ng
[5] Department of Civil Engineering, Federal University of Technology, Akure, Ondo State, Nigeria; badmuscve133705@futa.edu.ng
* Correspondence: so.yusuf@futminna.edu.ng; Tel.: +234-706-4709-421

Abstract: The continuous surge of humans from the rural areas to the cities in search for livelihood has assumed an unprecedented dimension in recent years. More disturbing is the dearth of supportive infrastructure to meet the growing need for decent housing and other social amenities. The use of digital technology in virtually every field of human endeavor has become common place and a contemporary value driven approach to resource allocation, mobilization, utilization, and performance. Many of a nations' economic sectors have recorded improved performance and resource optimization through the adoption of digital technologies. Notable among these include manufacturing, agriculture, healthcare, banking, to mention a few. Unfortunately, only a little can be said about the adoption of digital technology in the various and complex activities and operations of the construction industry value chain, hence the need for an expository study that would harness the benefits of numerous emerging digital technologies in the sector. This study adopted a systematic literature review (SLR) methodology on a rigorous and extensive study, involving recent relevant scholarly researches (2016-2020) to assess the role of digital technology in infrastructure provisioning and sustainable cities development. It also examined the benefits and challenges of construction industry digitalization in developing countries. Findings of the study showed lack of government support, financial constraints, and lack of technical know-how, as major impediments towards the adoption and implementation of digital technologies in developing countries. The study concluded that the benefits of digitalization of the construction industry is enormous and includes sustainability of the environment, society, and economy amongst several others.

Keywords: Digital technology, Infrastructural development, Sustainable cities, Developing countries

1. Introduction

Digitalization of operations and processes in various sectors of a nation's economy is growing in significance, and this has seen technological trends impacting positively on most businesses. The dynamics introduced by digitalization has left businesses with no better option than to review business techniques, corporate culture, and organizational values to meet customers ever evolving needs and aspirations. This means businesses are required to embrace processes that need to be digitalized [1], gather data from varied sources [2], establish organized and effective consumer interaction [3], and ensure efficient information exchange in a digital manner [2]. Such measures will incorporate the usage of digital drivers like smartphones, computers, smart wearable devices, as well as the internet [4]. Drawing from these, [5] revealed that about 90% of businesses across different

sectors and countries would be repositioned digitally, and this would give them competitive edge among best of class. Notably businesses that have accepted disruptive change in recent years through digital technologies include the food industry [6], healthcare sector [7], energy sector [8], finance sector [9], transport sector [10], and education sector [11]. A general framework that would bring to the fore digitalization with advanced data analytic processes will set the stage for business organizations to reap associated benefits.

Despite the wide adoption of digital processes across various economic sectors, its application in infrastructure projects in emerging economies is relatively low [12,13], albeit the steady growth being recorded [14]. Generally, this low drive in the adoption of digital technologies can be attributed to the over reliance on traditional approaches, fragmentation or lack of collaboration amongst built environment professionals, and casualness in embracing change in the realization of infrastructure projects [15,16]. In Africa, alongside other developing economies, various factors have hinged on the successful delivery of infrastructure projects. [17] argue that inadequate power serves as a barrier in infrastructure development in most African countries where in 2015, about 50% of the world's population without electricity are from Sub-Saharan Africa, thus hindering sustainable development initiatives. Also, there is the problem of lack of proper attention to issues of environmental sustainability in low-income settlements. The low-income dwellers constitute a larger proportion of dwellers in growing cities as residents often times become victims of urban development inequalities; hence their vulnerability to the effects of climate and ecological change [18]. Furthermore, corrupt practices within the construction project delivery framework severely impacts on infrastructure development performance in the developing nation of Nigeria [19]. Other factors include governments' favouratism towards certain ethnic groups thus hindering sustained growth [20]. [21] argues that the sustainability and economic growth of African urban areas is largely connected to the quality and quantity of roads and other supportive infrastructure. The deplorable condition of roads in African cities constitute major challenge towards city growth and development. The aforementioned studies and a plethora of others allude to the various barriers or challenges that plague the development of infrastructure in Africa. It is therefore, pertinent to draw from existing literature relating to developing economies that infrastructure development greatly affects the low-income communities as they constitute the majority of population. The application of digital technologies could fast track the needed global progress in achieving sustainable development.

With the global move that cities become sustainable due to the increase in urban population [22], it is imperative that cities become smart through digitalization, hence setting the pace towards the realization of smart sustainable cities [23]. Smart cities incorporate investments in innovative technologies and services that involve energy, transport, and ICT sectors towards the delivery of more efficient services for its occupants [24], thus, fostering inclusive growth. Inclusive growth mean that citizens in such a system will be technologically empowered to promote sustainable goals. According to [25], over 68% of the global population live in the urban areas with concentration in Asia, Latin America and Africa with the fastest growing urban areas situated in Africa. In such case, the smart cities concept bears a lot of promise for the African continent which is mostly in need of sustainable development [26]. This will mean a massive technology uptake by cities to improve urban services as seen in the study of [27]. The study presented the case of the city of Windhoek in Namibia in its drive to become a smart city as it leverages on ICT developments supported by initiatives from ICT service providers, thus ensuring rapid technological advancement. In sum, digital technologies play key roles across the various sectors of an economy in ardent pursuit of sustainable smart cities. The state of healthcare can be improved as seen in a health tech firm in Nigeria where Artificial Intelligence (AI) is utilized for fast and remote medical diagnosis coupled with information on where to purchase drugs. In transportation, intelligent transport systems like advanced traveler and traffic management systems can predict congestion and proffer alternative route options to vehicles in real time, thus improving the efficiency of travel. People can equally receive information on the best time to leave their homes. Such a system can also provide information on traffic accidents and weather conditions which can allow people to plan for their journey [28]. Furthermore, ICT innovations in Africa exemplified by Worldspace, Eneza, and eGranary are recording giant strides in shaping the educational system more efficiently. Additionally, the use of ICT alongside Building Information

Modelling (BIM) presents a collaborative platform through which the public can participate with relevant stakeholders in real time for mass customized housing development [29]. While the sectors discussed are areas that any smart city initiative is meant to capture, it is pertinent to state efforts towards their actualization should be channeled towards sustainable energy efficiency as this is the key driver. Studies reveal that a low-carbon initiative is required for the actualization of low carbon cities, and this is a fundamental aspect of smart cities [30-32].

The discourse from literature has presented digital technologies and smart cities as novel approaches with immense potential towards the drive for efficient infrastructures and smart sustainable cities. Observably, although digital penetration in the built environment is relatively slow, there are huge prospects awaiting developing nations to exploit using mobile phones and the internet. From the foregoing perspectives, this study uses a systematic literature review approach to assess the role of digital technologies in infrastructural development and sustainable cities, and examines the benefits and challenges of digitalization in developing countries.

2. Methodology

The study fundamentally involved a systematic review of relevant literature from Google Scholar search engine and ScienceDirect databases. The choice of these sources was predicated on the fact that they offered a simplified advanced way of searching many sources of information such as academic and professional publications, conferences proceedings, online repositories, and other web sites. This method is similar to those employed in earlier studies where a systematic review of literature was conducted [33-36]. The search was restricted to peer reviewed journal articles and conference proceedings published between 2016 and 2020. The keywords used for the search were "digital technology", "infrastructural development", "sustainable cities", "construction", and "developing countries". The result of the search is presented in Tables 1 and 2 below.

Table 1: Search results from ScienceDirect database using the specified keywords

Publication Type	2016	2017	2018	2019	2020
Conference Proceedings	12	21	5	16	23
Journal Article	16	23	16	45	43
Report	-	1	1	-	-
Generic	-	1	1	1	-
Total	28	46	23	62	66

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Table 2: Search results from Google Scholar using "Challenges of digitalization in developing countries", "benefits of digitalization in developed countries" as keywords

Publication Type	2016	2017	2018	2019	2020
Conference Proceedings	15	20	11	18	16
Journal Article	22	14	24	28	35
Total	37	34	35	46	51

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The publications from the searches were further analyzed and sorted according to relevance and availability using the following criteria;

- Focused only on digitalization in the construction industry with the keyword "Challenges of digitalization in developing countries", "benefits of digitalization in developed countries", "Digital technology", "Infrastructural development" "Sustainable cities", "Construction Industry", and "Developing countries".
- Written in English language
- Published between January, 2016 and December, 2020.

- Excluded publications focused on 'digitalization of agricultural sector', 'smart manufacturing', 'digitalization in education', 'digital entrepreneurship', 'digital marketing', 'digital banking'.

3. Results

A total number of 428 publications made up of 225 from ScienceDirect and 203 from Google Scholar were retrieved. After the screening based on the specified criteria bothering on relevance and availability, one hundred and seventy-three (173) publications were selected from which 21 publications focusing on digitalization in the construction industry were extracted as presented in Table 3 below.

Table 3: Publications on digitalization in the construction industry

Source	Title	Document Type	Objective(s) of Study	Study's Methodology	Main Findings	Limitation of Study
Praharaj, *et al.* [37]	Innovative Civic Engagement and Digital Urban Infrastructure: Lessons from 100 Smart Cities Mission in India	Conference Proceedings	To explore the relationship between active civic engagement and the availability of basic digital infrastructure and socio-economic standards in Indian cities.	A mixed method design: Literature review, secondary data, and semi structured interviews.	This study provided insights on factors that lead to the success or failure of cities' online citizen engagement platforms.	The disparity in digital infrastructure between different socio-economic demographics is a challenge for cities in emerging economies.
Nasiri, Ukko, Saunila and Rantala [4]	Managing the digital supply chain: The role of smart technologies.	Journal Article	To examine how digital transformation of companies can fuel smart technologies, to improve relationship performance.	Questionnaire survey	Digital transformation of the companies alone cannot enhance relationship performance, it needs to be integrated with smart technologies to achieve this goal.	The use of cross-sectional data.
Wang and Moriarty [38]	Energy savings from Smart Cities: A critical analysis.	Conference Proceedings	Assessed the potentials for smart city policies to help make significant energy savings in urban transport and building construction and operation.	Literature review	Existing potentials will not be realised unless supporting policies are in place. There is need to overcome the challenges of data privacy, security and reliability.	Need for case studies /empirical data on the application of smart technologies for energy saving.
Mark and Anya [39]	Ethics of Using Smart City AI and Big Data: The Case of Four Large European Cities;	Journal Article	To provide fresh insights into the field of smart information systems (SIS) in urban European contexts and how developers are approaching the ethical implementation of such technologies.	Case studies, Interviews	The effects of using SIS within smart city projects have not yet materialised, because of their infancy.	Lack of empirical research done on smart cities, specifically analysing how they ethically use SIS technologies.

Source	Title	Document Type	Objective(s) of Study	Study's Methodology	Main Findings	Limitation of Study
Davila Delgado, *et al.* [40]	Robotics and automated systems in construction: Understanding industry-specific challenges for adoption	Journal Article	Investigation into the industry-specific factors that limit the adoption in the construction industry.	Literature review, and an online questionnaire were conducted.	Identified challenges were grouped into four categories and ranked in order of importance: contractor-side economic factors, client-side economic factors, technical and work-culture factors, and weak business case factors.	Focused only on robotics.
Shah, *et al.* [41]	A survey of smart city infrastructure via case study on New York	Conference Proceedings	Explored the technologies and projects implemented in New York City of the USA to make it a smart city.	Case study	Many technologies have already been implemented in New York City as an initiative to make it a smart city.	Limited to New York City.
Theofilatos, *et al.* [42]	Identifying infrastructure risk factors in Africa.	Conference Proceedings	An overview of the infrastructure risk factors in African countries.	Secondary data analysis	In-depth discussions on macroscopic (generic level) and microscopic (infrastructure element level) potential risk factors.	Unavailability of data
Kodongo and Ojah [43]	Does infrastructure really explain economic growth in Sub-Saharan Africa?	Journal Article	Examined the relationship between infrastructural development and economic growth	System Generalized method of moments (GMM)	Spending on infrastructure and increments in the access to infrastructure that influence economic growth and development in Sub-Saharan Africa	Silence on the adoption of digital technologies for infrastructural development
du Toit *et al*[34]	Urban green infrastructure and ecosystem services in sub-Saharan Africa	Journal Article	To consolidate research undertaken on urban green infrastructure and the associated ecosystem services in sub-Saharan African cities.	Systematic review	The most represented ecosystem services were regulating and provisioning, with supporting services getting the least attention.	Lack of in-depth studies on all ecosystem services.
Arimah [21]	Infrastructure as a Catalyst for the Prosperity of African Cities	Conference Proceedings	Investigated how the provision of infrastructure contributes to the prosperity of African cities.	Expert Opinion Survey from a diverse selection of cities.	High degree of water shortage characterizes majority of African cities, poor road infrastructure in African cities poses a major challenge to prosperity.	Absence of digital technologies to drive these infrastructural development.

Source	Title	Document Type	Objective(s) of Study	Study's Methodology	Main Findings	Limitation of Study
					Telecommunications is the most developed form of infrastructure in African cities.	
Adegun [44]	Developing Green Infrastructure in a Johannesburg Informal Settlement: Investigating Residents' Willingness to Pay	Conference Proceedings	This paper considered the development of green spaces in an informal settlement in Johannesburg, South Africa.	Questionnaire survey	It suggests preference for a user-pay model within this informal and low-income context.	-
Sovacool, *et al.* [45]	The decarbonisation divide: Contextualizing landscapes of low-carbon exploitation and toxicity in Africa	Journal Article	To document and humanize how communities cope with the negative impacts of decarbonisation, to reveal tensions and tradeoffs between global climate policy and local justice concerns, and to steer more informed local, national, and global sustainability action.	Triangulation approach; case study and interviews.	Revealed that the ongoing transitions to low-carbon societies are being underwritten by serious social and ecological injustices at opposite ends of the supply chain	Too conceptual
Kunkel and Matthess [46]	Digital transformation and environmental sustainability in industry: Putting expectations in Asian and African policies into perspective	Journal Article	Examined the potential linkages between structural change and digitalization, identified the drivers of structural change as well as the economic impacts of digitalization on these drivers.	Literature review	There is a lot of evidence that suggests linkages between digitalization and structural change, but not done in an explicit manner.	Conceptual in nature
Oke, *et al.* [47]	Drivers of sustainable construction practices in the Zambian construction industry.	Conference Proceedings	Assessed SC in Zambian Construction Industry (ZCI)	Questionnaire survey	An average level awareness but low implementation. Major drivers towards the adoption of SC practices include; legal requirement, building regulations, advocacy and	Not integrating digitalization with sustainable construction

Source	Title	Document Type	Objective(s) of Study	Study's Methodology	Main Findings	Limitation of Study
					awareness, developing regulatory mechanisms, and clients demand.	
Okereke, *et al.* [48]	Governing green industrialization in Africa: Assessing key parameters for a sustainable socio-technical transition in the context of Ethiopia.	Journal Article	Explored the conception and implementation of green industrialization in Ethiopia.	Used the socio-technical transition (STT) perspective framework for assessing sustainable transition programmes.	(i) An imperative for climate change mitigation and economic growth; (ii) strong government commitment to a greening agenda; and (iii) evolving innovation system.	Absence of digital technologies to drive green Industrialization.
Pardo-Bosch, *et al.* [49]	Key aspects of building retrofitting: Strategizing sustainable cities.	Journal Article	To capture the principal needs and challenges of building retrofitting replication and scale-up strategies	Business model tools for strategizing sustainable cities.	Municipalities need to develop business models to guide their transition from a traditional city to a sustainable one.	A business perspective
Ershova and Posokhov [50]	Comparative Analyze of Infrastructure in Developed Countries.	Journal Article	To understand and find the ways the infrastructure in the UK, Brazil and Russia will be developed in near future by analyzing the finished projects in last 10 years.	Comparative analysis and Literature review	Under the right conditions, market should grow to over $120 billion in five years.	Conceptual in nature
Colla and Santos [51]	Public safety decision-making in the context of smart and sustainable cities.	Conference Proceedings	To identify, within the context of smart and sustainable cities, how the strategic decision-making process in the area of public safety in a small Brazilian city.	Semi-structured interviews	There are limited resources in several aspects of the police departments for the effective management of their ICT infrastructures.	Public safety perspective
Jin and Fu [52]	The development experience and inspiration of urban energy system in developed countries.	Conference Proceedings	The study focused on analyzing comparatively the practice of supply, consumption, technology and mechanisms about energy system of the topical foreign cities.	Literature review and space–time series clustering	The key factors that influence the evolution of urban energy supply pattern include economic and social factors, resource endowment, policy system, and technology development	Integration of digital technologies in the provision of smart energy

Source	Title	Document Type	Objective(s) of Study	Study's Methodology	Main Findings	Limitation of Study
Maruf, *et al.* [53]	Adaptation for sustainable implementation of Smart Grid in developing countries like Bangladesh.	Journal Article	Highlighted the required adaptation of the potential prime features of Smart Grid technology to the context of Bangladesh.	Review	Bangladesh's renewable energy sources heavily depend on the solar sector which also needs to be diversified with wind energy and tidal energy	Conceptual approach.
Maskuriy, Selamat, Ali, Maresova and Krejcar [36]	Industry 4.0 for the Construction Industry—How Ready Is the Industry?	Journal Article	The study explored the state of Industry 4.0 in the construction Industry; identified its key areas; evaluated and interpreted the available evidence.	Systematic Review	This review demonstrates the lack of a complete understanding on what Industry 4.0 entails for the construction industry.	Lack of theory and a limited number of available studies.

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A compilation of 35 randomly selected papers from the authors' collection were analyzed based on the following co-occurred keywords; A - Sustainable construction/infrastructure of Smart cities; B - Digitalization/Digital Technologies; C - Zero Energy; D - Context of Developing Countries; and E - Context of Developed Countries. This is necessary because sustainable construction of smart cities is driven through the adoption of digital technologies, while the concept of sustainable construction and smart cities is incomplete without efficient design and practices to deliver buildings with minimal energy consumption. The idea of zero energy building is to drastically reduce the cost of emission of carbon and energy by minimizing the use of non-renewable energy [54]. There are few publications in Africa that captured the co-occurred keywords, however, scanty literatures were found in South Africa, Nigeria, Kenya, Ethiopia, Zambia, Botswana, and Ghana [47,48];[55]; [43]; [56]; and [57]. About 50% of the papers analyzed in this category as shown in Table 4 had at least 3 or more of the co-occurred keywords (A - E), while 46% and 40% respectively were in the context of developing (comprising some countries in Sub-Saharan Africa, and the Middle East) and developed countries.

Table 4: Cluster of co-occurred keywords of 35 targeted papers

Source	No. of Studies	A	B	C	D	E
[21,43,47,48,55,58,59]	7	√			√	
[38,49,60,61]	4	√	√	√		√
[37,39,62,63]	4	√	√			√
[64-66]	3	√	√		√	
[41,67,68]	3	√				√
[56,57]	2		√		√	
[53,69]	2		√	√	√	
[70,71]	2	√	√			
[54]	1	√		√		

[52]	1			√		√
[72]	1	√	√	√		
[45]	1	√		√	√	
[73]	1	√	√	√	√	
[74]	1	√		√		√
[40]	1		√			
[75]	1		√			√

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4. Discussion of findings

4.1 Challenges of digitalization in the construction industry

The major limitation of this study was the unavailability of sufficient data to give a generalized view on the adoption level of digital technologies for the provision of smart cities in African countries. This limitation according to [76] could be attributed to the region's low literacy level, income and technological penetration. In view of this, the study identified through literature the challenges facing the adoption of digital technologies in the construction industry which is applicable to most developing countries especially in Africa. These challenges were categorized into nine (9) major factors as shown in Table 5 below. Financial constraint, technological barrier, data security amongst several others were identified as major impediments in the adoption of digital technologies. Many developing countries are plagued with poor economy with huge debt profile, technological backwardness and lack of practical experience on digitalization by construction industry professionals amidst moderate level awareness [35,70,77-81]. Despite being a key success factor, awareness alone is not enough due to the complexity and high technological requirements of digitalization in the construction industry. Other limiting factors challenging the adoption of digital technologies in the construction industry are lack of qualified personnel [77,78,82], lack of government support [70,79], resistant to change [70,78], data management [35], and internet facility [84].

Table 5: Challenges facing the adoption of digital technologies

Drawbacks to the adoption of digital technologies	No. of Studies	Source
Financial constraint	7	[35,70,77-81]
Technological Barrier	4	[70,77,78,82]
Data Security	3	[33,78,83]
Lack of qualified personnel	3	[77,78,82]
Lack of Government Support	2	[70,79]
Resistant to change	2	[70,78]
Lack of awareness	1	[81]
Lack of data management	1	[35]
Internet facility	1	[84]

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4.2 *The benefits and role of digitalization in the development of sustainable smart cities*

The benefits of digitalization and its role in the development of sustainable smart cities is enormous. Many cities are becoming smart to improve the quality of life for their residents. In fact, smart cities allow the right balance between economic, social and environmental costs. Smart cities that represents a conceptual model of urban development [85] is based on human, collective, and technological capital exploitation. [86] describes a smart city "as a city with smart network infrastructure, and consists of smart citizens who live in smart homes (buildings), which are located in a smart environment under a smart security and safety system, that benefit from a smart education and smart healthcare system, and managed by a smart governance and administration system that makes smart policies, especially in a smart economy and smart finance". Thus, a major driver to achieving these is through digital transformation of the construction industry. Some of these practical benefits were identified from few active practices in some developed countries. For instance, [87] posits that the digitalization in building construction optimizes building elements such as walls and slabs for thermal insulation and structural capabilities. Similarly, [78] identified innovative technologies as answers to perennial problems of project performance with respect to completion on-time, within budget, and to customers' requirements. [88] in their study also categorized benefits of digitalization into stakeholder engagement, design support and review, construction support, operations management, and training as shown in Table 6. Cumulatively, this study identified 27 benefits from selected papers as shown in Table 6. According to a study by [89], the applicability of integrated BIM, IoT, and blockchain technology to design intelligent construction systems was elaborated.

Table 6: Benefits of Digitalization in the construction industry

Source	**Benefits of digitization in the construction industry**
Chowdhury, Adafin and Wilkinson [35]; Reynolds, Henderson and Roche [84]; Foresti, Rossi, Magnani, Guarino Lo Bianco and Delmonte [85]	Increase in collaboration; Integration; Monitoring; Safety; Cross reference of knowledge; Competitive advantage; Improve productivity; Increase IT security and data protection; Better risk management
Aghimien, *et al.* [90]; Salta, *et al.* [91]	Saves time; Increases Productivity; Increases speed of work
Ghaffarianhoseini, *et al.* [92]	Technical benefits; Knowledge Management; Diversity Management benefit; Standardization benefit; Integration benefits; Economic benefit
Kaufmann, *et al.* [93]	Reduced sourcing costs through optimized specifications; Quantities, and facilitated negotiations; Reduced security incidents; Facilitated risk awareness; Eased construction progress tracking
Davila Delgado, Oyedele, Demian and Beach [88]	Stakeholder engagement; Design support & review; Construction support; Operations management

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There is a marked evidence from secondary data obtained from relevant case studies on the roles digital technologies towards the development of sustainable infrastructure and smart cities around the world. It is noteworthy that the Authors could not find any substantial case studies in Africa, as study results presented in Table 7 were majorly from Europe. Methodologies, case study location, as well as main findings of 14 selected papers were presented. According to the study of [41], the role of digital technologies is evident in the transformation of New York city to a smart one, while the use of technologies have been adopted for disaster management in the smart city of Jakarta [94]. The study of [95] in Spain showed how technologies have improved mobility and living condition in

major Spanish cities (Barcelona, Madrid, Valencia). The study of [68] on the smart cities of Porto and Ahmedabad proposed the use of digital technologies to reduce traffic congestion, promote green energy, and increase tourism to replicate the rapid development of cities such as New York, Singapore, Barcelona and many others. A similar study in Bogota, Colombia by [96] discussed how artificial intelligence (AI) was used to solve the issue of traffic congestion. Another study by [4] posits that smart technologies facilitate the relationship between digital transformation and relationship performance. In addition, earlier studies of [97,98] support the significant role digital technologies play in sustainable construction practices. The former opined that adequate IT infrastructures drive smart city development, while the latter asserts that mobile technology greatly impact on the sustainability of all industries. Similarly [80] supported previous authors that digital technologies is applicable in virtually all aspects of the construction industry, but practical application is still at formative stages when compared with other sectors. The study further reiterated the view of several scholars that digitalization is imperative in contemporary construction practices in achieving sustainable development.

Table 7: Case studies on the role of digitalization in the infrastructural development of sustainable cities

Source	Title	Document Type	Case study	Objectives	Methodology	Main Findings
Yu, *et al.* [99]	Slum Upgrading Programs and Disaster Resilience: A Case Study of an Indian 'Smart City'	Journal Article	India: Ahmedabad	To identify slum residents' current disaster management (DM) strategies, their perceived needs, and preferences for infrastructural upgrades.	Interview, focus group discussions, and case study	Some physical and non-physical infrastructure needs were not considered in traditional slum upgrading strategies. Hence, the need to reconsider Ahmedabad smart city development plan.
Shah, Kothari and Doshi [41]	A survey of smart city infrastructure via case study on New York	Conference Proceedings	USA: New York City	Explored the technologies and projects implemented in New York City to make it a smart city.	Case study	Many technologies have already been implemented in New York City as an initiative to make it a smart city
Heller, Liu and Gianniou [97]	Enhancing Urban Resilience through Technology and Social Media: Case Study of Urban Jakarta	Conference Proceedings	Indonesia: Urban Jakarta Smart City	To analyze the progress and impact of technology in disaster management	Interview, Secondary data, and field assessment	The use of technology and social media to improve disaster management through effective planning, response and decision making.
Aletà, Alonso and Ruiz [95]	Smart Mobility and Smart Environment in the Spanish cities	Conference Proceedings	Spain: A case of 62 cities	To show dynamically and graphically the scope of development of Spanish Smart City initiatives in terms of mobility and environmental issues.	The holistic concept of Smart Cities was adopted	Spanish smart cities are characterized by mobility and quality-of-life factors. However, environment results require improvement.

Source	Title	Document Type	Case study	Objectives	Methodology	Main Findings
Girardi and Temporelli [100]	Smartainability: A Methodology for Assessing the Sustainability of the Smart City	Conference Proceedings	Italy. Expo Milano 2015 site	To evaluate to what extent the smart cities' development pursues sustainable development goals.	Smartainability approach of estimation	The implementation on the Expo Milano 2015 site demonstrates that Smartainability methodology is able to give decision makers useful information on benefits generated by smart solutions deployment.
Praharaj, Han and Hawken [37]	Innovative Civic Engagement and Digital Urban Infrastructure : Lessons from 100 Smart Cities Mission in India	Conference Proceedings	India: 100 smart Cities Mission	Explored the relationship between active civic engagement and the availability of basic digital infrastructure and socio-economic standards in Indian cities	The case study analysis from smart city initiatives in the form of 'Talk London' and 'My Ideal City Bogota'	Engaging people in online platforms for civic deliberations is not simply a matter of digital infrastructure, but is influenced by a complex set of socio-economic and political variables.
Walnum, Hauge, Lindberg, Mysen, Nielsen and Sørnes [61]	Developing a scenario calculator for smart energy communities in Norway: Identifying gaps between vision and practice	Journal Article	Norway: Furuset in Oslo	Presents a scenario calculator designed to link detailed measures with overall climate goals	Scenario calculator using Key performance indicators, Demonstration, and Interviews	The tool is relatively detailed, as it enables input on energy use, energy technologies and energy carriers down to the level of the individual building.
Heller, Liu and Gianniou [97]	A Science Cloud for Smart Cities Research	Conference Proceedings	Denmark: Sønderborg	Presents the solution to flexible infrastructure based on open source technologies, and its application in a city and building research.	Visualization tools, Case application	Smart City research involves huge amounts of data from various sources, and the availability of powerful IT infrastructures that can handle this complexity and volume of data is vital.
Girardi and Temporelli [101]	Industry 4.0 technologies assessment: A sustainability perspective	Journal Article	World Economic Forum, 2018	Examined Industry 4.0 technologies in terms of application and sustainability implications.	Developed a hybrid multi-situation decision method integrating hesitant fuzzy set, cumulative prospect theory and VIKOR, sensitivity analysis.	The results showed that mobile technology has the greatest impact on sustainability in all industries.

Source	Title	Document Type	Case study	Objectives	Methodology	Main Findings
Thellufsen *et al* [74]	Smart energy cities in a 100% renewable energy context	Journal Article	Denmark: municipality of Aalborg	Presents a methodology to design Smart Energy Cities within the context of 100% renewable energy at a national level.	Guiding principle that; local action should be balanced to match national or global action.	A Smart Energy System vision for Aalborg to become 100% renewable in 2050 was designed in such a way to fit into a common best solution in Denmark.
Mark and Anya [39]	Ethics of Using Smart City AI and Big Data: The Case of Four Large European Cities	Journal Article	European cities: Amsterdam, Helsinki, Copenhagen, and Hamburg	To provide fresh insights into the field of smart information systems (SIS) in urban European contexts	Case studies, Interviews	The effects of using SIS within smart city projects have not yet materialised, because of their infancy.
Nasiri, Ukko, Saunila and Rantala [4]	Managing the digital supply chain: The role of smart technologies	Journal Article	Finland: SMEs	To examine how digital transformation of companies can fuel smart technologies, to improve relationship performance.	Questionnaire survey	The study affirms that smart technologies stimulate the growth in relationship performance.
Solaimani and Sedighi [102]	Toward a holistic view on lean sustainable construction: A literature review	Journal Article	NA	Provided a comprehensive understanding of "how Lean helps achieve and maintain sustainability in construction sector"	Systematic Literature Review	The current body of knowledge of sustainable construction is skewed toward economic values.
Alaloul, Liew, Amila, Zawawi and Mohammed [80]	Industry Revolution IR 4.0: Future Opportunities and Challenges in Construction Industry	Journal Article	NA	Presented a general idea of Industrial Revolution (IR) 4.0 in Construction Industry development	Review	Digitization affects all practices, but practical applications are still in infancy stage. IR 4.0 concepts should be integrated with construction production, novel expertise must be applied to the intellectual engineering of modern construction, enhance the level of incorporation to achieve the sustainable development.

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In view of the expositions obtained from numerous case studies and extensive scholarly reviews from literature, the Authors assessed the role of digitalization in the development of smart cities and sustainable construction practices. Majority of the study's findings are traceable to Europe, and a few North American and Asian countries. However, lessons learnt from these could be adopted in developing countries to up-skill the construction industry for sustainable environment, economic, and social development of the region, considering the massive infrastructural deficit, natural resource

depletion, and unprecedented level of environmental degradation. Infrastructure is essential for the growth, development and functioning of cities to achieve economic improvement and higher livability standards. Infrastructures such as road networks, power and communication facilities improve urbanity, which is crucial for economic emancipation and social development. [103]'s study on ECOWAS countries observed how these infrastructural deficits had affected the agricultural sector resultant from inadequate access to water, absence of storage facilities, insufficient health services, and a bad transportation system [104]. Thus, through effective implementation of digitalization, we will be striving towards achieving Sustainable Development Goal (SDG) 9 (Industry, Innovation, and Infrastructure) and SDG 11 (Sustainable Cities and communities) to keep up with the global trend. Although some developing African countries are currently in the process of digital transformation of certain economic sectors -manufacturing, production, IT, aviation, banking, etc. Unfortunately, the construction sector is not fully imbued. The latter is partly due to the unique and complex nature of the sector, coupled with several other challenges identified in this study. Nonetheless, it is important to note that the construction industry makes and a key economic player of most nations, hence the growing emphasis for the sectors' full digitalization of operations in her quest for infrastructural development, sustainable construction practices, and provision of smart cities.

5. Conclusion

Harnessing the potentials of emerging digital technologies in the construction sector is imperative considering the salutary effects and the advantages it confers to other economic sectors that have long embraced this revolutionary trend, for example- manufacturing, production, IT, aviation, and banking. This paper primarily sought to investigate the role digitalization (digital technologies) plays in the infrastructural development of sustainable smart cities. Robust studies involving extensive literature reviews and case studies gave insight on the adoption level, benefits and challenges of digitalization in construction sector of developing countries. The systematic literature review (SLR) approach on related studies across the globe revealed some existing smart city initiatives in the European region driven by emerging digital technologies. Critical result findings show that digital transformation of smart cities led generally to improved living condition, efficiency, sustainability, and promotion of green energy. The studies also revealed that the adoption of smart technology improved waste management, air quality, water management, park management, smart public transportation, and city lighting. Regrettably, studies showed low application of digital technology in construction practices in Africa, with South Africa having just a few. Study results show that the low-level deployment of digital technologies in most countries of the African continent was as a result of bad governance and political instability, poor economic performance, and social insecurity. The study categorized the major challenges of adopting digital technology in the construction industry as financial constraint, technological barrier, data security, lack of qualified personnel, lack of government support, resistant to change, lack of awareness, and poor internet facility. Of note, the studies showed that the application of some digital technologies have not fully materialized in the construction industry as many are at conceptual stages of development with few practical applications.

The study recommends that government substantially fund innovative technologies and fix the challenges that militate against their development and application, by strengthening their economies, good governance, political stability, priority to security of lives, properties, and general livability standards. The study further recommends improved awareness and technical know-how of construction personnel, creation of smart home ownership incentives, and the development of policy and institutional frameworks that will engender the construction of smart homes in the sub-region.

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